Illumination Engineering and Electric Utility Services
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Lecture No. # 20
Conclusions on Illumination Engineering

Yeah, welcome to this course on illumination engineering and electric utility services.

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Today we take up lesson 20 titled conclusions on illumination engineering. We are half way through the course, so having come half way the course has got two basic components. One on illumination engineering and electric utility services, before we take up the electrical utility services it's time we had a re look at what we had done in the last 19 lessons.

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Therefore this lesson tries to recap the summary of material covered in the area of illumination engineering. It's about the 50% of the course which we have targeted and if you see in one line the 19 lessons covered the need for lighting, behavior of eye to the lighting principles of artificial lighting, appropriate measurements and relevant calculations and applications in various areas. In these terms we had internal applications, external applications or interior lighting or exterior lighting. So we try to have a quick recap of the entire thing 19 lectures in this lesson.

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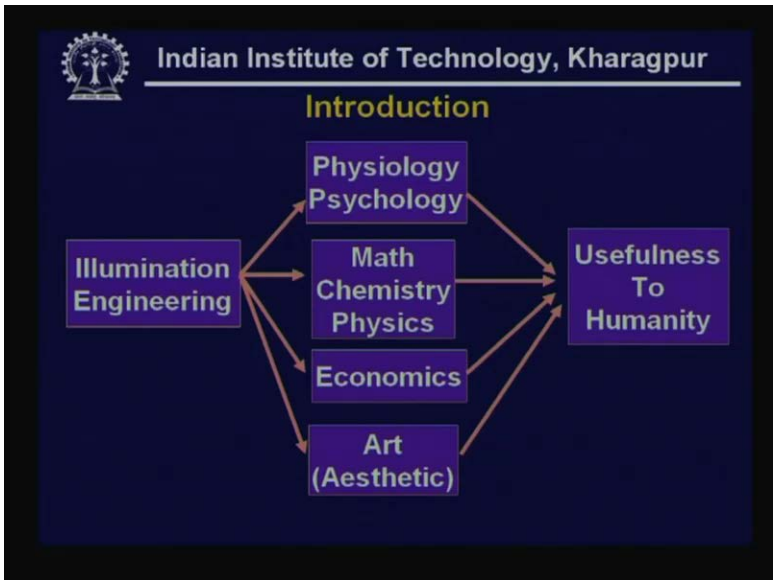

Going to the beginning, it was with the introduction where we emphasized unlike other areas of engineering and science, illumination engineer or illumination engineering needs concepts of

physiology, psychology which are related to the human behavior and human anatomy whereas exact sciences of math, chemistry, physics along with the economics and aesthetic sense which architect have to be useful to the humanity. So that is how an illumination engineers need to be much more than an engineer in true sense.

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Now good lighting is necessary so that we can perceive things very clearly and pleasantly because eyes are the perception, through eyes we get most of the information. And the artificial lighting is enabled us to have our activities extended round the clock which were earlier restricted only from dawn to dusk and this has to use some kind of a physical phenomena and needless further to emphasize that all these sources employ electrical energy and that's one of the reasons why half the course has been devoted to electric utility services which will begin in the next lesson. The electric current sources in sense could be either DC or AC as we have already seen. The introduction does cover some aspects of, basic aspects of electrical energy.

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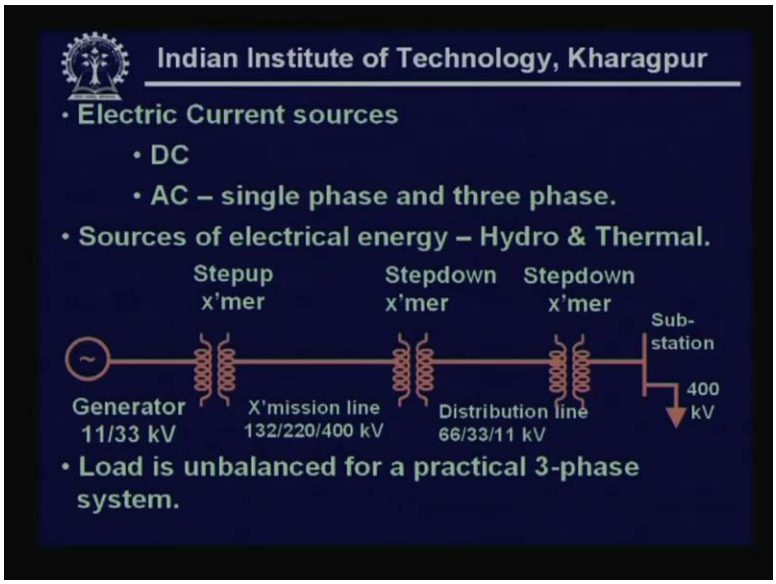

The normal usage has been the AC single phase or three phase and the energy per say could be hydro and thermal of course there are renewable energy resources because these are, these days non-conventional energy resources are coming up. The diagram here shows in total sense what a power system consists of, you have right from the generation and which is at 11 or 33 kv down to the user and at 400 volts. Now what we find? We have stepping down at two levels that is transmission level and the distribution level through the transformers in fact some of these things will be covered as a part of your second part of the course on electrical utility. Load as already said is always unbalanced and it is in three phases.

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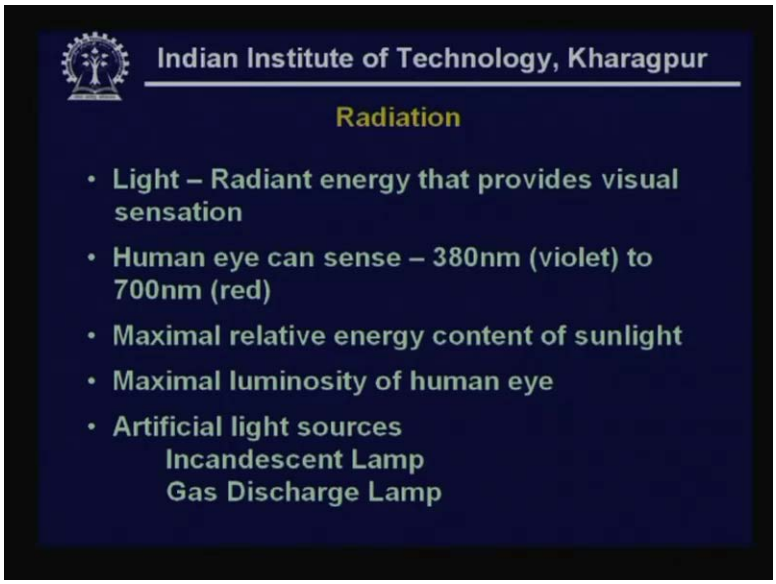

The next lesson tried to look into the radiation and light is the radiation radiant energy that provides visual sensation and we have seen that there is a certain sensitivity of human eye and therefore the radiant energy from the sunlight which is the natural source of light can be categorized into three distinct regions. One the region below 380 nanometers called the ultra violet region and the other above 600, 700 nanometers wave length that is the infra-red and the visible region which if you pass a natural sunlight through a prism you can see the, it's splitting into the various colours which we normally refer as vibgyor and are also observed to be found during a rainbow.

Now the relative content of the energy is very high around the blue green zone for a natural sunlight considering sunlight is a maxima around noon time and the sensitivity of the eye which is the response of the eye to this light which we can also call as a luminosity of human eye is also found to be incidentally close to that. Now with this information available one needs to look at what kind of a light source that may be there. Therefore artificial light sources could broadly be categorized into two, one an incandescent lamps other gas discharge lamps.

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The physical processes employed therefore for lighting are incandescence which basically is a form of a light radiation by virtue of heating of a filament, luminescence and is the radiation from the heating of a gas or a vapor metal vapor. Fluorescence is radiation being at a particular wave length which is reconverted through certain materials into visible zone like you have the fluorescent lamps which are radiating in the ultra violet zone but with the help of phosphors, this ultra violet radiant energy is converted in to visible zone. Then you have there are certain materials which can retain light and reradiate at a later point in time phosphorescence that is what we call and in fact these are used highly in having luminescent sign boards on the highways etc.

So a combinations of luminescence and fluorescence are being used, incandescence no doubt has the origin of artificial lighting is not highly used because it predominantly depends on the what

you call heating effect and as already seen in several of these lessons, the efficiency of these lamps is talked in terms of the light output in terms of lumens for every watt of energy that is consumed and that is very high for an incandescent lamp.

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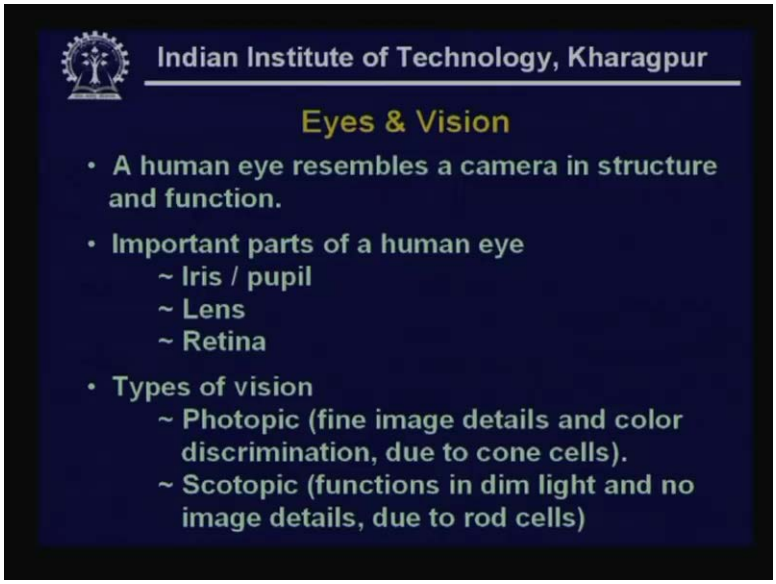

The next lesson was to do with the eyes and their behavior with the vision. And in this respect the human eye resembles a camera in structure and function. It has three important parts like iris or pupil which allows light to go in similar to the, I mean the shutter opening and lens you have a similar lens and retina response corresponds to the film. And these, with this we have two basic categories of vision which we call photopic and scotopic which means fine image details and colour discrimination which is due to the nerve cells which are often called cone cells and scotopic which helps us in seeing in dim light and get an image details, this is due to the rod cells. So there are two categories of nerve fibers that enable us to view.

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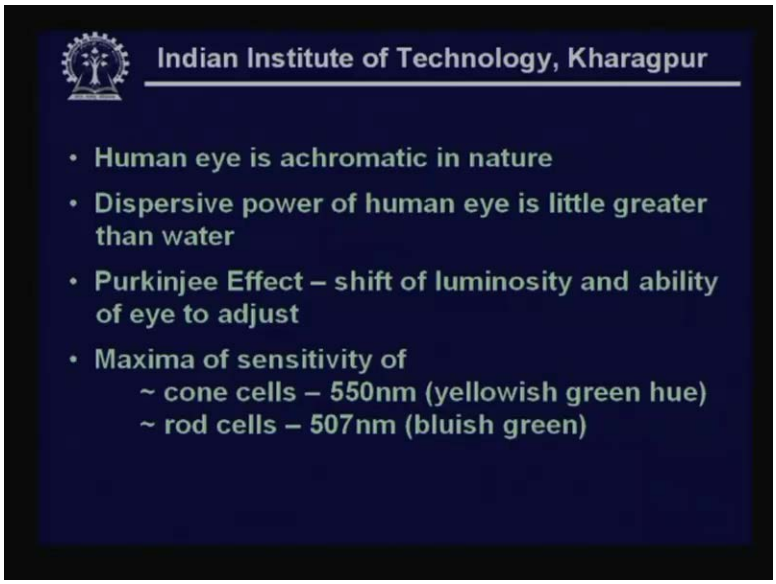

The human eye is in sense it is achromatic in nature and it's dispersive power if you would like to attribute it to it is a little greater than the water and there is a shift of luminosity and ability of eye in fact that is where when we are trying to design the lighting systems, we try to see that human eye has an excellent adjustability depending on the conditions. But how does it do? It does with the help of an optical muscle. So the, obviously they tend to have some fatigue getting set in to it. So, to avoid that, the adjustability one has to look at how the eye is able to adjust with minimal fatigue.

In fact all of us have experienced that over a days' time eyes do get tired which after a nights rest become comfortable in using. So the Purkinjee effect is what is the ability of eyes to adjust with use is what we call, in fact the eye defects are talked in terms of use abuse and misuse I would say. The sensitivity of the cone cells is around 550 nanometers which is around yellow green, yellowish green and the rod cells is around 507 nanometers bluish green.

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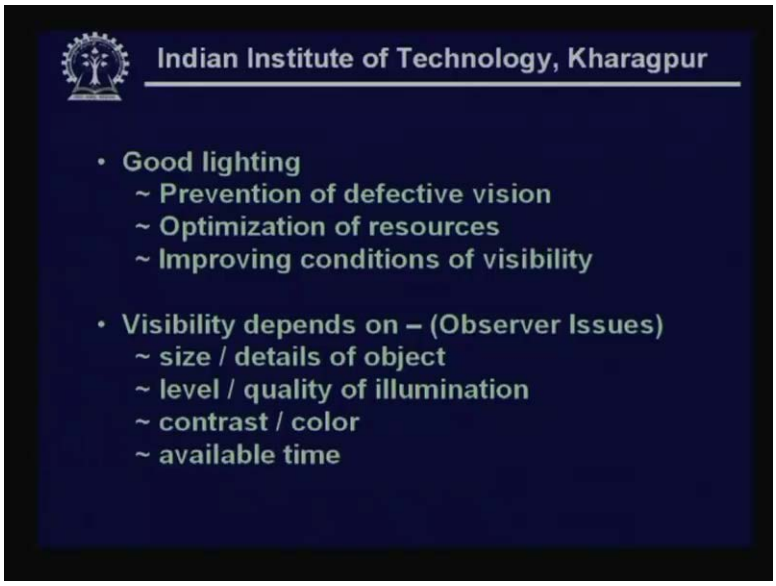

Incidentally, the eye sensitivity and what you call the response of the eye and the incandescent lamp radiant energy output and to a large extend spectrum of light output from the natural light are coincident. The good lighting therefore aims at preventing any defective vision, optimizing the resources and a making visible condition so that the efficiency of the user improves. Obviously it depends on various issues such as the object being observed, level and quality of illumination and the contrast and colour because contrast and colour are going to decide how much of adjustment the human eye has to do and the available time.

