Illumination Engineering and Electric Utility Services
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Lecture No. # 13
Glare

Electric utility services, today we take up the lecture 13 which is titled glare.

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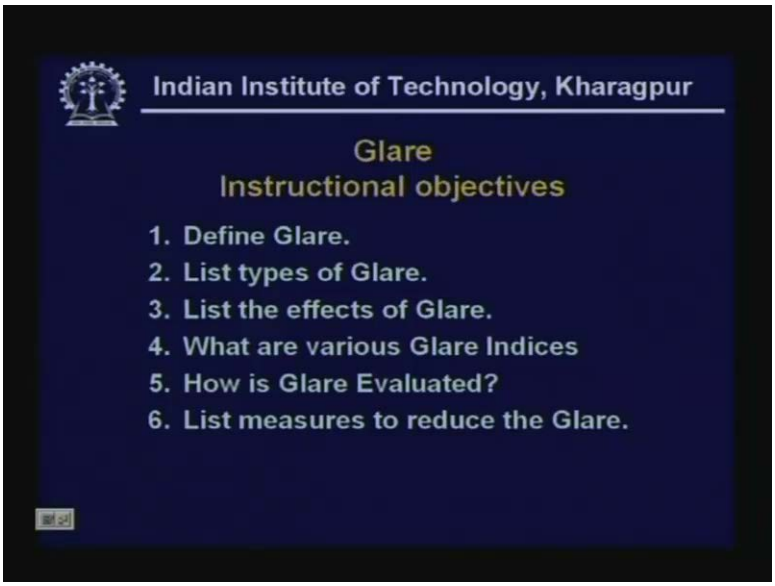

Now having learnt about need for lighting and having known how the artificial sources can be employed for light and having also understood how to go about measuring these things and how various quantities with reference lighting are mentioned, we had a look at various lighting installations that is what form illumination systems. Now there is a need before we look at specific applications of lighting systems to see what else could affect our efficacy as far as lighting goes and that is being addressed in today's lecture which is titled glare. Therefore the instructional objectives have been, define glare the first one that is what the glare is and in fact recall that we mentioned as far in the lecture on the eye that any white object in the line of vision tends to obscure our vision probably first and foremost it deters us from observing what we are supposed to observe.

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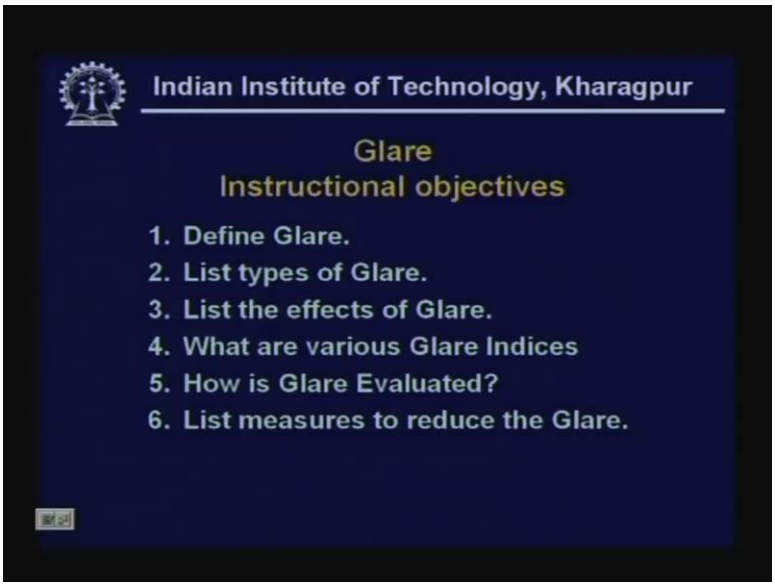

Secondly it may injure the eye or cause fatigue in the eye and this bright source of light in the line of vision is what we call glare. So the first thing we look at is define glare and then we have a look at the various types of glare that are possible that is why the second objective have been listed as list types of glare. The third objective is what is the effect of this glare. Well, we say there is a bright source of light in the light of line of vision. Primarily it obscures the vision but then there are secondary effects, the third objective tries to look out those secondary objectives, secondary effects.

Now having said what the glare is, what the glare types are and the effects of the glare it becomes necessary from an engineering point of view to understand for a particular installation how do we evaluate the glare or what kind of a indices can we put for measuring. In fact we said that anything needs to be understood needs to be measured and quantified and that is where this comes handy. Therefore the next objective is various glare indexes and in fact the objective 5 is listed as how is glare evaluated. This tries to compare the various systems that are available and the more commonly used system is elaborated and having now come up to the evaluation level,

the next important thing is to understand the measures that can be adapted to see that the glare is not there and therefore the objective is listed as measures to reduce the glare.

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So, we look at glare, what did we say? Glare is the brightness within the field of vision that is by definition any bright source in the field of vision that is in the line of vision, in the plane of vision the eye level is what we call glare. What does it do? It causes discomfort. We are all experienced a bright head lights of an automobile coming in the opposite direction in fact blinds you, there is a temporarily blindness and there are lot of discomfort, it annoys you because you may be oriented towards particular direction, you may be locating a particular address and in this process your objective is disturbed, it is annoyed. And if continued for longer time it causes a fatigue in the optical muscles which we call as eye fatigue and therefore glare not only does make vision blinded or temporary blindness, it reduces the visibility of an object.

The primary effect as we say is the reduction in the visibility of an object but associated with that we have discomfort to the eye. It creates annoyance in the mind primarily because the objective to towards which you have been working gets distorted and obviously if they are conflicting bright sources there could be interference and may not result in effective visualization of an object. And incidentally the most common fault with the lighting installation that has been designed is the glare design. That is to say that not much care is given to glare, this is because all engineering aspects are not taken into account, randomly the lamps are placed and as a result the location may create bright sources in the plane of vision.

Having learnt what glare is and having looked at what it could be doing that is the bright sources in the field of vision causing discomfort or reducing the visibility is what we call as glare and is common.

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What are other effects? If you look at the gamete of effects that it can have, the first thing is it could injure the eye. If persistent bright source or of intense magnitude is incident on your human eye it can injure the eye and associated with that is the nervous system gets disturbed and leads to lot discomfort and in trying to adjust to intense bright light there can be fatigue in the optical muscles. What does this all do? All this leads to, what we call the reduction in the efficiency and as a result it leads to interference with the clear vision. Obviously when all these happen, it may not be possible for the person to know any obstructions in the path of its activity. Say for instance you are working at a machine and you have a bright light coming into your eyes, as a result any object moving in the task space may not be visible to you because of this intense bright light coming in the line of vision and there could be an accident that is accident risk increases considerably in the presence of glare, this has to be borne in mind.

Now when does one experience glare? We said whenever light is buyed in the plane of vision is then we call it glare. So how do we experience? We experience from lamps, naked lamps which is a common practice with most domestic users then windows, open windows when the bright light comes into them then poorly designed luminaries and other areas. Now there is another condition that it occurs when these lamps, windows, luminaires or any space is in the work environment much brighter than general brightness. We did mention that the certain general brightness is required in any environment and the gradation, there is a certain proportion ratio between the two brightness necessary so that one does not have glare. Now if that be the case what are the types of glare? The glare can be classified into two categories. One, direct other reflected glare.