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In fact it is the visibility depends on various things like how good the persons eye is I mean there are any defects you could have fatigue, how much of distraction is there and individual efficiency. These are related to your observer. Now what could be the reasons for fatigue? Fatigue could be by virtue of the source itself being moving or rotating source, it could be having a glare. Glare as we say arises when the line of vision is coming in the, I mean or there is a bright source of light in the line of vision.

Now this does happen when you try to read some of those printing which has got double impression and whenever pupil is dilated or opening becomes larger and there is sort of fatigue, focusing on the source of a glare also gives rise to fatigue.

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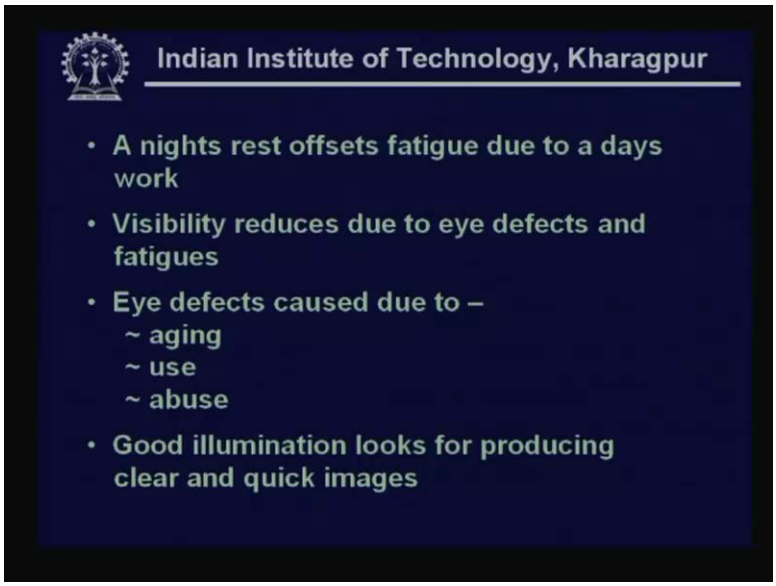

Now as already mentioned a night's rest always offsets fatigue due to a day's work similarly a week end rest does offset the fatigue over the week. Now there are issues of reduction in visibility because of eye defects and fatigue. Eye defects could be due to age, use and abuse as also. Good illumination should always look for producing clear and quick images. So that is the aim.

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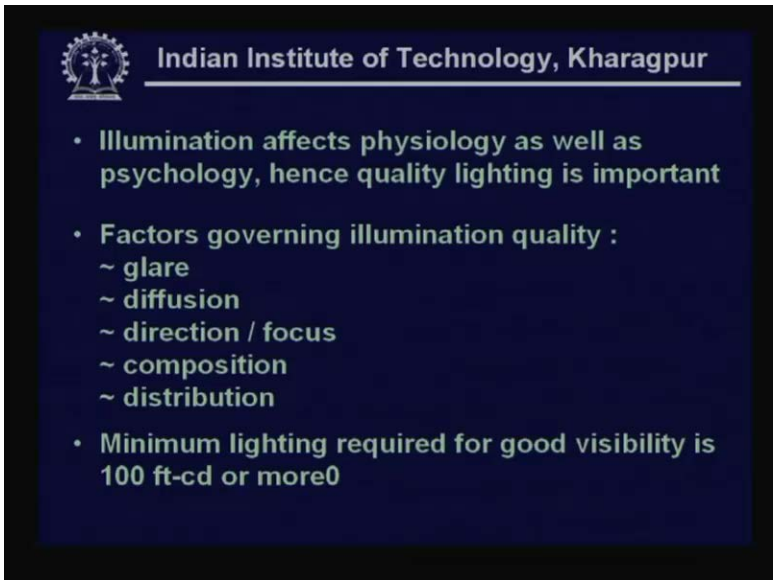

So, any lighting system looks for this because the light provided effects physiology as well as psychology and this is what we mean by a quality of lighting. In fact we need different levels of lighting or different kinds of lighting for different applications. Now illumination quality as already mentioned depends on the direction, how it is distributed and if there is a glare or there is no glare. This is from the functioning of the lighting point of view and it is believed around 100 foot candle is good enough for good visibility. This is a minimum requirement for a good visibility.

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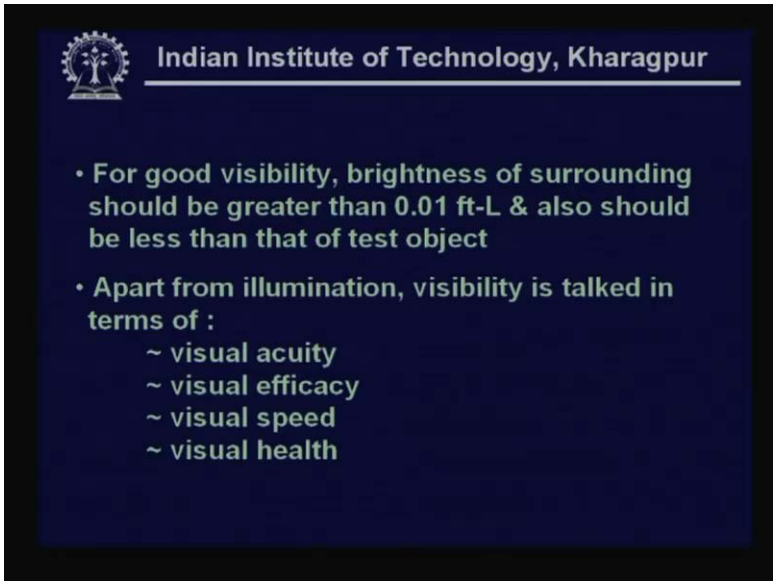

Brightness of source, see there are two issues as we look into the photometry that becomes clear once again. One is the brightness or luminance intensity of the source other is the illuminance, illuminance or the luminance intensity on the surface of the object. Now here we are talking about brightness of surrounding. See, unless there is a certain match between the contrast and the object being observed with respect to the environment, it may not be possible to have good visibility.

So good visibility, brightness of surrounding should be well above 0.01 foot lamberts and should be less than that of the test object. Test object means the object of interest. Now coming to the talking about the eye, there are certain indices or certain terms used to talk about the visibility aspect, one of them is visual activity or the performance, visual efficacy how good it is, speed the moment you are shown an object are you able to recognize, the health meaning the if there are any defects or not.

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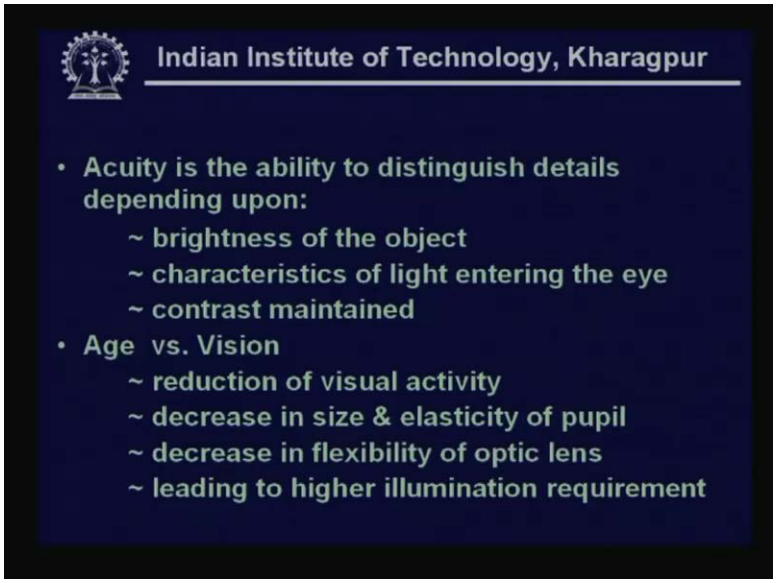

Now acuity by definition is the able to distinguish details depending on the brightness of the object, characteristics of light entering and depending on the contrast that is maintained. All of us are very clear in fact it's very easy if you have a sharp contrast like a black board and a white chalk, it becomes very easy to read. So these apart, age has effect it reduces visual activity and this occurs due to the decrease in the size of the pupil and reduction in the elasticity of the muscles and there is reduction in flexibility of optic lens and therefore we find that with the age we need higher levels of illumination compared to the youngsters.

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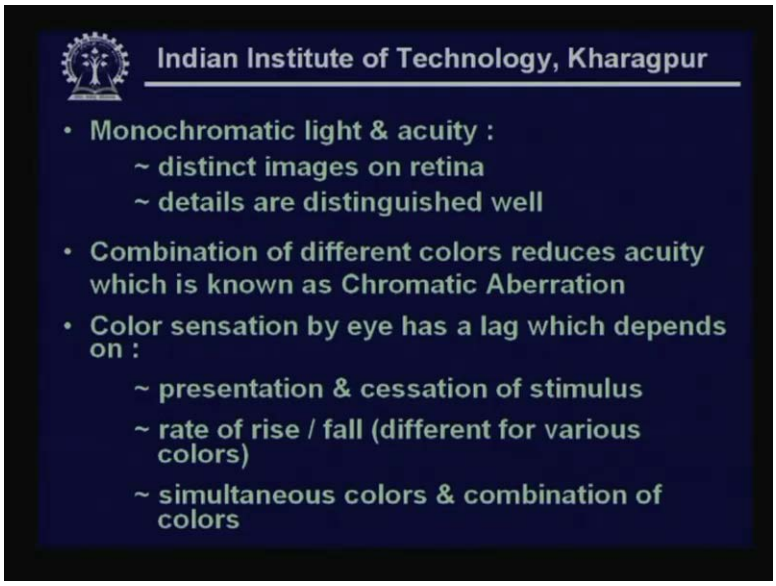

The monochromatic light enables to get distinguish images on the retina and details are very well distinguished. It is in fact found if you have combination of different colours, there is a reduction in visual acuity because what happens is the eye adjustment for different colours becomes focused at different points and that leads to what we call chromatic aberration. There is a certain lag also associated with colour sensation and this depends on how the colour is presented and how the stimulus is removed or the rate at which it is given whether the colours are given simultaneously or combined, these are the issues.

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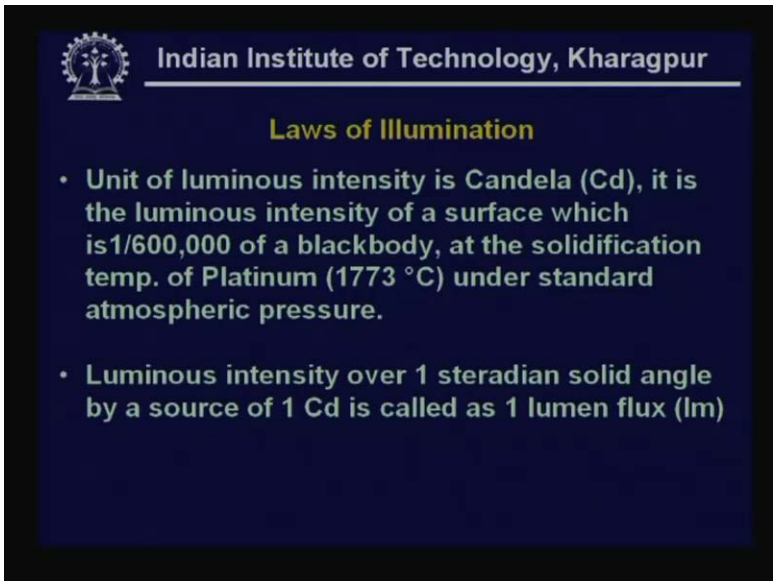

Having looked at how the eye behaves, we had a look at the certain issues that govern the light radiation which we could call as loss of illumination. Here to begin with we looked at what should be the standard for a unit of light which was originally believed to be a candle has been given as a candela. It is the luminous intensity of a surface which is 1 by 600,000 of a black body which is the solidification temperature of platinum under standard atmospheric pressure. Now luminous intensity over a one steradian is what we call as the light flux and is termed as lumen. If you consider a light source as a point source, the total light radiating out over one solid angle by a source of one candela is what we call 1 lumen and therefore when the whole light is radiated in all directions, we associate what we call mean spherical luminous intensity which is nothing but average intensity into solid angle or MSLI.

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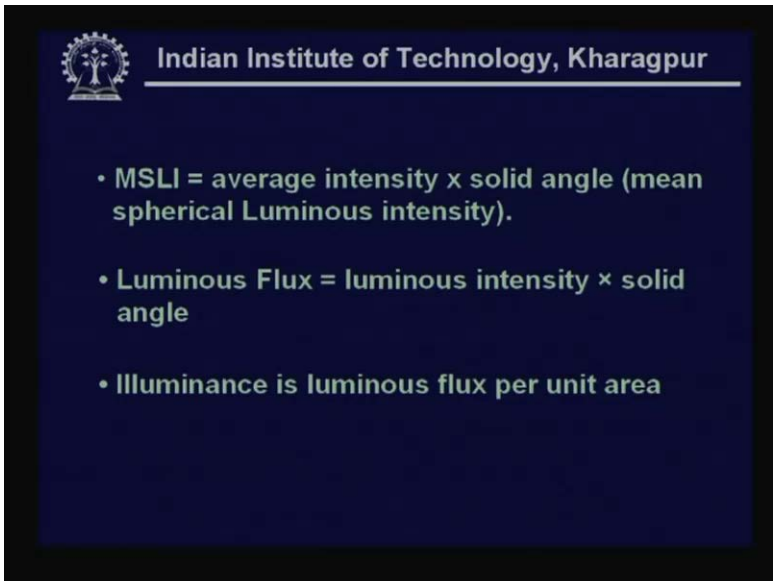

The luminous flux is luminous intensity into solid angle that's what we have already said. So if you have 4 phi steradian if we take a complete sphere from a one candela source, you could expect it is 4 by lumens. Illuminance is luminance flux per unit area. What is this? This is the effect of this source on the object surface of the task surface per unit area, the light flux falling perpendicularly to the task surface. In fact all the recommendations which we as a user we look at, we talk in terms of illuminance and it is standard unit is lux.

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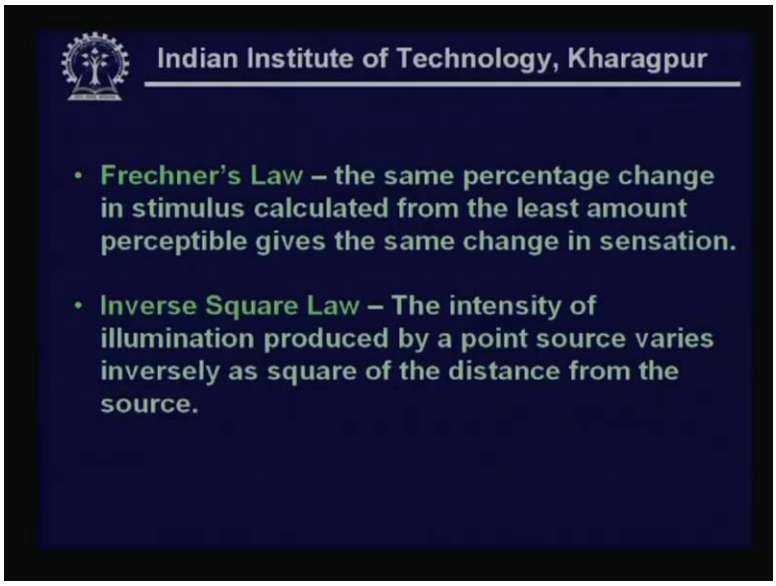

There are two laws, the one of them governing this is a frechner's law which says that if there is a percentage change in stimulus from the least perceptible amount, it gives the same change in sensation that is one. The other of course we have name the… (Refer Slide Time: 19:29) we have the inverse square law which says intensity of illumination by a point source varies inversely as square of the distance from the source. Now when we employ this and extend this, you will find similarly if you have a line of source you will find that the intensity would vary intensely with the distance whereas if you have a large sheet of source it would be independent of the distance.

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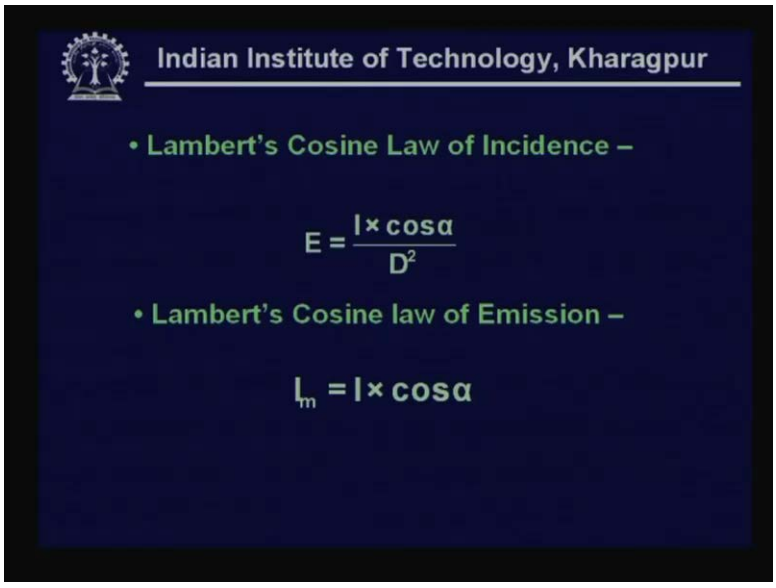

Lamberts cosine law of incidence basically talks about given the candle power at any distance over the, what is the illuminance it is given this. And similarly for the source in a plane we could talk in terms of a cosine law of emission where intensity is intensity per unit area or per horizontal surface due to the source is specified. This is about the laws.

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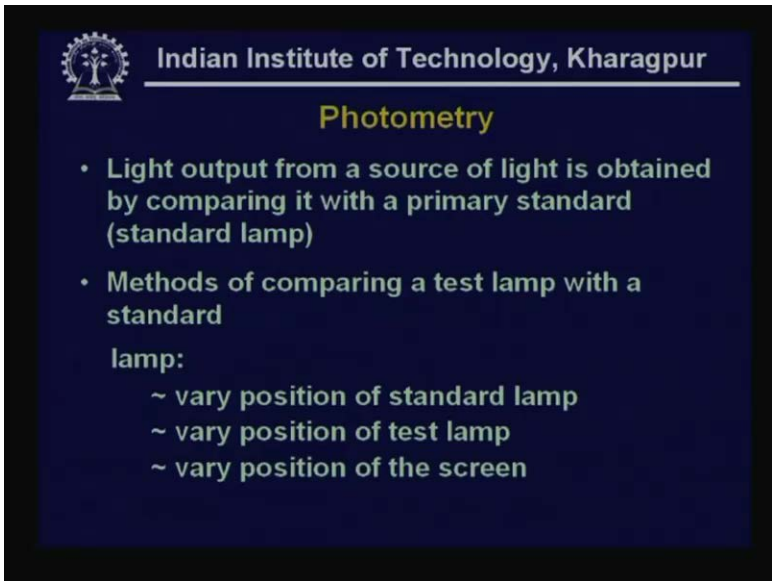

Having quantified, having felt the need for the light source and how eye effects, it's time there was a need to look at the measurements. The measurements are done using photometry which in fact use some kind of a photometric benches where the light output from a source of light is compared with the primary standard or a standard lamp and the methods of comparing could be test lamp for the standard lamp by varying position of the standard lamp or varying position of test lamp or varying the position of the screen. The screen is the one which is placed in between the two lamps and there on which we try to adjust or balance to get the same brightness on either side. Now these days in fact we do have what are called as a photometers or light sensitivity lux meters which employ the electronic circuits or photo electric devices which directly based on the voltage generator are calibrated in terms of a, what you call the intensity in lux.

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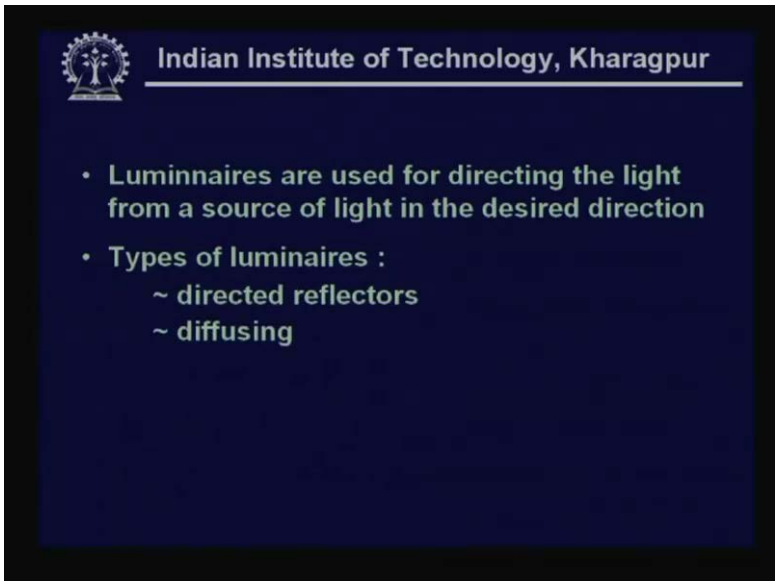

The luminaires are used for directing the light from a source of light in the desired direction apart from giving the fixture, in fact there could be directed reflectors and diffusing because one is you reflect the light to get it in the direction. We are talking of luminaires right here in the photometry essentially because when you are talking making the photometric measurements, you are looking at the light output and unless light is directed, the light radiates in all 360 degrees and all light may not be useful in the task. So, we will take up the luminaires once again when we talk about the lighting systems.

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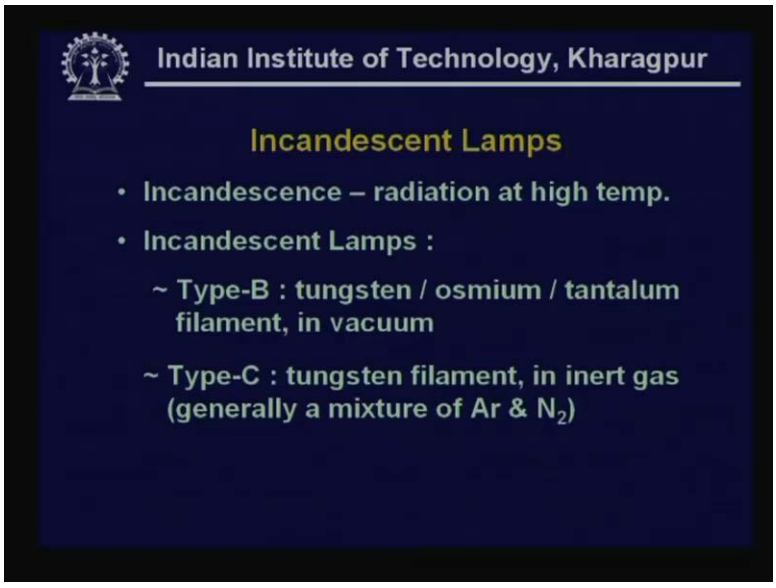

The next thing is to look at the sources themselves. We said there are various phenomena that are used and broadly they could be incandescent lamps and discharge lamps. Incandescent lamps is radiation at high temperature and there are two categories one which have, which these days use tungsten which evolve over a period from carbon, tantalum, osmium in vacuum medium and had the problem of what is called as a lamp darkening because of the tungsten getting evaporated at that temperature getting deposited due to convective currents on the bulb surface.

As opposed to this we have type C tungsten filament in inert gas generally a mixture of argon and nitrogen when enables the evaporated tungsten to recombine and get deposited back on the filament. In addition to this filaments are coiled so that they occupy less space and there is less scope for the material to evaporate. Why is tungsten chosen?

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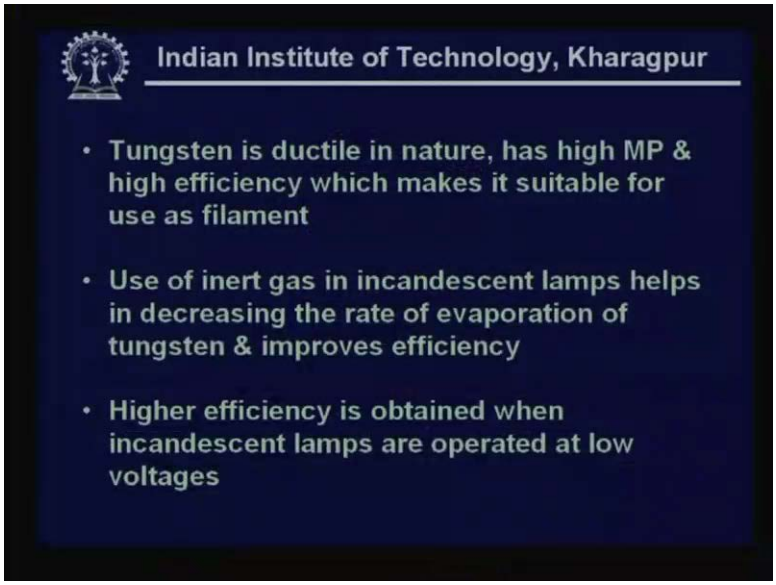

Tungsten is chosen because the ductile in nature has a high melting point and efficiency and suitable for use as a filament. Use of inert gas helps in decreasing the rate of evaporation and there by improves the efficiency. In fact that has been the reason you will find that these the vacuum based incandescent lamps are there in only low wattage. Obviously here I must mention once again that most of the times we talk in terms of the wattage. We know I want to get more light in a particular room, if I want to loosely talk about it I might say okay let me get 50 watts or 100 watts of lamp. So the wattage really tells me whether I am going to get a higher light or lower light and there that's why you find these vacuum lamps are there at 5 watts to about 25 watts. However the efficiency of these lamps has been much low and that is what led to the improvement of what you call discharge lamps into the picture which effect this.

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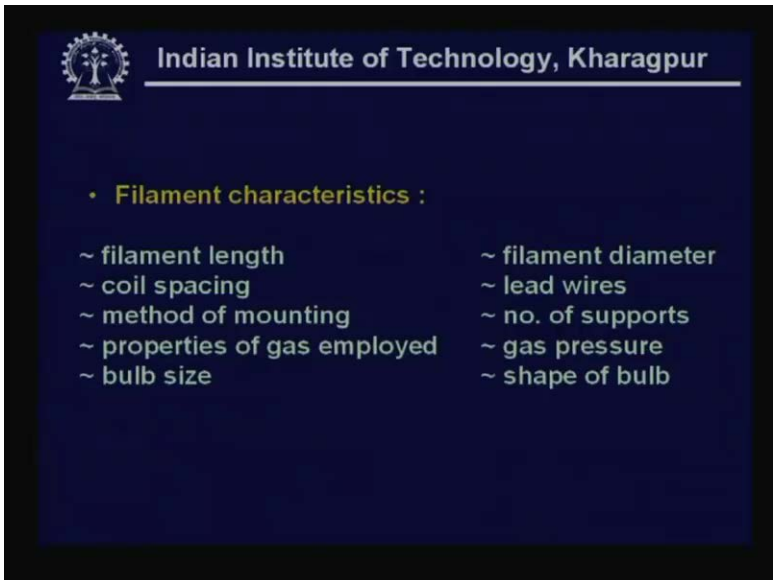

So the filament characteristics of course depend on the length, the spacing of the coil, the way they are mounted and of course the gap gas is to be employed for a low, employed for avoiding the lamp darkening. You also have to have leads to take in and take out and the glass envelope is what we call bulb and that shape does matter filament diameter decides what would be the radiation output.