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So, if you directly place observer in the plane of bright light or if you look at a naked lamp of high wattage directly you can experience glare. The reflected glare is this particular light flux getting reflected from another surface. It could be furniture, it could be walls, it could be any other object in the environment. Therefore we see that direct glare is presence of bright luminaire or the lamp system in the field of vision whereas reflected glare is reflection of light from such a source from a glassy surface. And in fact it's observed that such a reflection may not be intense but it is much more annoying than direct glare.

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In fact direct glare being intense may make us close our eyes involuntarily but this not being of sufficient level, it may what you called creates annoyance. So we need to avoid these. This can be done by a proper choice of interiors that is we maintain complete interior of a system very well prepared considering reflecting factors and try to see that very little bright light gets reflected and causes any glare. See the direct glare, the best way to minimize or avoid direct glare is never have lamps brought up to the eye level that is you mount the luminaires or the illumination system well above the line of vision or field of vision. In the process we reduce brightness and light flux in the normal field of view. Talking of illumination systems we did mention use of florescent lamps for low bay industrial lighting and discharge lamps of high power or halogen lamps for high bay lamps. Remember naturally the envelope of a fluorescent lamp is diffusing in nature and there is very little, the glare levels are much lower that is how one could see the application of scientific basis of reducing direct glare.

The disability glare I mean glare could be further graded disability means whenever a person experiences glare, if it impairs the vision all together that is when it is called disability glare. If it is very bright and exposed for a long time then it could cause disability of the vision and that is when it is called disability glare. As opposed to this, there could be discomfort which is very common and the amount of discomfort depends on time of exposure. How do we distinguish between discomfort glare and disability glare? The discomfort glare is a temporary discomfort but there is no reduction in the visual ability of the eye but only gives fatigue which upon some amount of rest gets reduced.

Now when we say we are trying to look at gradation of the glare, there we classified as direct or reflected. As opposed to this depending on the brightness and depending on the effect it can have, we can call it disability glare, discomfort glare, annoyance glare. That means the level of discomfort or level of reduction in efficiency or reduction of the visibility is lower in discomfort glare compared to disability glare.

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The annoyance is essentially means that it is more than the general brightness luminance in the in the environment and causes some discomfort very marginal which comes in the way of efficient working but it does not really effect the vision to that extent. This in order to quantize one looks at what is known as solid angle subtended by the lamp at the observer eye in the field of view. In a normal field of view, it says field of view here but I must say it is the normal field of view. So all these brings to situation where glare needs to be quantized which you can call as glare evaluation system or glare indices that is what we look at. So, what we had taken care so far was what glare is and what it does to our eyes, how one experiences glare and how it can be classified. For the purpose of evaluation, one of the simple systems is the American system which is followed in entire North American continent is the visual comfort system or it is in fact abbreviated as VCP.

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It consists in looking at the number of people or the percentage of people who are comfortable in viewing a particular installation from the opposite end. That is if you have a set of illumination system and you directly look at the illumination system in the line of normal line of vision and depending on the number, a large number of people let's say 50 people or 100 people and then say in fact this is the subjective evaluation and based on this one gives the what you call a VCP index.

Now as opposed to this there are other systems which have tables depending on the layout of the rooms, proportions that is height to space length this thing what you called height to length ratios and other systems which work on the figure of merit. Now in fact in applying VCP often a source of 1000 lumens is taken as the base source from a luminaire and in the system if 70% of people say it is comfortable that is when VCP is about 70% it may be said that it is glare free. Now as we go along when we look at the other systems I said there could be tables. A tables are based on two indices, one is the task illuminance we had already seen from the vision perspective there is certain illuminance level required for a particular task and in order to do that

you can very well see higher the luminous flux, higher will be illuminance on the task surface and therefore there is every chance of the lamp being bright and there is scope for glare that is what is to be seen. So, therefore let us see how other systems are there.

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You know you do this, the British method in fact talk in terms of zones and they have classified the application and thereby they have come up with a glare index. As opposed to this we have the Australian system which depends on the luminance limit system. Remember illuminance is the effect of the light on the task surface whereas luminance is brightness of the source and illuminance was measured in terms of lumens per meter square or lux whereas brightness or luminance is measured in terms of candela per meter square. Also recall that lumen output of lamp is talked in terms of polar curves which not necessarily lamp, lamp together with luminaire, luminaire in fact tries to control, direct and modify these curves.

So you have luminance curves and therefore this system which we are calling luminance limit system, it specifies for a particular height to width ratio. What is the kind of the limit that can be there and the appropriate installation is compared with that. We consider depending on a room dimensions, mounting height and taking a base lamp, you remember the base lamp we talked about was 1000 lumens. Then there has been a shielding angle specified in fact this shielding angle decides what will be the solid angles subtended by the eye beyond which it will create glare.

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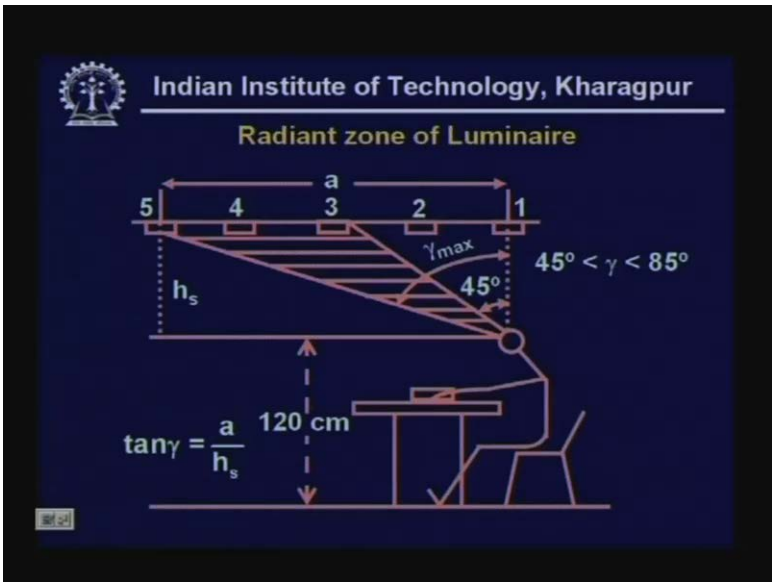

Now trying to understand what is this radiant zone of a luminaire, let us look at this picture. This picture shows a person at work on a table and the width of the space is around a unit and as you can see the top most line indicates the plane of luminaires where there are 5 such luminaries located 1 2 3 4 5. And the height of this plane from the plane of vision or from the line of vision as can be seen is h_s. Now I told you there is a critical angle, we talk of shielding angle and as far as this system of zone of illumination is considered under the British system which has the upper and lower limits which are fixed as 45 degrees to 85 degrees.

Now you can see the zone clearly marked in the diagram in fact what we observe is that the plane of vision is about 1.2 meters, this is the height at which a typically average person working has his plane of vision, if he is sitting on a table. So, the critical angle which we said a gamma can vary from a minimum of 45 to a maximum of 85. Now we see the zone being defined based on obviously the luminaire plane is ending at luminaire 5, therefore gamma max is defined with respect to the straight line coming from that luminaire to the eye which is the gamma max. Now it should be less than 85, if it is more than 85 there is every scope for creating trouble.