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Bulbs are designed for uniform radiation and they are having accurate consumption of power and to give good efficiency.

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The rating of course depends on the life rating typically these are rated for about 1000 hour's kind of a thing these days. So coming to the other category of lamps they are the discharge lamps. As I said the first one was the incandescence then is the luminance which is the radiation by virtue of a gas being gas or a metal vapor being made conducting. So they, this is the chemical or electrical action on gas or vapor producing radiation and in fact fluorescence is the other form of discharge lamps where radiation is absorbed at one wave length and is reradiated at another wave length like you have the fluorescent lamps where UV radiation is converted into visible radiation. The most lighting schemes use a combination of these two and they give the light output or the luminescence efficiency in terms of lumens per watt much higher than what you get from incandescence.

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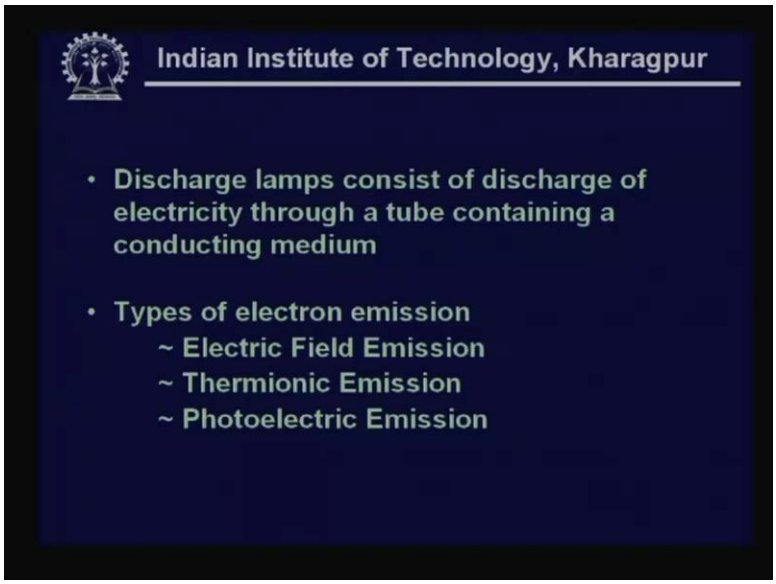

They are essentially consisting of a discharge of electricity through a tube containing a conducting medium and types of electron which depends on electron emission. This could be based on electric field that is you create a field by shear application of the voltage you have the electron emission which could be called as a cold condition or cold cathode type. Other alternatives would thermionic emission where there is a filament which is heated and there by the cathode emits electrons being at a higher temperature.

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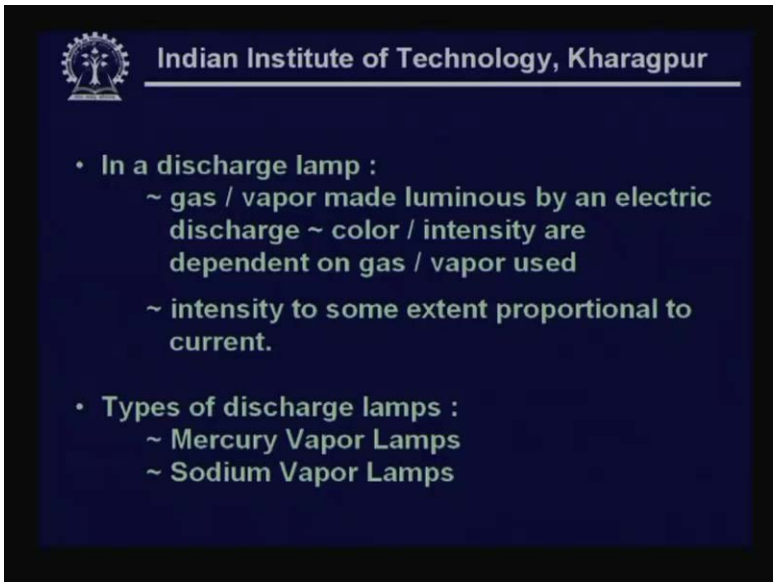

So, in a sense a discharge lamp has a gas or a vapor which is made luminous by an electric discharge whose colour intensity depend on the gas or vapor used an intensity is proportional to

the current. Here it strikes an arc and arc is predominantly a constant current phenomena therefore there are additional accessories required, the discharge lamps commonly in use are mercury vapor lamps and sodium vapor lamps.

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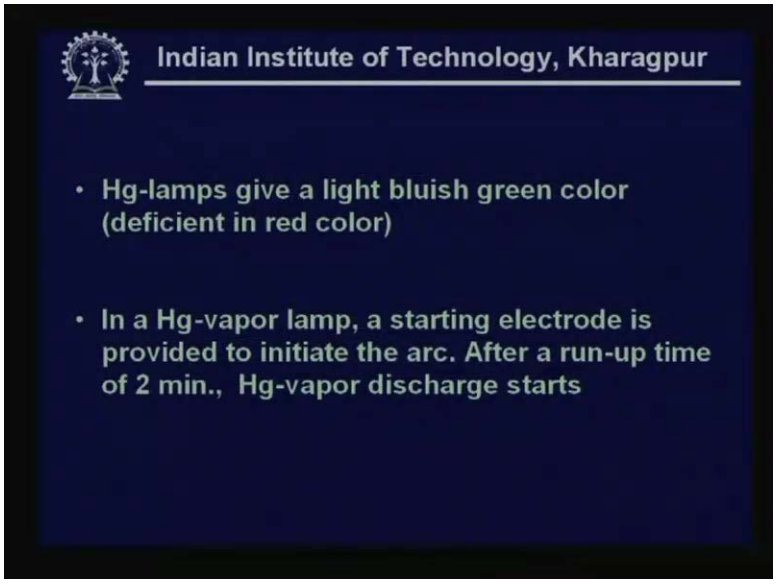

Mercury vapor lamps give light bluish colour, there is a some deficiency in red colour but in a mercury vapor lamp starting electrode is provided. All of them need a starting because it needs ionization or gas to be struck and there is a run up time which is around 2 minutes the vapor discharge starts.

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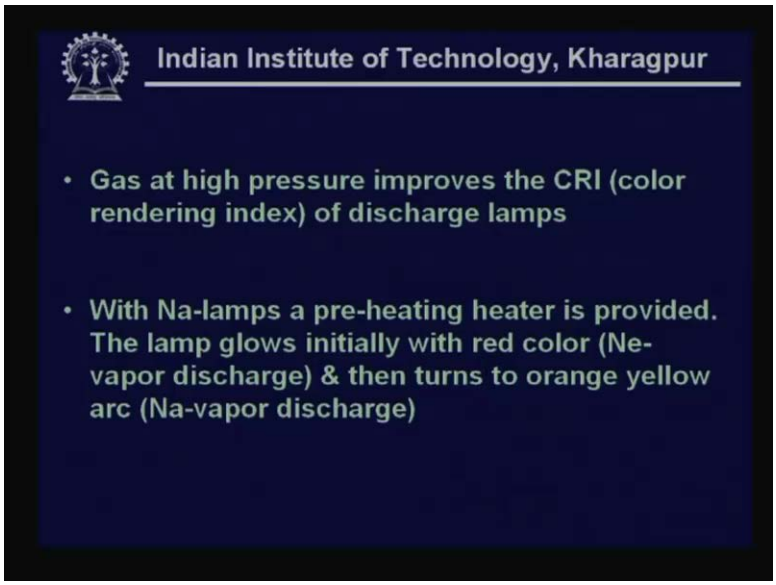

As opposed to this gas at high pressure improves these are, see they are categorizes low pressure as well as high pressure. In high pressure there is a good colour rendering. Now what is this colour rendering? In fact we have not said anything about it. Colour rendering is the issue which enables observing the object colour in total. With sodium lamps a pre heating heater is processed lamp glows initially with red colour.

Why does it happen, because the starting element or a starting electrode is by way of neon vapor and then it turns to characteristic orangish yellow which is a sodium vapor discharge. Now here of the lamps we have covered, there is a certain thing called the utilization. As we have already seen the continuous spectrum is obtained in case of a incandescent lamps whereas discharge lamps tend to give what is called as a line spectrum but line spectrum we saw the utilization ratio considering the human eye sensitivity is much higher in case of a sodium vapor lamp whereas which is lesser in case of a mercury vapor lamp because it has got two bands. One band in the visible zone and one band in the ultra violet zone, in fact that is where the fluorescent lamps comes into picture to employ usefully use that.

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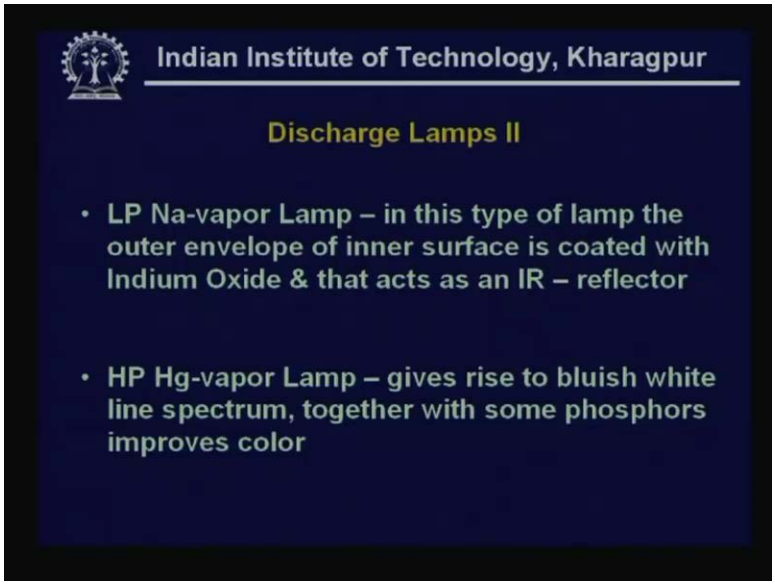

The low pressure sodium vapor lamp has the coated interior and therefore it reflects most of the thing and ensures that there is good radiation whereas high pressure mercury vapor lamp gives line spectrum and in order to have that's why in order to get good colour rendering sometimes phosphors are added. In fact the mercury vapor lamp together with metal halides which is often used in sports lighting is aided to give the, what you call colour rendering. Some luminance in power that is put in the tubular lamps, it enhances the brilliancy of light that's why we are saying that.

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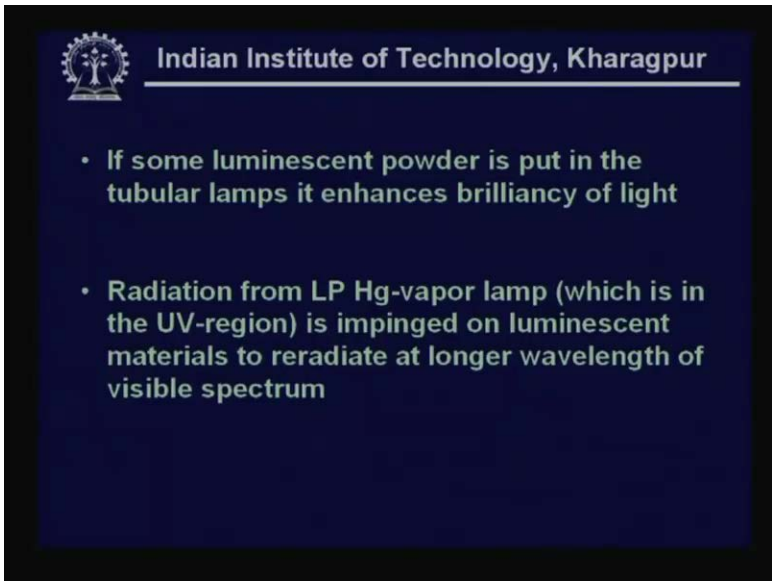

The radiation from low pressure mercury vapor lamp impinged on a luminescent material reradiates at a longer wave length of visible spectrum. So this is what we call as the fluorescent lamp or colloquially known as tube lights.

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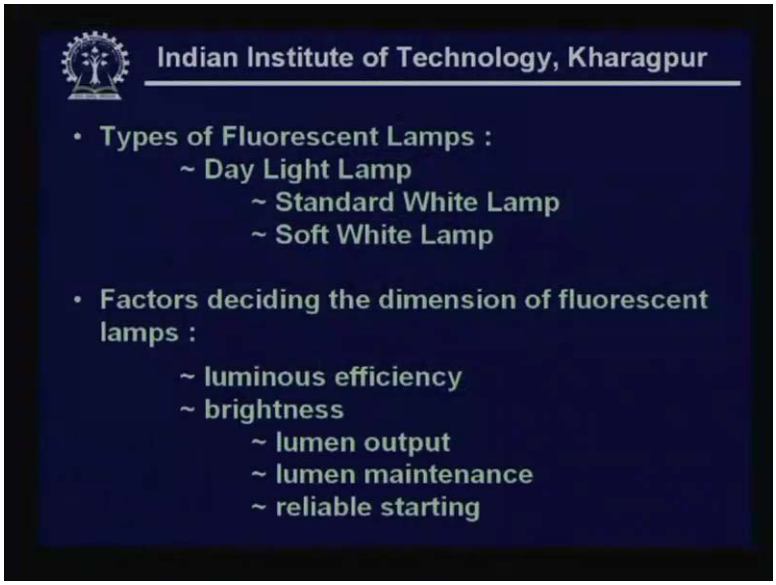

The types of fluorescent lamps could be day light lamp, standard white light lamp, soft white lamp in fact this is a line source and the factors that decide the type of fluorescent lamps are the luminous efficiency of course you remember lot of energy which is getting wasted in a low pressure mercury vapor lamp in the UV reason is being converted into what you call visible light therefore the efficiency increases brightness.