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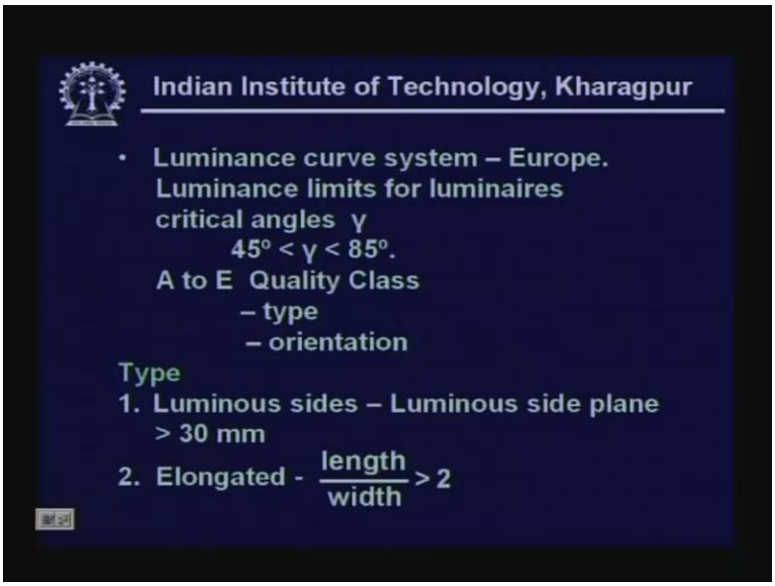

In fact based on this what is called as luminance curve system has been taken for the purposes of evaluation. It is a sort of standard in the European continent, here it may not be wrong to mention that the world famous lighting company the Philips is in fact located in Europe and this could be in fact taken as the best way of evaluating. Now we were talking about the quality class. The quality class is from the user's point of view, from the point of view of tasks it could be A to E type. What do we mean by type? Type means if you have a lamp system whether the lamp allows light, see if you consider an incandescent lamp, a single incandescent lamps it's like a point source which radiates light flux in all directions. Rarely it is used as single lamp in real applications except at homes. As opposed to this, it could be a matrix of lamps when it forms a kind of a plane of light or the next best which we use is the fluorescent lamps which are a line source of light.

So, this is where the type comes into picture. It could have a luminous sides. Now whenever these sides are greater than 30 mm that is if you have 4 florescent lamps placed in a single luminaire and you have a diffusing luminaire placed then you can find that light radiating in all 4 directions. We are saying it a sides because normally these kinds of lamps, the light radiates only axially, okay. As opposed to this and then it is said to be elongated whenever length by width is much greater than 2 which is the case for most fluorescent lamps. This is as far as type, so we need to look at the critical angle which could be anywhere from 45 to 85. We could see the angle form it the eye whether it is in the critical zone we saw how we can define a zone of illumination considering the plane of illumination and plane of eye then comes the orientation. Now the orientation of the light flux, there are two orientations which are possible.

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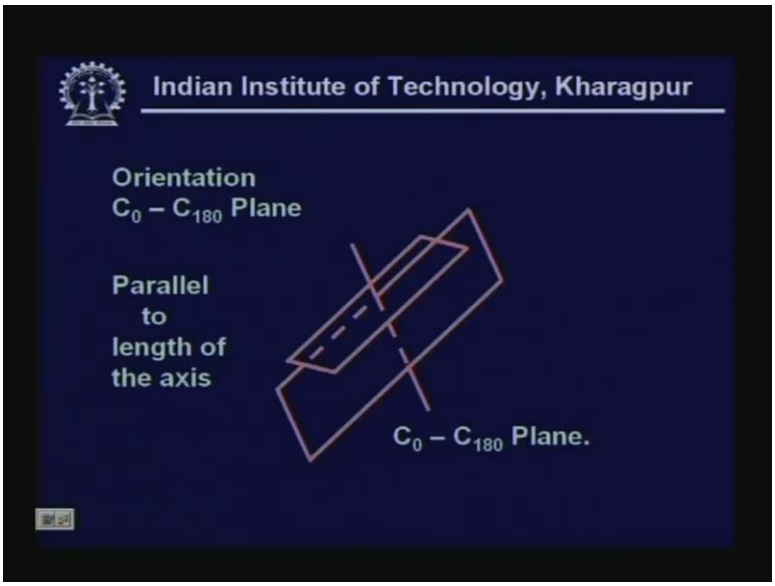

Now the picture here shows a fluorescent lamp and there is one plane where we are looking at the light flux distribution is the plane parallel to the length of the axis, this is what we called C_0 - C_{180} plane. Here I must again mention one thing in open air applications often times it is difficult to take care of the glare and most of the issues which we are talking about glare evaluation, glare limitation pertain to the interior lighting. And for most purposes interior office lighting is using fluorescent lamps which are predominantly line sources. So if we do not have sides illuminated, we said sides illuminated becomes important and the width is greater than 90 mm, mostly we have elongated type.

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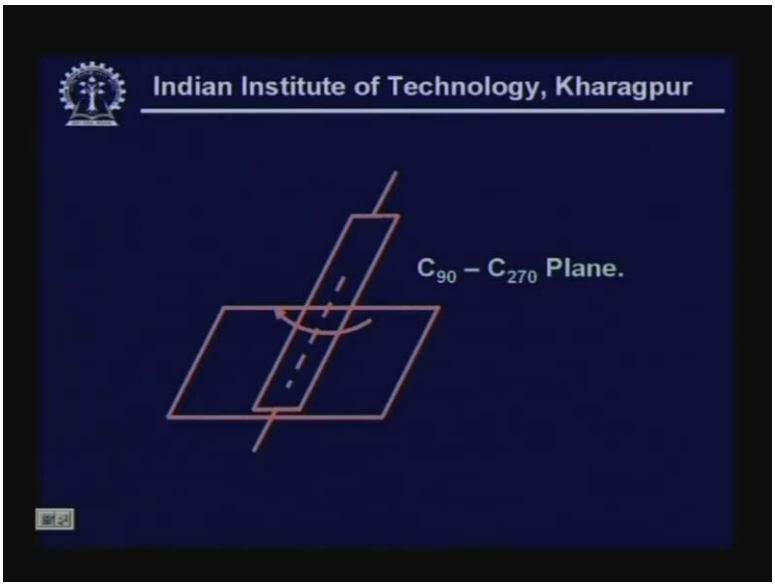

As opposed to this there could be a plane where we will constitute that is C_{90} to C_{270} plane that is perpendicular to the length of the axis. So we have the critical angle which should be I mean the zone of the thing between 45 to 180, 45 to 85 and we also look at the type whether it has luminous sides or not or sides are not effective then the orientation whether along the axis or perpendicular to the axis then one can look at the requirements.

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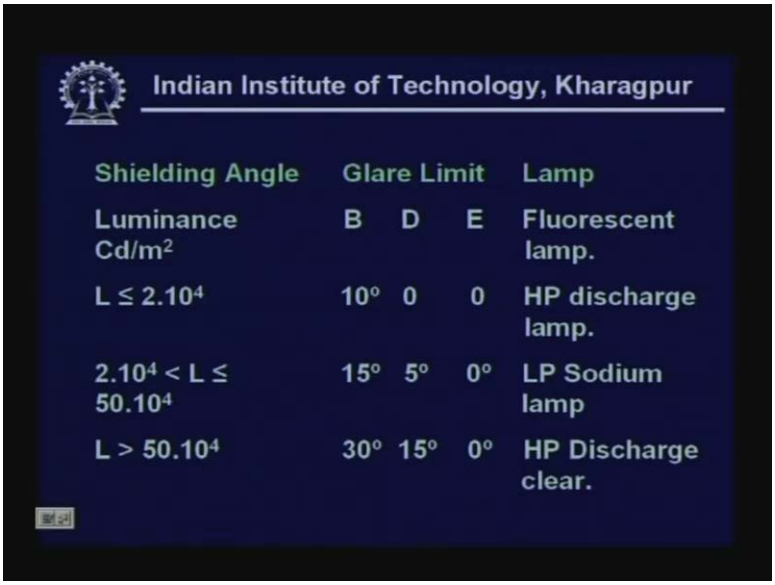

Now here this table in fact which is based on British system talks about the luminance levels. The first column gives us the luminance levels and the last column talks about the various common lamps and gives the limit of the shielding angles. We find that this is the zone of illumination which enables glare free application.