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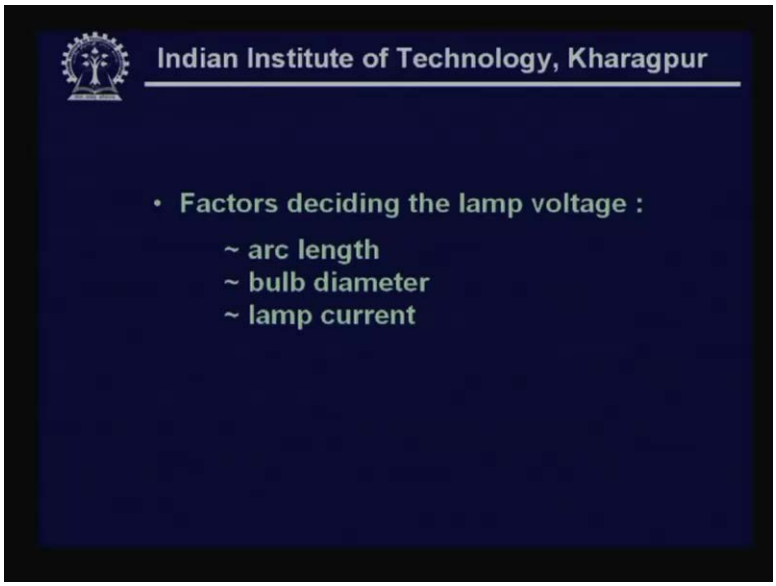

And the lamp depends on the voltage at which it is go on a operate in fact we find that the voltage required to maintain the arc is much lower than the initial voltage and therefore this depends on the diameter of the bulb, arc length and the current. I told you these are all depending on a discharge or an arc discharge which is a constant current phenomena.

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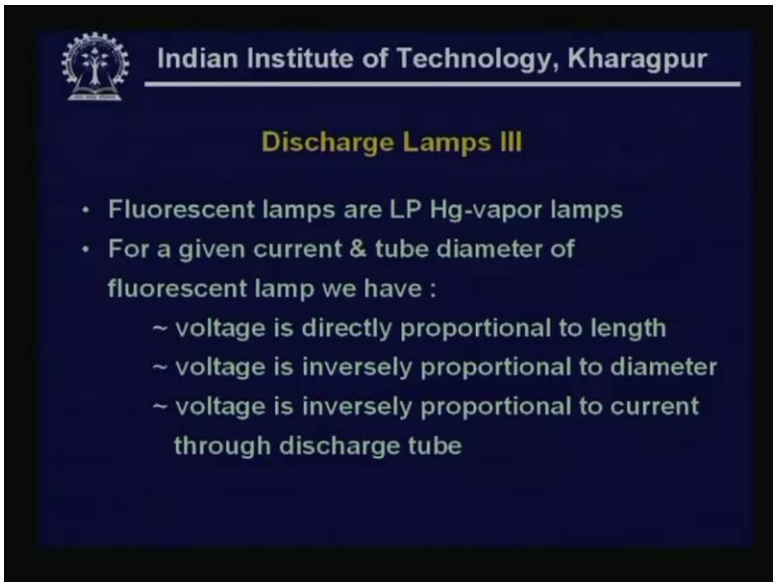

Continuing with the discharge lamps, the fluorescent lamps are the excellent example of low pressure mercury vapor lamps and for a given current and tube diameter, voltage is proportional to the length, inversely proportional to the diameter and is inversely proportional to the current through the discharge tubes. These are the observation based on the studies.

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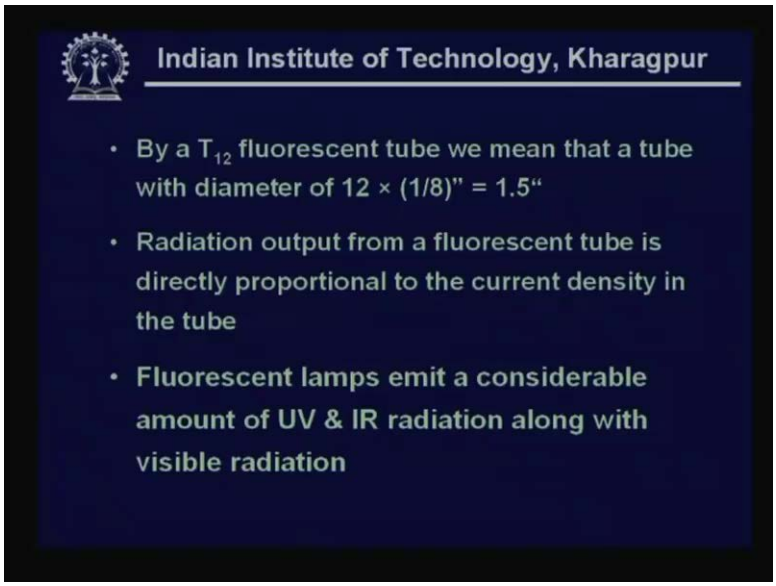

And they are normally talked in terms of a T sub some number like for instance if we say T_{12}, its fluorescent tubes that has a diameter of 1.5 inches. In fact these days we get slim or thin type of fluorescent tubes and T_5 is what we call and that is a very state of arc situation. Now the radians of the radiation is all obviously proportional to the current density therefore diameter decides what kind of a thing. They emit considerable amount of UV and IR along with visible radiation and this UV radiation is what we are making useful.

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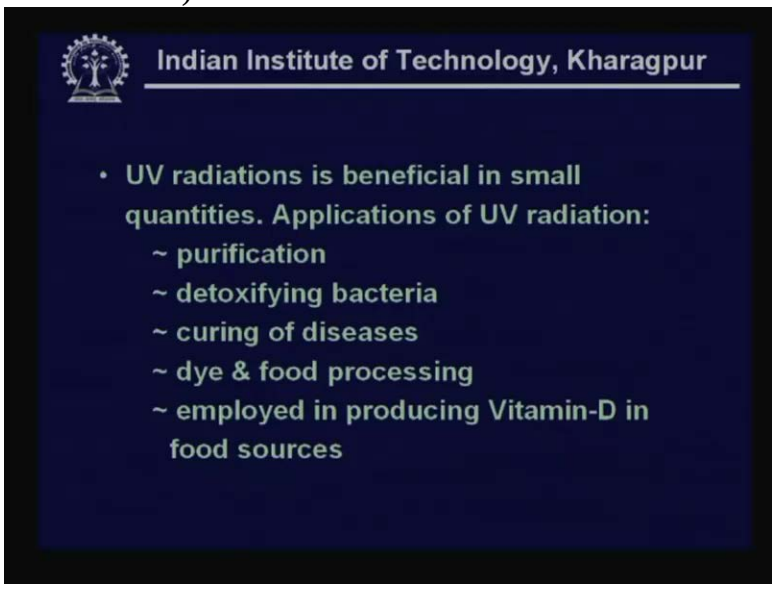

In fact UV lights as such are also used in purification that is all of us are using water purification systems which are essentially based on this. In health for detoxifying bacteria, curing of diseases and food processing for preservation and enables in producing vitamin D in so food sources.

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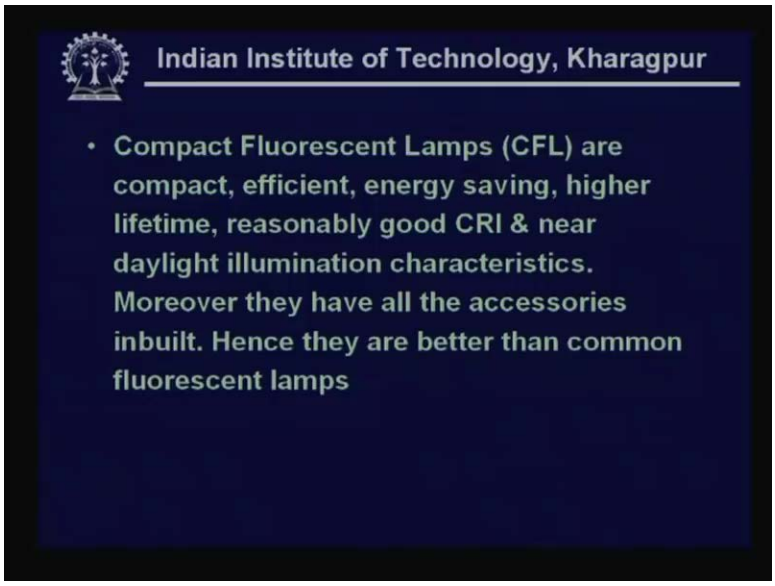

Compact fluorescent lamps are nothing but the compact efficient energy saving higher life time. Fluorescent lamps which can be retrofitted into the same outlets where incandescent lamps have been put. Now recall that they need a higher starting voltage for the arc to strike, so in order to and arc is a constant current thing. So there is an impedance required to be placed in series to maintain the current and this impedance takes the form of a coil which we often call inductive coil called choke. So there are several accessories involved, all of them are built within the same envelope.

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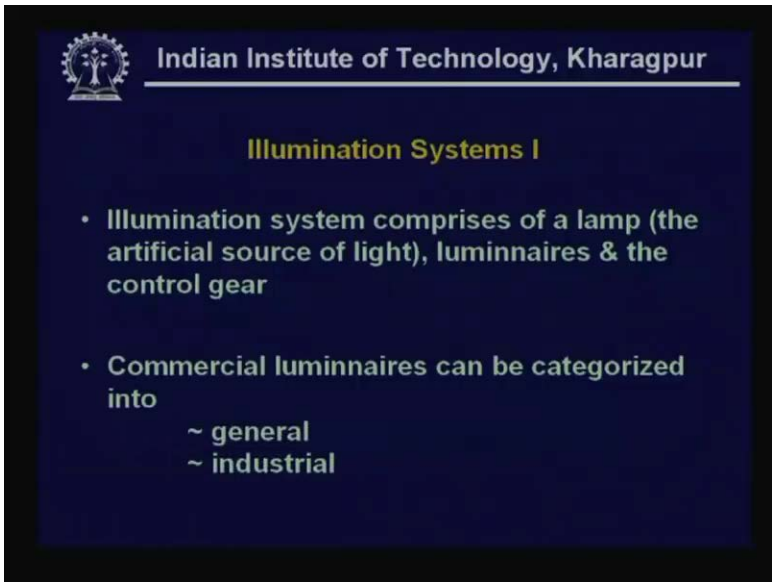

Illumination systems, so having talked about the lights now the time to look at the illumination systems, illumination systems comprise of what? The source of artificial light lamp, luminaires which suspend or support them and the control gear. Control gear meaning you need to switch on, switch off, direct or vary the level of illumination. There are luminaires are categorized as general and industrial. Industrial requirements are most stringent because it could be hazardous environments could be there depending on the nature of the industry.

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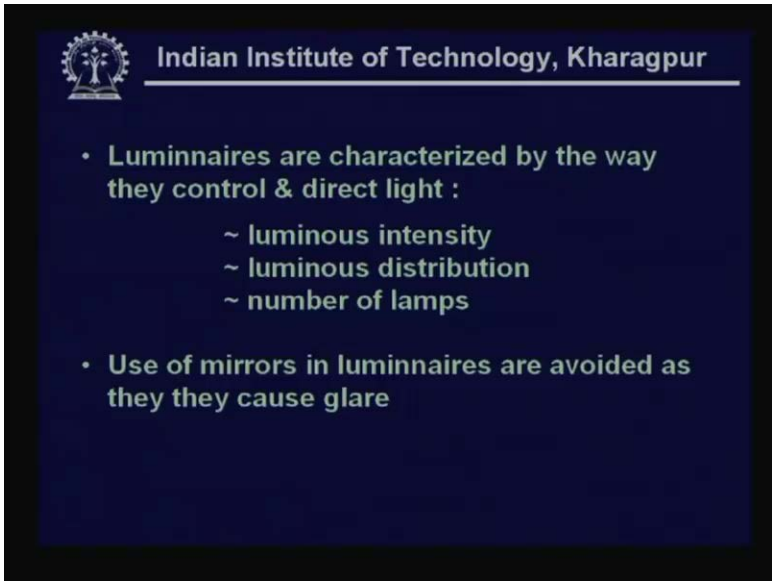

Now depending on the way they control and direct light and they distribute the light they are categorized okay. In fact we have seen luminaires which direct the entire light let us say for interior applications towards the ceiling and we perceive the light by way of redirection. Use of mirrors in luminaires is provided to direct the light where you want. You would like light to be directed towards the task.

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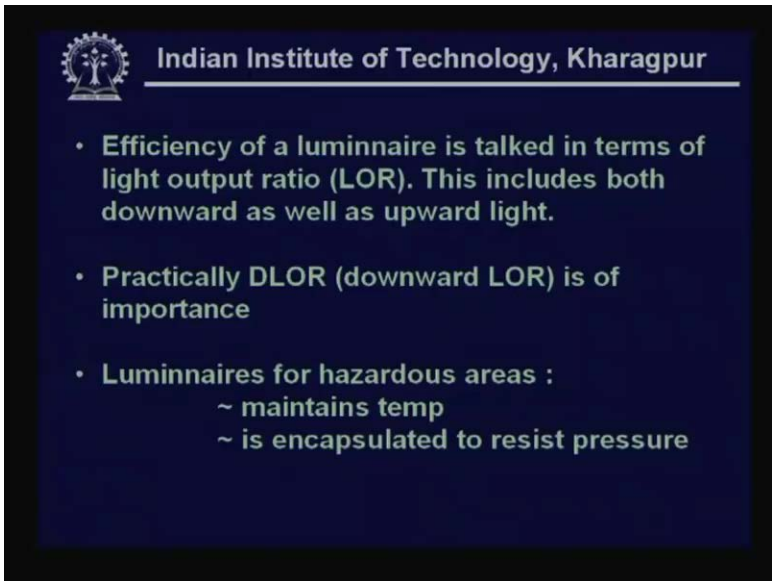

Now there is a term LOR or light output ratio which is essentially talks about the efficiency of a luminaire. Now the luminaire efficiency includes a total output. Let us say a lamp or a set of lamps are provided in a luminaire, the ratio of the light radiated towards the task or downwards to the total light is what we call light output ratio. Practically down light, down, downward LOR is of importance but if we have some reflectors in fact these days most of them have what is called the mirror optic reflectors so that most of the light going towards upward direction is directed downwards towards the task. Luminaires for the hazardous areas needs to be taken care. They have to be encapsulated so that there is no pressure build up.

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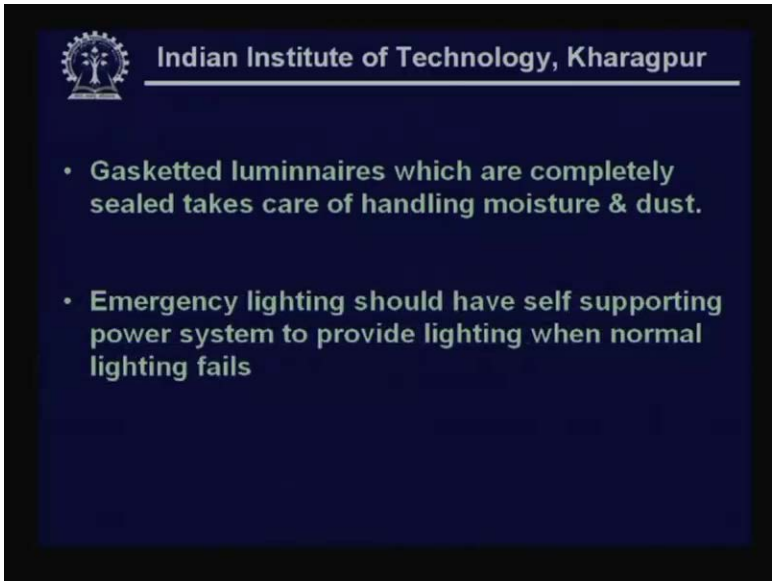

And recall in most of these fluorescent lamps which are being extensively for interior application or there is a, what you call starting device called the starter which is nothing but a bimetallic strip which opens up. That is there is a spark involve and if this is not controlled, it can be hazardous and lead to fire hazard. Now these have to be sealed and taken care so that the moisture and dust does not enter because that can be lead to the thing.

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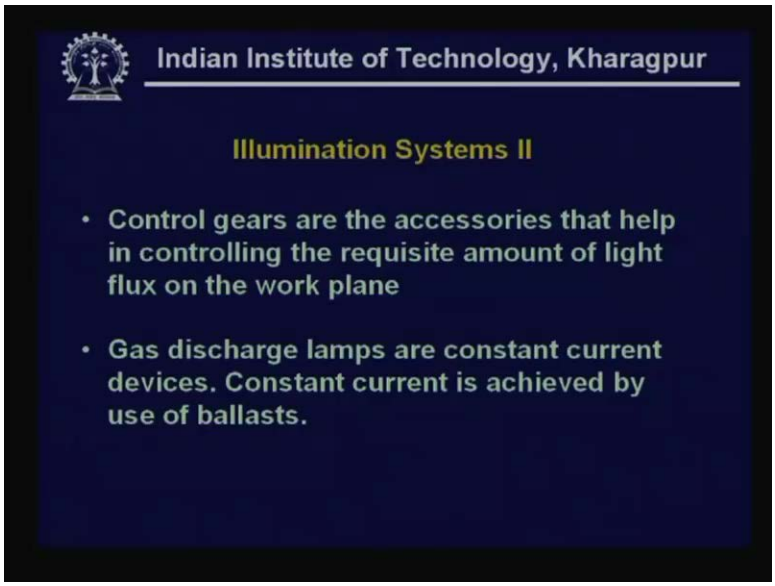

Continuing with the illumination systems, there should be some control gears which help in controlling the flux on the work plane apart from that you have the accessories. The use of ballast which I have already told they are called chokes that the impedances which take the form of an inductive coil in case of a, what you call AC application whereas it may take the form of a resister in case of a DC operated fluorescent lamp.

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Now these ballast should be such that they do not themselves cause any interference, they should be able to start in fact it's a and at the same time they need to see that power factor system is maintained. In order to do that we add what are called as a capacitors in the series with the system or in parallel of the line.

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Now most lamps have starting voltages greater than the spark over voltage and therefore there are starters or igniters as already told you, told to you, igniters are used in some mercury vapor lamps these are small three electrode devices which are again controlled by electronic circuits. The third electrode when the gate pulses are given, it gives rise to the closer of the switch.

Apart from local and general lighting, you can need to have the light flux control which are sometimes obtained used by using what are called dimmers. Dimmers are nothing but auto transformers which vary the voltage. This can be used only when you are using certain incandescent lamps especially in the theater lighting and stage lighting where you want to enhance a particular thing or reduce that is where you do use this. In fact these auto transformers were initially developed for this kind of a thing and that's why they were also termed as demostats.

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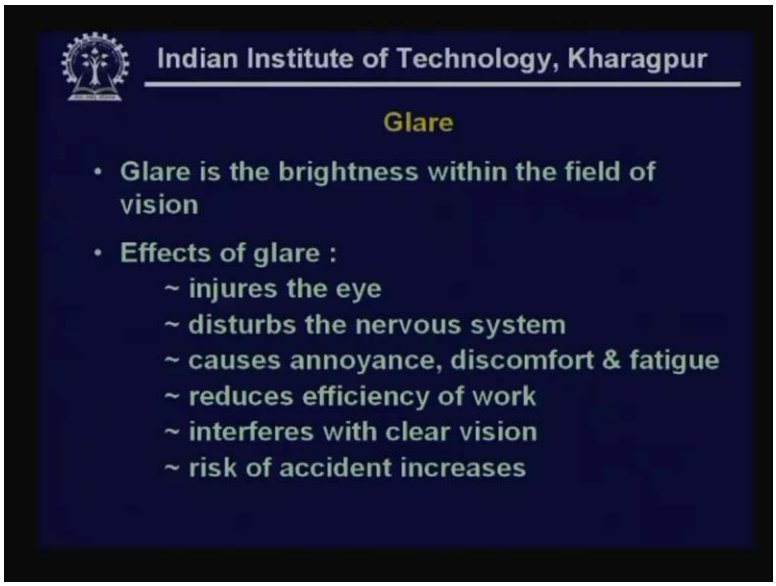

Now one of the issues which was there in performance of the eye was glare. Glare is a very important thing therefore the next lesson, try covering the glare and as already defined is the brightness within the field of vision and this could injure the eye. It could disturb the nervous system when the glare is less it can create a noise but if it is more it could be discomfort and fatigue. Now there by it reduces the efficiency of work because you will not be able to see clearly and if it is happens with the street lighting, it can create accidents.

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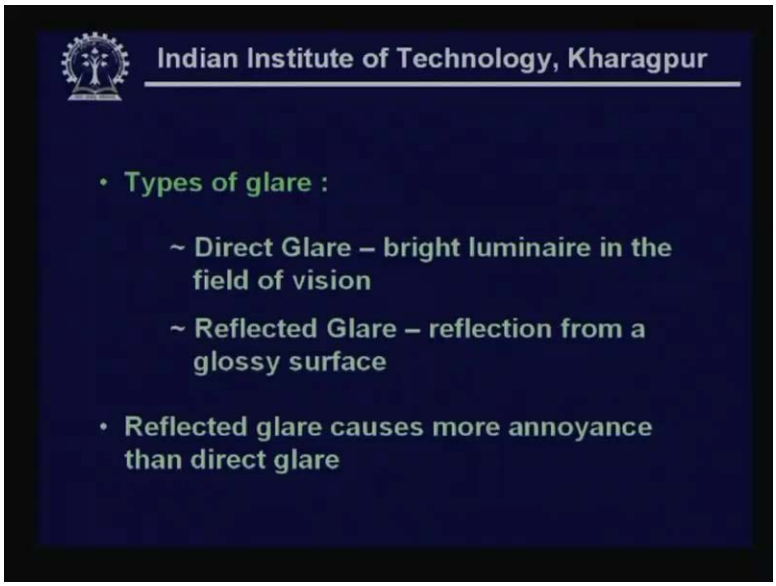

Now the glare itself is called as a direct glare where in case of a source is there within reflected glare is a basically, when this light falling on another glassy surface gets and another thing is you do get glare from the natural light through the windows. The reflected glare is does not really damage the eyes but it is only an annoyance but still it is to be avoided.

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One simple rule to minimize glare is never mount luminaires below the line of vision have them, in fact we find most of the time most of our interior lights are placed closer to the ceiling. Disability glare is what we call which impairs the vision. Discomfort glare meaning the longer you are exposed to the glare, the more discomfort you will get.

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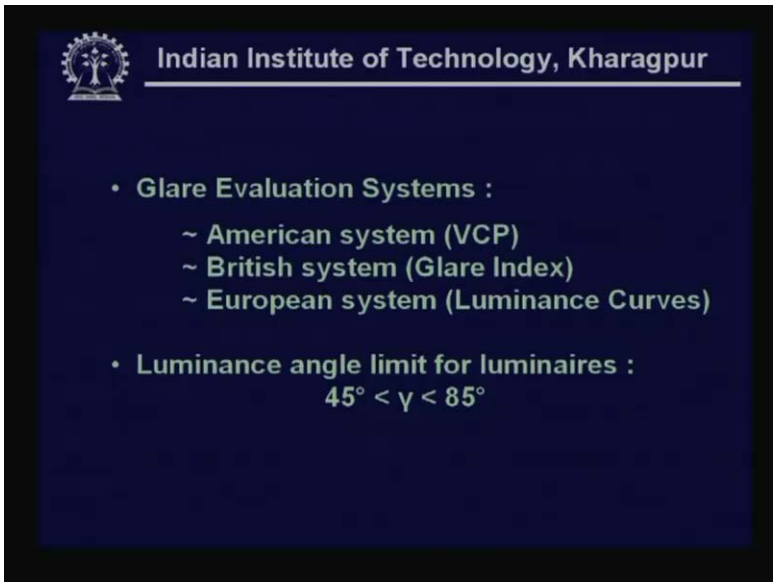

The glare evaluation system have been there one of them is the visual comfort index or the American system and the British system is a glare index and the European system which is for often followed is the luminance curves. Luminance angle for assessment of these curves is kept between the angles subtended at the eye between 45 to 85 degrees.

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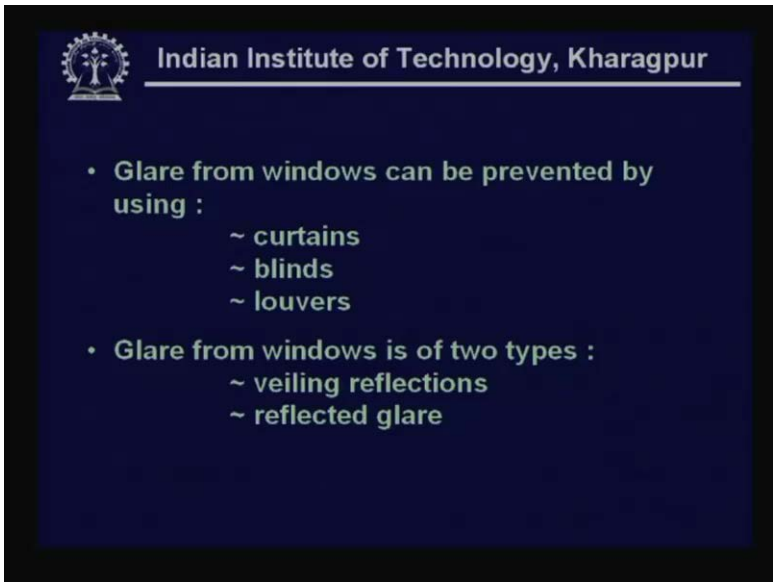

I said there could be glare from windows, this can be taken care by suitable design of curtains, blinders, blinds and louvers. And it is again it can be reflected the light entering through the window could again that reflected from another glassy surface or it could be veiling reflections.

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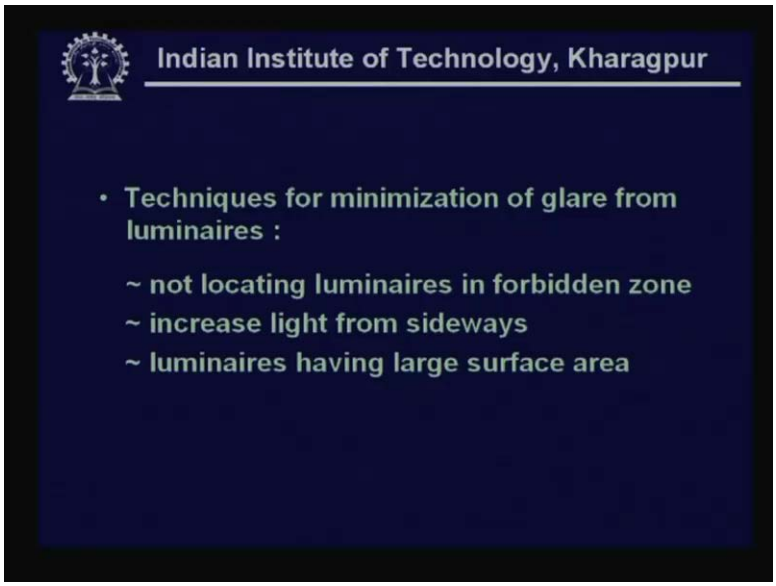

Now in all the glare is to be minimized and it can be minimized by not locating luminaires in the forbidden zone or that is you try avoid light coming into the line of vision bright sources and the other thing is have low intensity sources spread over a larger surface area there by brightness is limited and you and increase the light coming from sideways and at times you have a light placed in the opposite direction to avoid the glare.

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In this aspect there is one factor design in terms of the influence of lighting on the task visibility that is what we call contrast condition factor and task visibility is talked in terms of the total theoretical illuminance that is possible in a spherical direction with respect to the given

condition. The sphere illuminance which we say illuminance by the source provided equal illuminance intensity in all directions. This is also known as ESI or equal spherical illuminance. So this is how one talks about the task visibility. So this is the way to talk about the glare and too.