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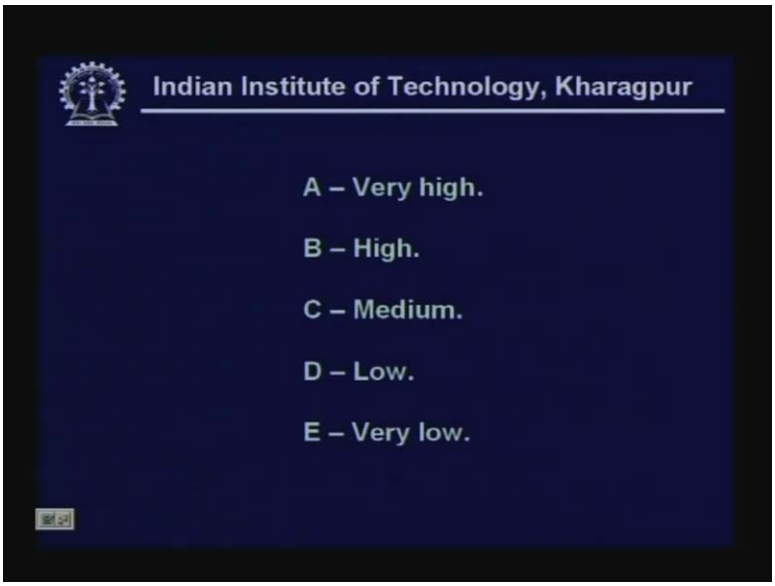

Now let us see what these classifications are. From the task point of the view class A means it's a very high quality tasks and that is needs good amount of illumination, there is good scope for glare too. B is high, C is medium for average day to day application it is the C category which is applicable. D is low, low can be tolerated for short durations but can be harmful over longer durations and E is the very low.

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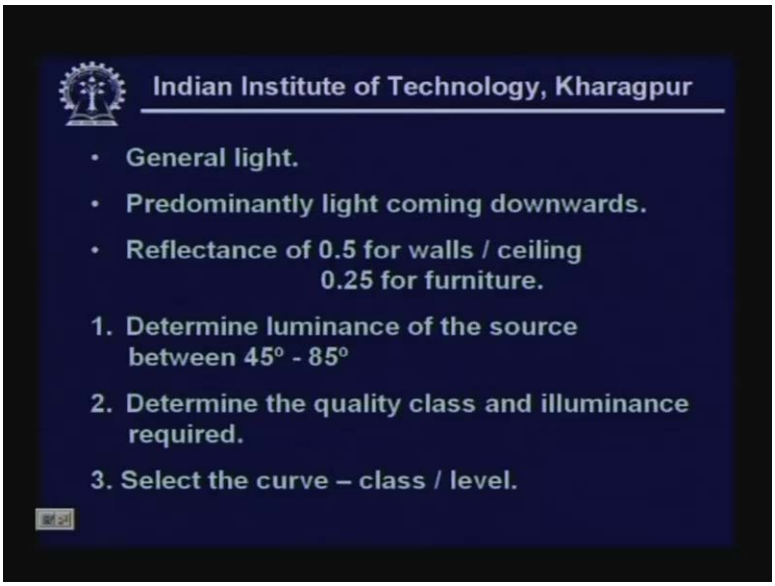

Now here we must say that always we do not have one set of lights taking care of all requirements in an environment. We said while talking about the illumination systems, there

should be a general light in the environment which enables free movement and general thing. This apart depending upon the task criticality, one has local lighting and in fact we did mention depending on the nature of a task, we do have mechanisms to control the light flux too. And most of the times this light, general light is predominantly light coming downwards. See the common fact is either to have lamps suspended from the ceiling if the roof light is very large or placed recessed in the roof.

Now the moment you have this, there may be no scope for direct glare if they are mounted well above the line of vision. Well, though there is no direct glare, it's a task requirement calls for high illuminance levels, the sources may be of high brightness in which case they can be potential sources of reflected glare. We take care of this while taking care of the, what you call interiors, we had mentioned earlier also. So it is recommended that typical reflectance of 0.5 is advisable for walls or ceiling and about 0.25 for the furniture. Having said so much it is important now to look at the most widely used luminance curve system or luminance limit curve system in trying to evaluate the glare of a place, how do we do that? First thing is remember we talked about the critical zone being between 45 to 85 degrees. So, from the manufactures polar diagrams which we have, we determine the luminance of source between 45 to 85. Source I said it means the installation in this case including the complete thing. Then determine the quality class and the illuminance required. Just now we talked about the quality class between A to E from very high to very low then we select the curve based on the class or level, will show you little while from now. We will see the various tables for various classes and the appropriate curves.

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Once we select the curve we determine the maximum angle. Recall the diagram where we saw gamma max based on the length of the illumination plane and height of this plane from the eye level and we consider only that portion of the curve which is above 45 upto gamma max then compare this with the luminance curve obtained for a light system.

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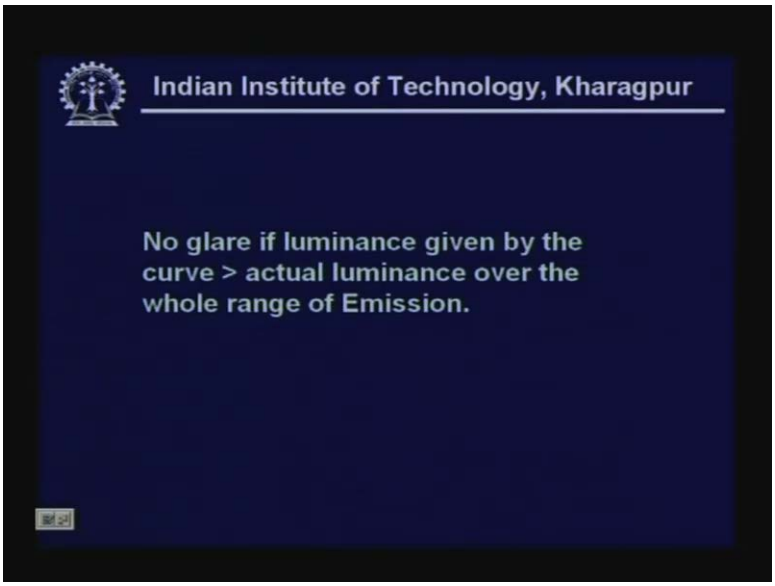

And if we find that illuminance given by the curve not illuminance, luminance given by the curve is greater than the actual luminance then we say it is glare free. Obviously it means the source in the zone of illumination or zone of eye, eye zone is not going to be very bright and therefore it is glare free.

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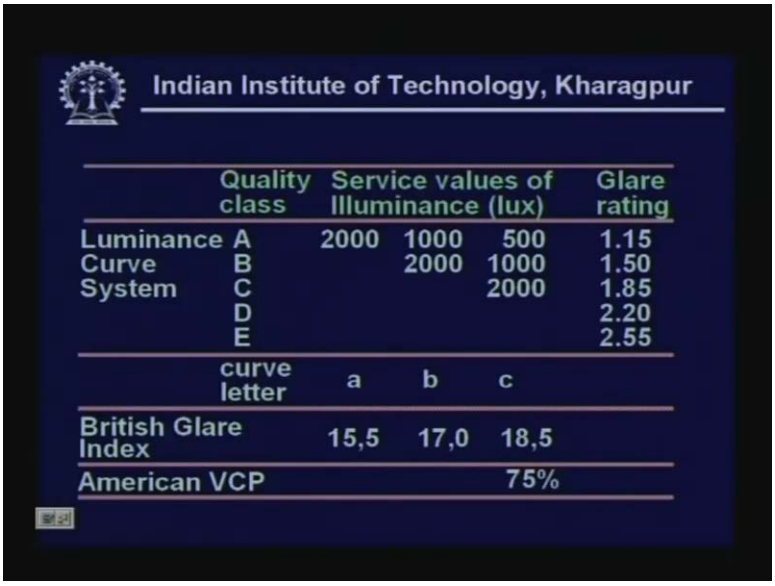

This will be understood as we go along; you see this table compares all the systems. You have the American VCP system, British glare rating or glare index and the first column talks about the quality class and it also list the illuminance levels.

One observation to be made is as you go along to the lower classes, the illuminance levels are changing. This is for various levels of… Now in fact we find there is a curve letter mentioned. Now this curve letter corresponds to the curve on the luminance limit curves to be shown, we will take that up.

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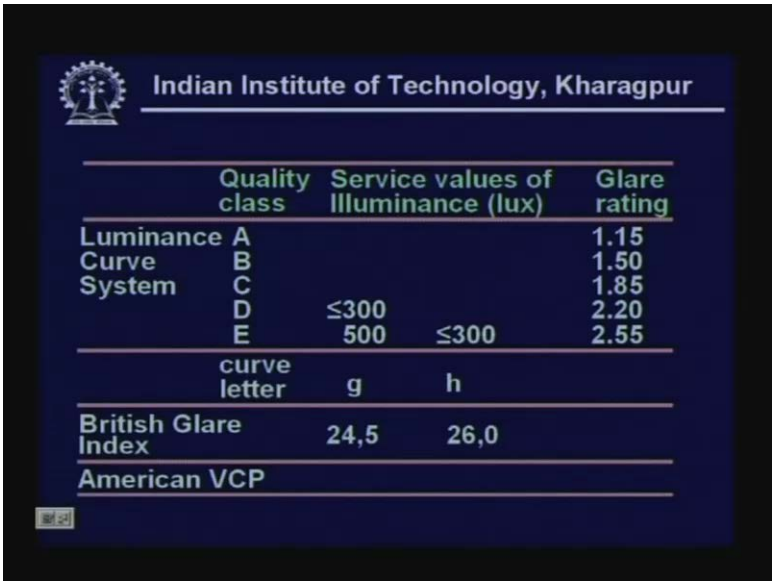

So this is you have for all possible conditions, what do we observe? We observe that for 5 classes we have considered for the illuminance levels varying from 300 to about 2000 lux it is been mentioned. And accordingly we have the corresponding glare index according to the British system and the American VCP has been given.
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So glare evaluation system as we see is one American which basically is VCP or visual comfort percentage. The British system is the glare index, the European is the luminance curve system and all this requires to consider the quality class. A corresponding to very high quality lighting, B corresponding to high quality lighting, C is the medium quality, D is the low quality and E is very low.

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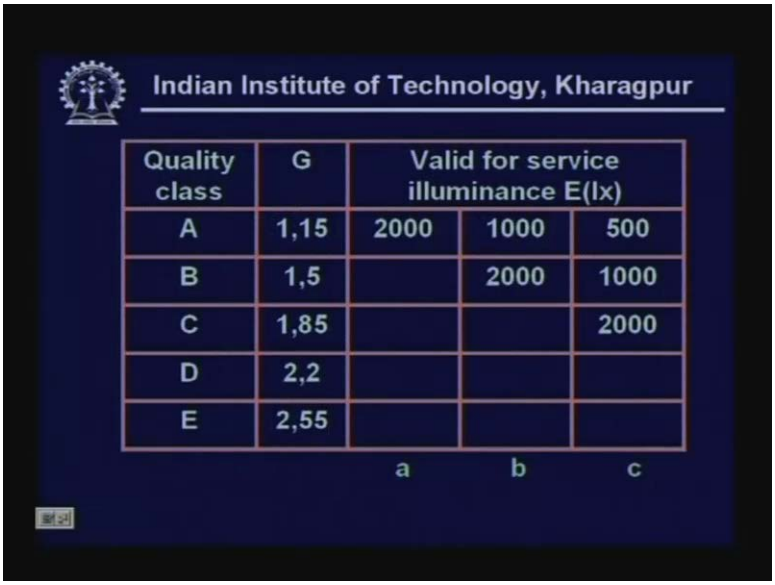

And once we do that in fact for different illuminance levels, the relationship between quality class and the limit curves are as shown. For instance if we are looking at a service which requires high quality with 1000 lux and the curve to be used is B or as opposed to a 500 lux good quality would require a curve D to be used in the luminance limit curve system.

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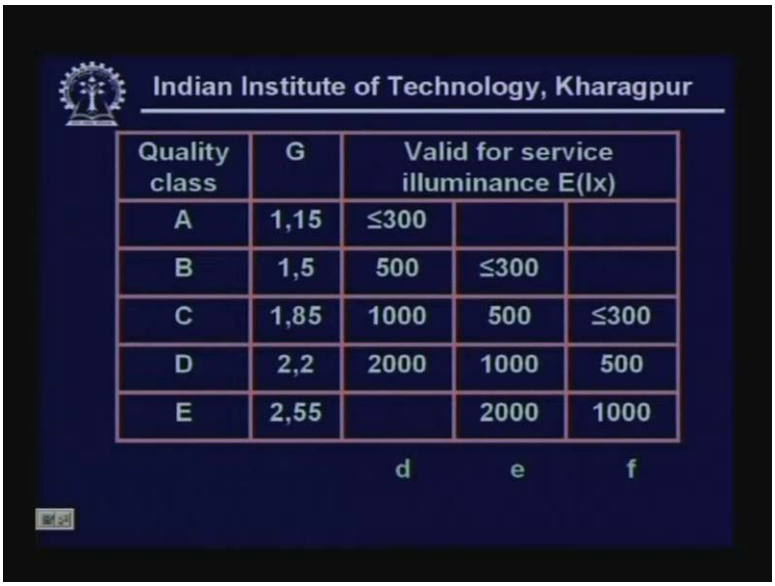

So likewise you find different levels that for illumination requirement.