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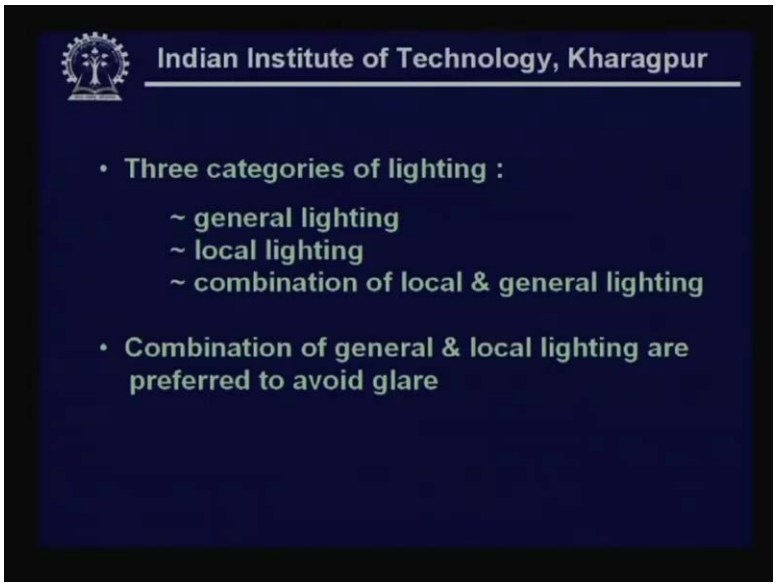

In fact lighting using general lighting together with local lighting also helps to a large extent in taking care of the glare and this is the about the glare.

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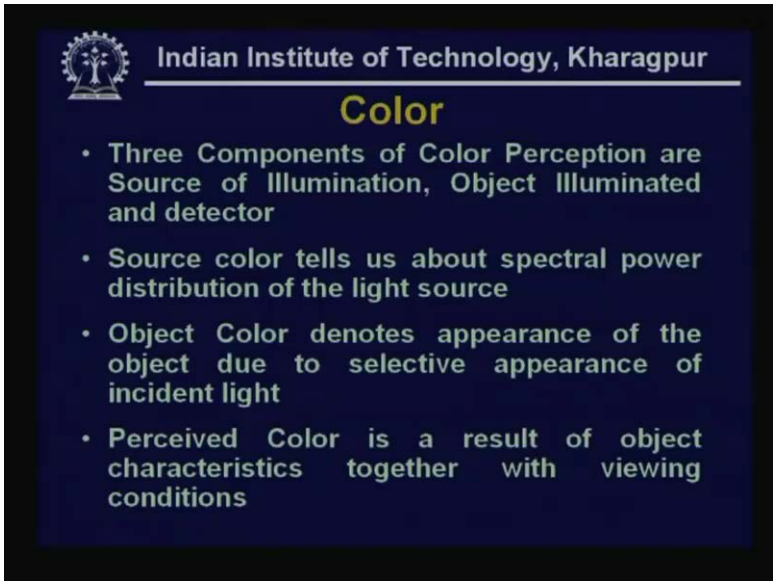

The next topic which tried to cover was the colour. Colour has three components, one is the perception how we perceive and the source of illumination, the object illuminated and the detector. Detector, which is the detector? Detector is obviously human eye, source colour tells us about the spectral power distribution which is associated with the source whereas the object colour is the colour that appears due to the selective appearance of the incident light. So the based on the way the object reflects, you perceive and perceived colour is the result of object characteristics together with viewing conditions, it depends on the external lighting and visual health of the person.

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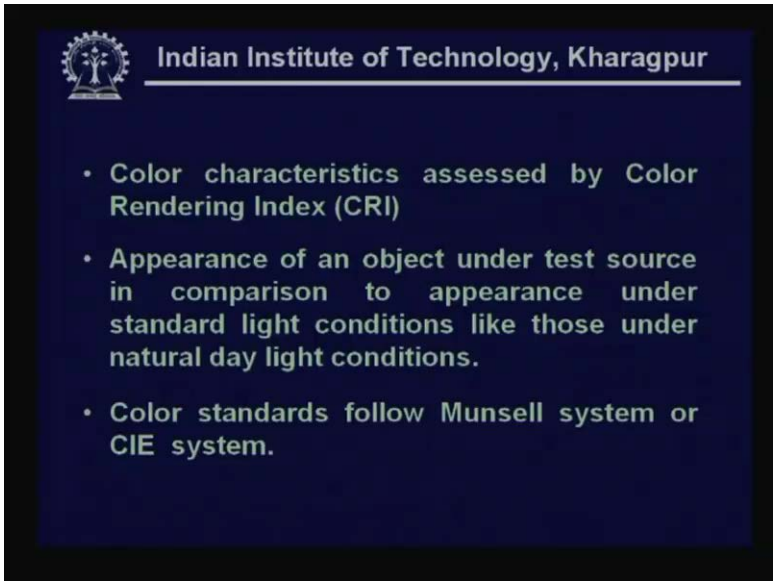

Now often these characteristics are assessed by what we call colour rendering index and appearance of an object under test source in comparison to a standard light conditions is what we mean by colour rendering index and this has to be like those under natural day light conditions. In fact colour standards follow different systems like Munsell system, CIE system and LAB space system.

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Now having said so much it's time we had a look at the recommendations for interior lighting. The good interior lighting requires good intensity so that you are able to see clearly and distinctly. Often the recommendations talk about the horizontal illuminance distribution which is made to be uniform. It's preferred to have soft well diffused light. Colour of course depends on the purpose, you may have certain colours in depending on the like in a game mood they may have different colours whereas in a normal office environment you need to have reasonably good quality day light conditions and above all the source locations should be well above the plane of vision that is a plane passing through the average individual.

Let's say if we are talking about an office where people are sitting, so the work table could be around 0.7 to 0.8 meters from the floor and the eye height could be around 1 meter. So it should be at least above 1.5 meters the light location that's what we mean.

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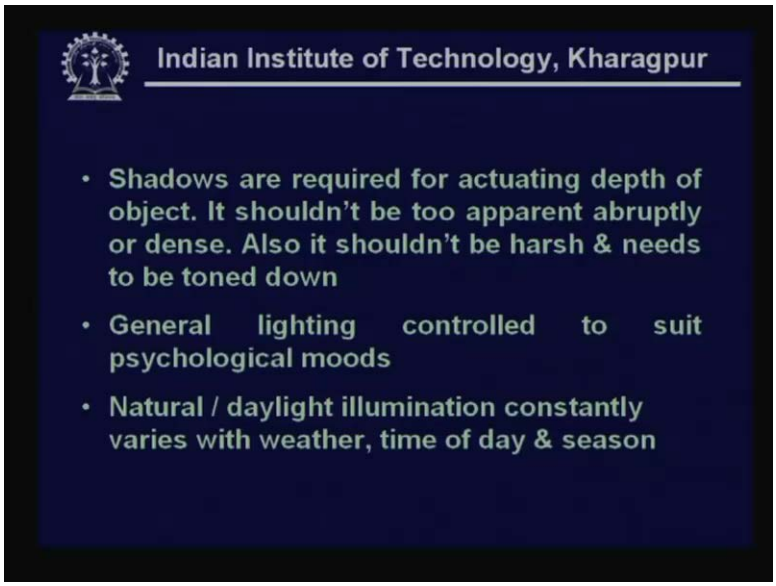

And certain shadows are necessary for actuating the depth of the object, so it should be there but they should not be apparent or abrupt or dense and at the same time it should not be very harsh. General lighting is provided in most places along with some local lighting called the task lighting to give the enhanced illuminance levels and also one has to bear in mind that the natural or day light illumination varies with weather, time of the day and season. Therefore the location of the windows becomes very important.

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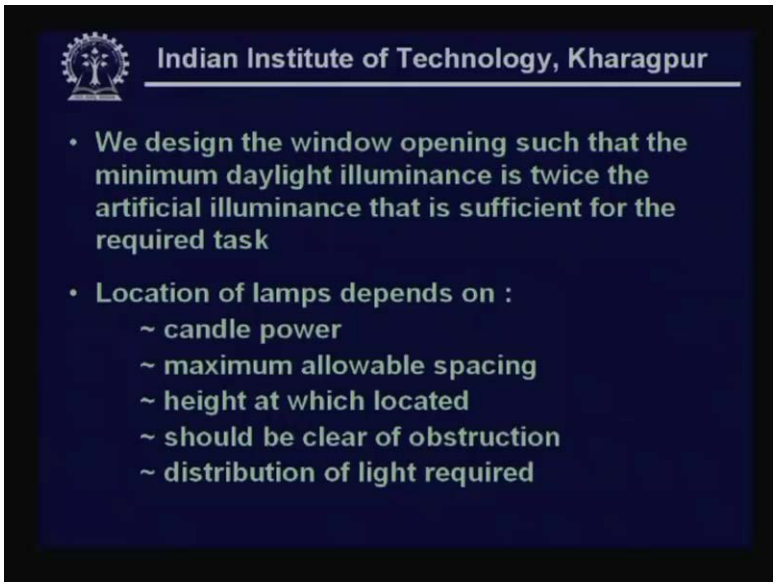

The minimum day light illumination, illuminance is twice that of the artificial illuminance that is sufficient for the required task.

So the way we design the windows is that even during the day minimum light due to this is twice that of the artificial light which we may employ for performing in the night. Now one may sight in this particular instance that especially in the closed corridors, you need higher levels of illumination during the day than during the night because when you are coming from outside in order to have rapid adjustment, in order to have gradual reduction in the intensity level you need to have a higher illuminance levels. However the number of lamps and how we were gone to decide that we have seen, it depends on the candle power and the height at which it is located, what type of our obstruction is there and what type of task is being performed, how it is to be distributed.

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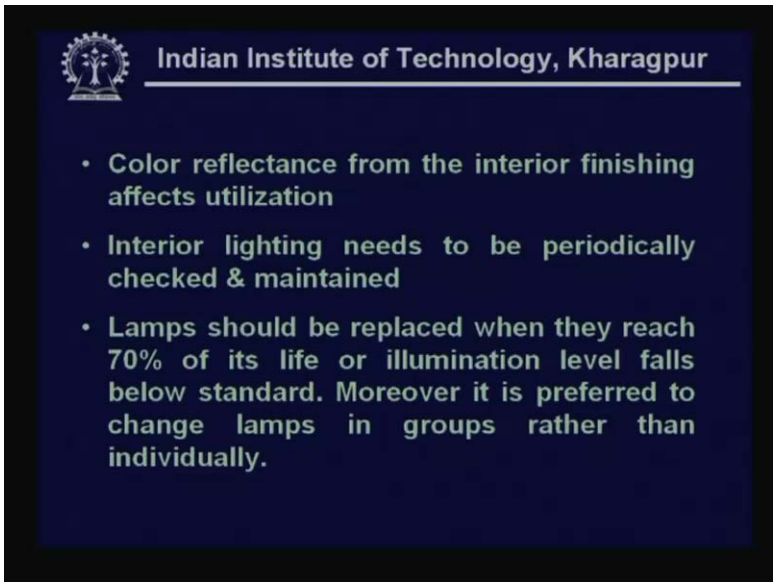

And the interiors have to be matched so that the proper reflectances are there and no doubt like any other system, lighting system also needs to be periodically checked and maintained. And in large offices and large interiors it is better that they are replaced in groups rather than individual lamps and whenever they reach 70% of its life, it's better that they are replaced.

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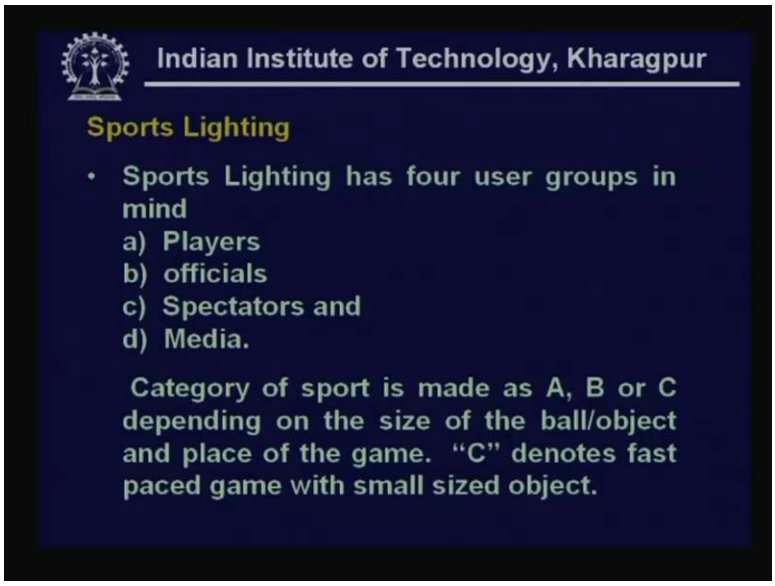

Now coming to this sports lighting, sports lighting has four user groups, this comes under the category of the exterior lighting in mind one is the player, two officials, three spectators and 4 media. The category of sport is made as A B or C depending on the object involved like most sports like we take football has got a ball, basketball has a ball, table tennis has a small ball, so the three different games which we have talked about have different size balls cricket has a… So these are the things therefore they are categorized A B B, C is what we mean is a fast paced game with small sized object like for instance you take cricket is a really fast game with a reasonably small ball whereas the issues…

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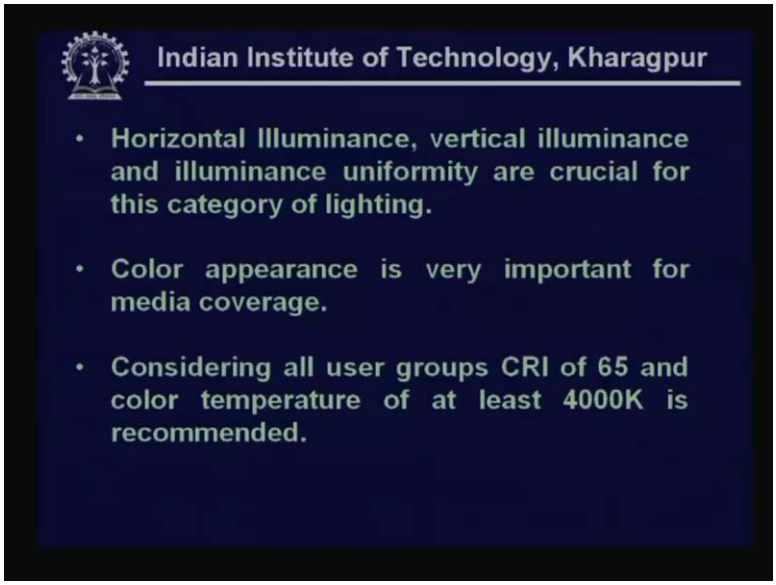

And therefore in order to talk about these recommendations, one talks about the horizontal illuminance because you need the play area to be very well let and vertical illuminance is required to be able to recognize the player and illuminance uniformity is necessary for this category of lighting. Now that is how one talks about illuminance uniformity indices which are the ratios from average to maximum and both horizontal as well as vertical.