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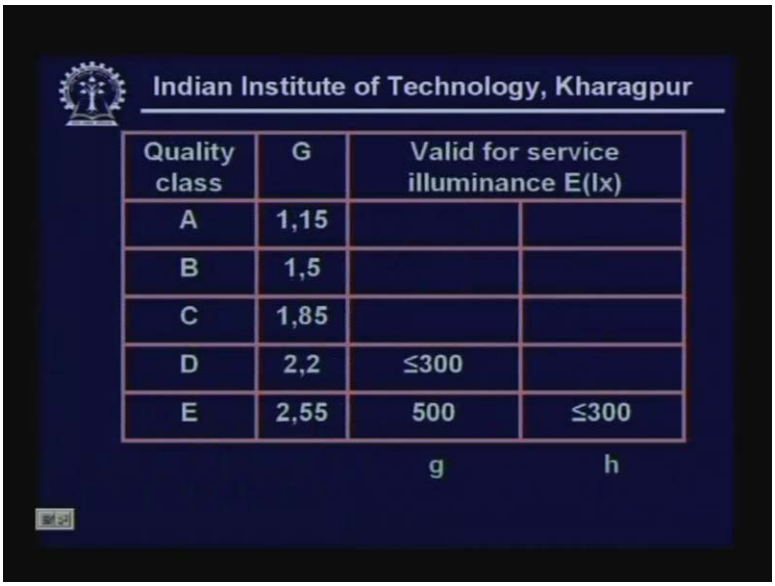

These curves have been specified. And as already told first and foremost is over the zone of elimination between the critical angles of 45 to 85, one determines the luminance of the system.

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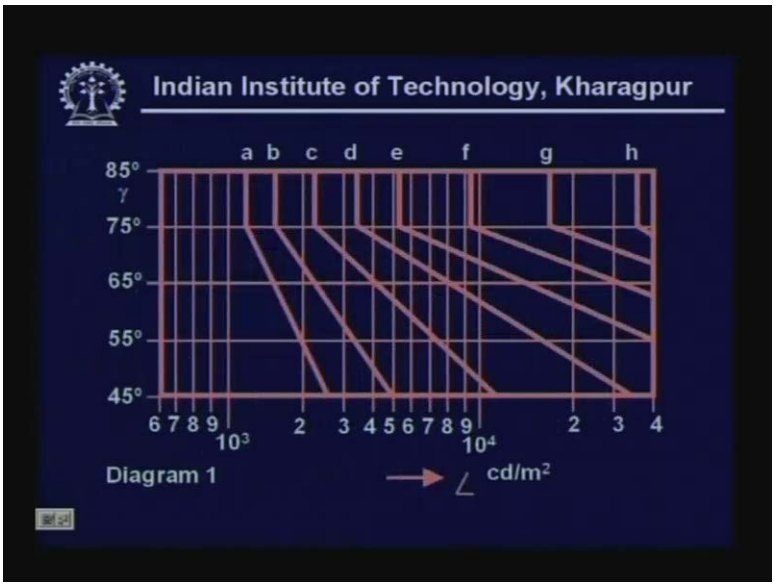

Now this diagram marked as diagram one shows the various luminance limit curves for various classes of illuminance as well as quality. We saw curve letters are obtained from the tables which we have already seen and they are marked a b c d e f g h. Incidentally this applies to your plane along the edge of the... We talked about the orientation and with no side illumination and the y axis here show the angle gamma from 45 to 85. So from the luminance, from the installation dimensions mounting height and the width one arrives at the gamma max. Let us say from the quality service requirement table we arrive at the requirement or the curve to be used as D and if you say the installation comes up with a gamma max of 65 degrees, we find that the curve D is to be used in this diagram and it varies from say 9 CD approximately 65 cuts off for D around 8 CD per meter cube, meter square to that is 8 into 10 power 3 onwards.

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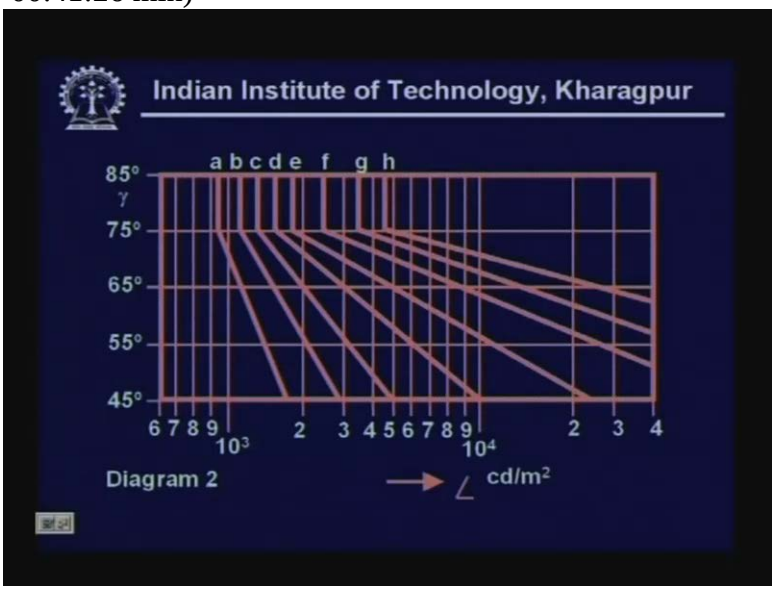

Then we compare the actual luminance curve with this and if this curve between 45 to 65 having said that the gamma max is certified is above the actual luminous curve then we say the installation is glare free. What we have here is a diagram two, this is to be applied when we are having luminous sides just as we had actually elongated I mean actually eliminated system, we could have lamp system with sides illuminated. Whenever sides exceed about 30 mm that is when we say their type of illumination is with the side illumination too. So this is where one thing of using this, so we have two diagrams the second is for side illumination systems.

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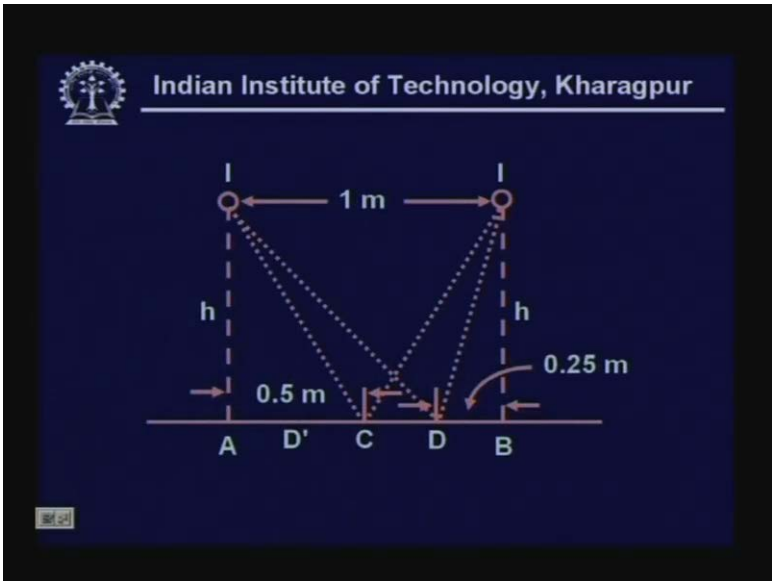

Now here is some calculation which shows how the mounting height really effects the illuminance at a spot. Now here you can see in this diagram, there are two lamps placed one meter apart at a common height H and we are looking at the illuminance on the plane below the lamps at the point A B C D and D prime. In fact the distance between B to D would be about 0.25 meters, between B C would be 0.5 meters. Remember considering the symmetry of the system, the illuminance at B and A would be same similarly illuminance at D and D prime would be same.