Now colour appearance per say is not important for the players who are basically playing for relaxing. In a tournament class yes, people are interested they are also it is the entertainment for others and there to some extent it is necessary to recognize the players but these days with the lot of media coverage, media coverage needs very good colour appearance and therefore recommendations have been given different ways depending on the different media like you have tv, tv coverage for the national level, international level and high definition television level. Considering the all user groups it was found that a colour temperature of 4000 k and 65 colour rendering index appears to be good for most class of sports. The illuminance levels of course depending on the category A B C you have the illuminance levels.

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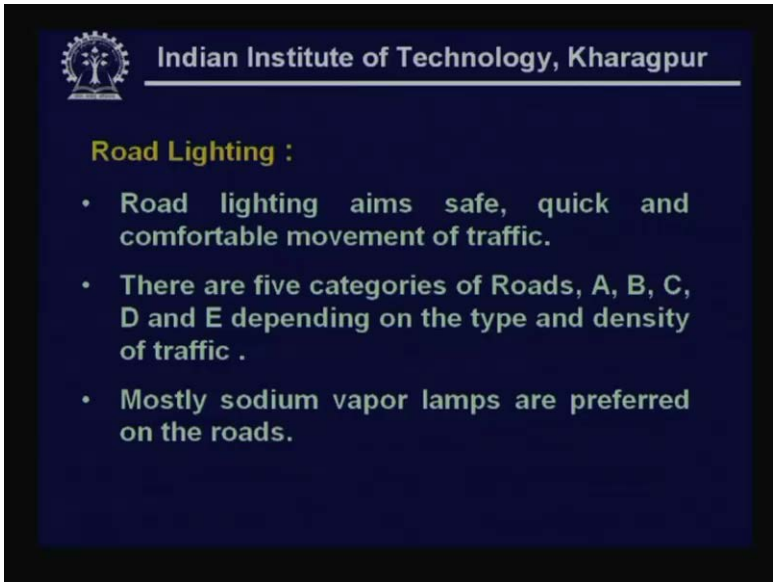

The next form of exterior lighting is the road lighting. The road lighting in fact aims at safe quick and comfortable movement of traffic. Remember that we are, this is second category of external lighting and there again you have to categorize the roads depending on the type and density of the traffic and the mix of traffic. What are we trying to do? If you have a high speed vehicle going then it needs to observe the obstruction much earlier and much more clearly and here again you need to have a good vertical illuminance levels whereas on the other hand if it is predominantly pedestrian traffic, the traffic speed is less so that is how one decides the category of the road. Mostly we find colour rendering is not so important and therefore high utilization ratios sodium vapor lamps are preferred on the roads.

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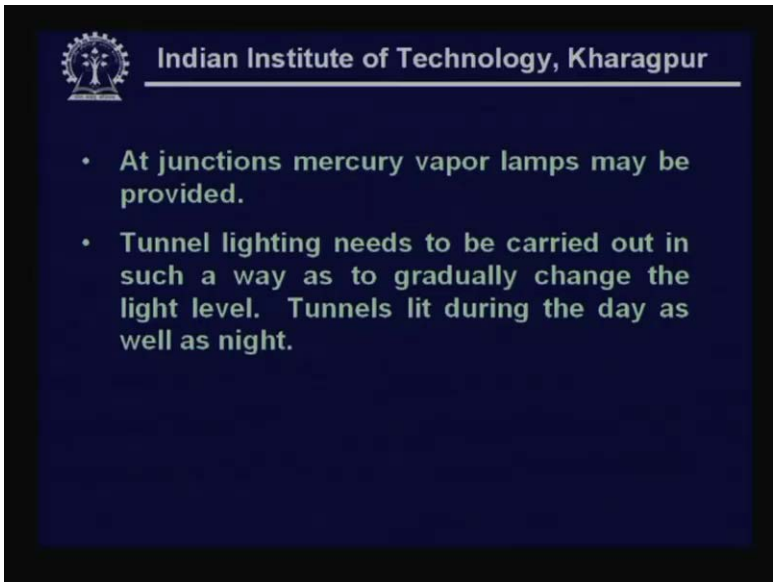

The junctions have to be identified therefore mercury vapor lamps are provided so that clearly you distinguish between the junction and the road. Now here again there is a special requirement as far as when tunnels are there in the roads. Tunnel lighting has to be carried out, gradually you have to change the level I said the level of the light has to be gradually increased or decreased and so tunnels have to be lit during the day as well as night whereas they require higher lights requirements during the day. Now some of the residential areas where there may not be heavy traffic and the gardens you could have post top lanterns which are convenient.

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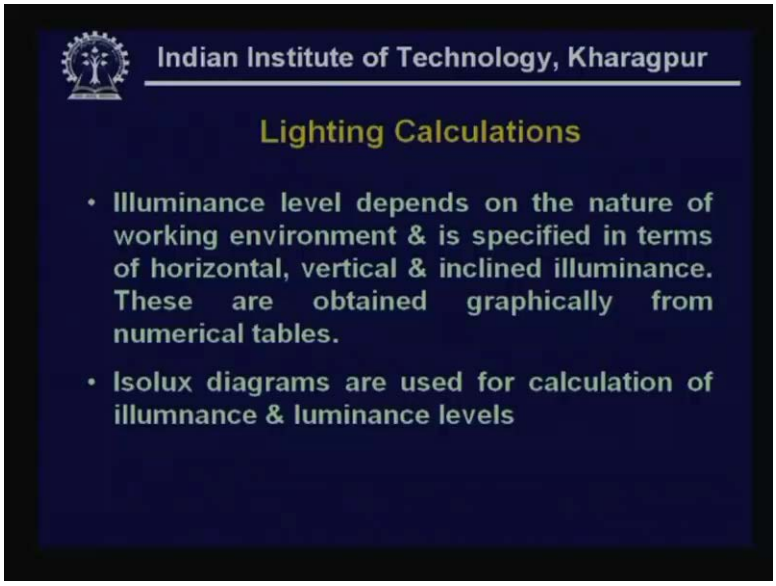

Then we took up the, what is call as the lighting calculations which are required how one arrives at the number of lamps and luminaires and this depends on the work environment it is talked in terms of horizontal vertical inclined illuminance which can be obtained graphically from numerical tables, in fact iso-lux diagrams are used for calculation of illuminance and luminance levels.

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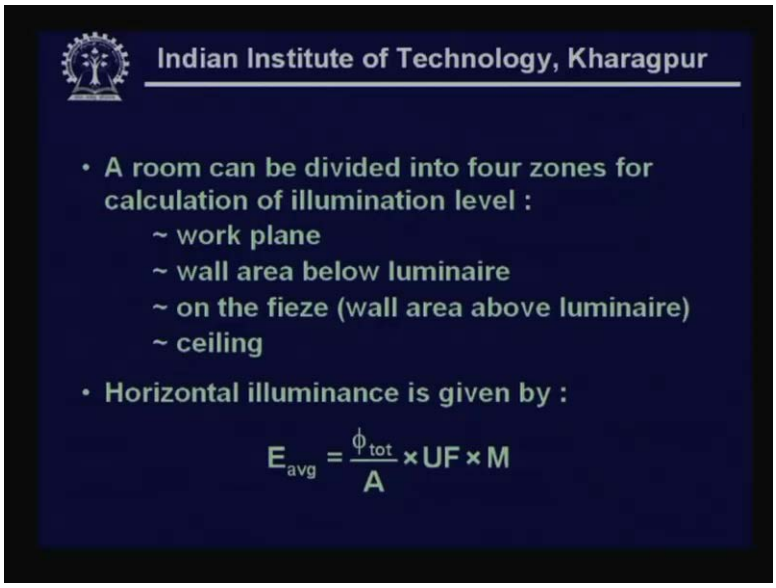

These days you do have software's and which can easily do these things, all these is incorporate. However as a student one needs to calculate oneself to understand how the software works. A room can be divided into 4 zones as far as interior lighting goes work plane, wall area below the luminaire which is called a frieze and wall area below the luminaire which is useful, ceiling and the frieze is the wall area above the luminaire. Based on this we talked in terms of the horizontal illuminance which is nothing but a low overall flux to the area multiplied by the utilization factor considering the loss and the maintenance factor m.

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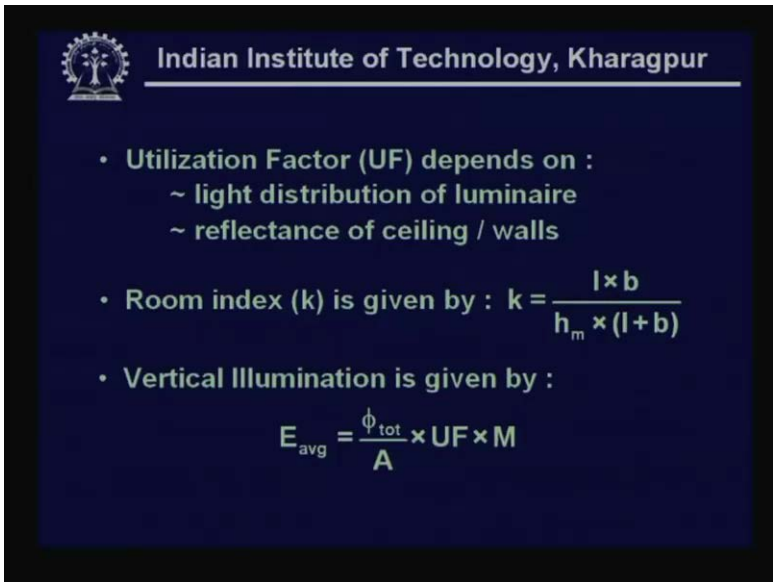

Apart from this we talk in terms of the roof room index which depends on the length, breadth of the room and the height. It may be observed that the utilization factor itself depends on the number of luminaires and how the ceiling involved are having their reflectances and therefore it becomes necessary to periodically take care. Similarly one talks about the average illuminance in the vertical direction too.

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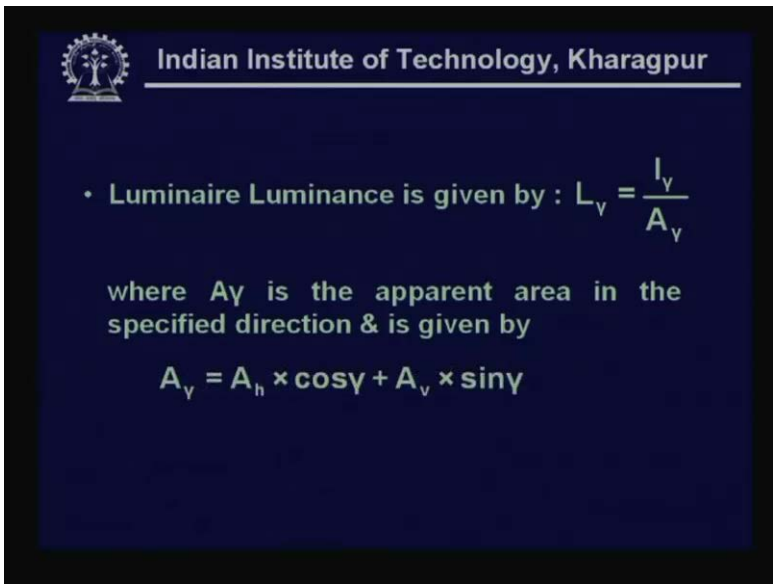

And luminaire luminance is talked in terms of the luminous intensity verses the area over that angle, the apparent areas specified in the direction of interest okay.

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Now the last thing which we look, took up with the lighting applications. The lighting applications, the first application which we can think of is the industrial lighting. Industrial lighting is depends on the nature of works, shape of space and the ceiling structure. Typically industries have very high ceiling and they can be having single storey or a multi-storey with the skylight or the light being available or high bay light. So whenever there is a high bay light invariably there are the sodium vapor lamps which are used Whereas sometimes you do need additional lighting for when the general lighting does not meet requirements you may have illuminated magnifying glass, stroboscopic lighting or monochromatic lighting depending on the various applications. In fact if you look at the fine PCP task you may need much more thing, whereas the fluorescent lamps with louvers and diffusers are preferred in the office lighting.
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The black boards in educational institutions or a chalk boards there is a need to have vertical illumination, this is also the same case in the auditoria. In shops and restaurants and other commercial places, local and colour lighting is employed because shops is one place where you are trying to advertise a product. So, you need to highlight a particular place or a particular product therefore there is increased requirement for local or colour lighting.

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Hospitals have varying requirement depending on whether it is for patients or technicians or doctors and operation theaters do need shadow free lighting with higher levels whereas ICU and X ray where patient is trying to rest, there should be minimum distraction you need very low levels. Some of the Indian standards for lighting applications are also covered as a part of this lecture and in fact they are all adopted from the, what you call CIE the international standards for lighting and the hand book of BIS gives complete details. Thank you. So this is the total summary of what has been covered in the 19 lectures on illumination engineering. So, we take up the second aspect the electric utility in the next lesson. Thank you.