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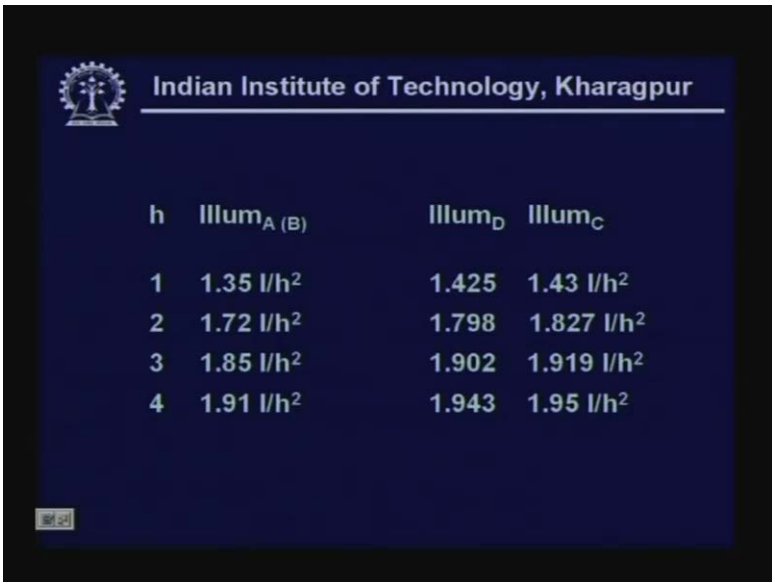

The calculated values could be in terms of the height or somewhat like this. As you can see the, by virtue of see if there were only one lamp illuminance would have be a maxima just right below the lamp. By the presence of two lamps we find it's a maxima around the midline. Now as you can see these calculations are shown for your, the variation with the variation of the height.

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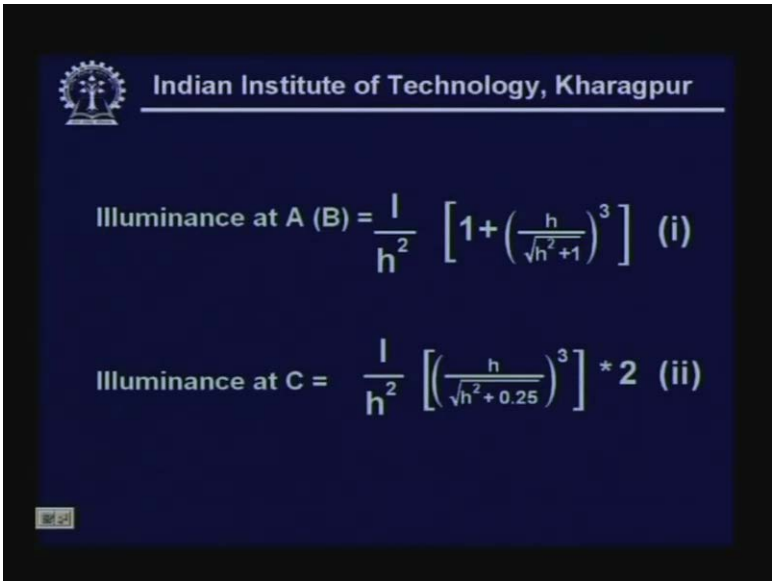

And the relationships may be recall these were got from the loss of elimination for illuminance at A and B and illumination at C in this way because and that at D or D prime is given by this. What do we observe in this process?

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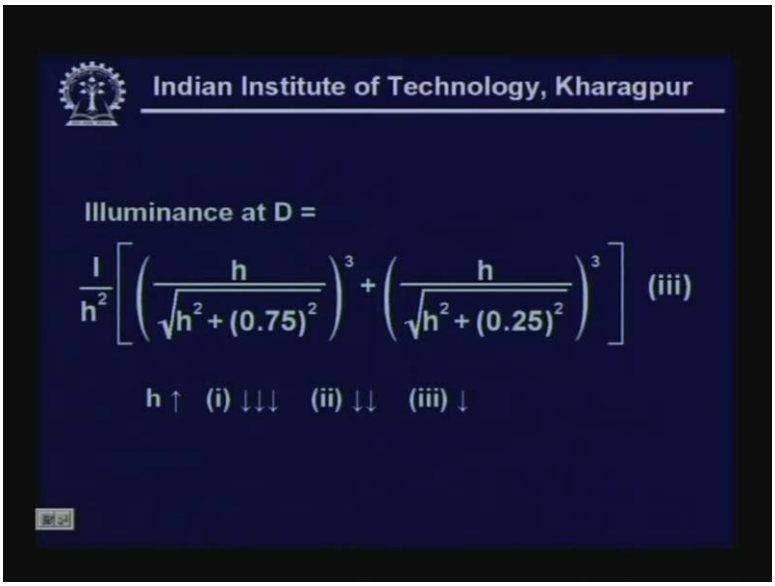

We find if you have recall that table once again, as the height is increasing the illuminance at just below the lamp is rapidly falling whereas quarter way 0.25 meters away is falling somewhat moderately and it is very slowly coming down at the center. So the mounting height does have an impact and therefore as opposed to a single lamp when we mount a system of lamps above, a combination effect could really give the required illuminance, the same time reduce the glare that is the idea of looking at this.

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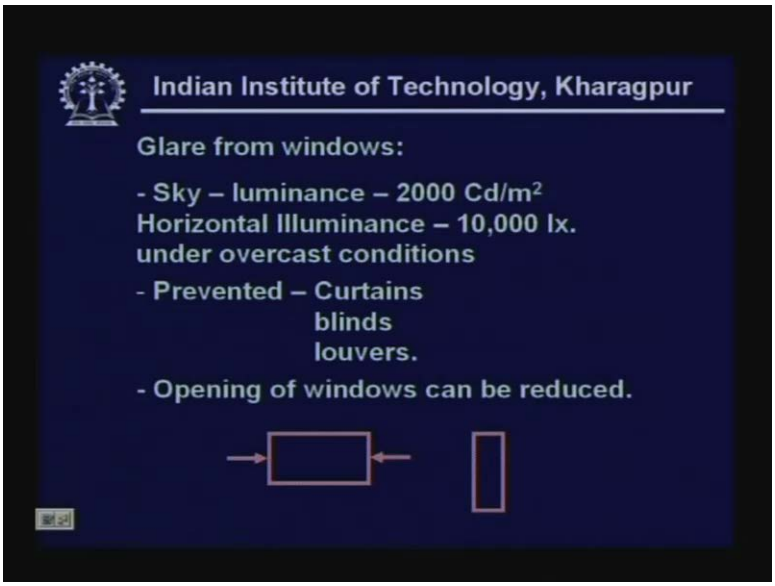

As opposed to this we have glare coming from the windows. In fact when we consider the sky with overcast conditions, we find sky luminance can be thought to be about 2000 candela per meter square which corresponds to a horizontal illuminance of 10000 lux. The best way to prevent this is to have curtains, blinds and louvers. Now remember one of the things which can reduce this is to reduce the opening of windows. However from another point of view of ventilation is not advisable to completely reduce the area of a window and therefore instead of having wide windows, one may resort to having long narrow windows which helps in reducing.

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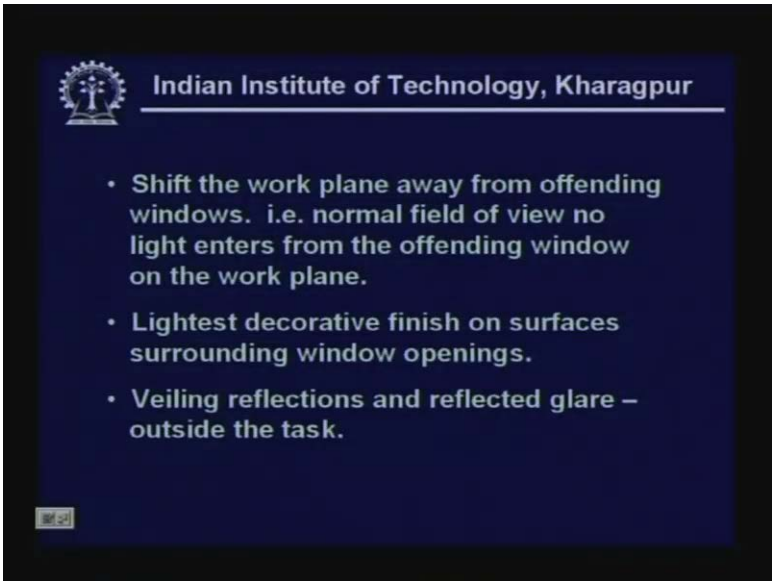

So coming to the reduction of this glare, you may have to locate the work plane away from the offending window, in fact the glare from windows is often experience by students in the class rooms where the black board, if directly in the light of bright light coming from the windows students unable to see and no light is allowed to enter from the offending window that can be done with the help of a proper design of interiors. And the next thing is one has to have interiors with light decorative finishes around the opening so that any light entering is absorbed and very little gets reflected and the reflections coming through the folded curtains is what we call veiling reflections and it should be such that it is outside the task.

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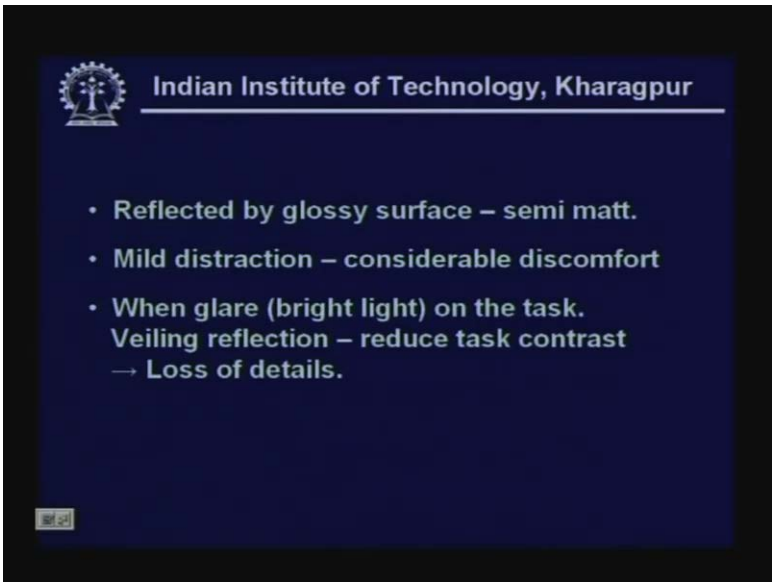

These when they are reflected by a glassy surface or a semi matt surface, they become very important but one must say with all this, there is a mild distraction which creates discomfort but it does not really what you call cause any damage or discomfort to the eye. The glare if it is on the task, one has to look at the contrast and see that there are no loss of details.

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Now in total the glare is minimized by luminaires located carefully and saying that they are never located in the forbidden zone and try to have more light from sideways at right angles to the direction of viewing and thirdly they should have large surface area low luminance, in fact

the calculation shown with two lamps has shown. We could have if you have large number of lamps it is possible to get the more uniform illuminance on the work surface and for the same light output brightness per unit area can be reduced in the plane of vision. This is how we could do with larger luminaires with low luminance and obvious work surface should have very little deflection and max surface gives that.

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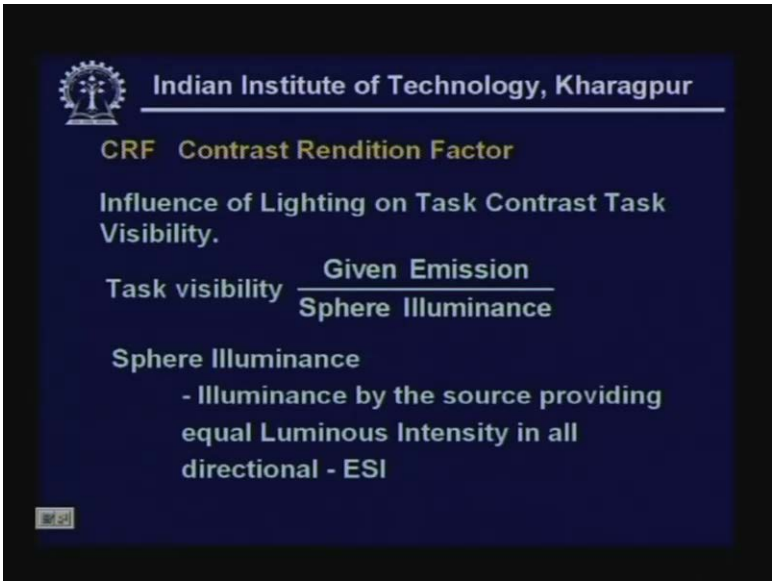

Now here we are talking about the contrast and this is what brings in contrast rendition factor and this is dependent on the task contrast visibility which is defined as the given emission to the sphere illuminance. Now supposing we have a lamp providing equal luminous intensity in all directions then that is known as sphere illuminance. Take any lamp, the total luminance if it was the only a point source that would be the spear illuminance and take the actual emission in the situation.

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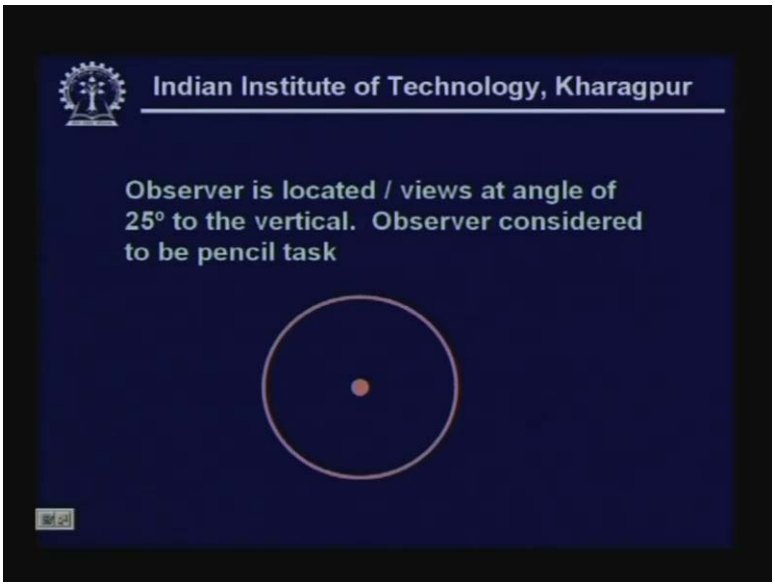

And this is what we called task visibility. Now this is best, this is believed is best when observer views at an angle of 25 degrees to the vertical and this is considering one is looking at a task is basically this circle with the dot shows that angle and observer is considered to be viewing a pencil task in fact it is believed that is the it is the most tenuous thing to look at a pencil task.

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So in total the summary of this lecture could be glare is the brightness within the field of vision. The glare effects could be worst could be injuring the eye. Nominally disturbs the nervous

system causes annoyance discomfort and fatigue there by reduces efficiency of work and interferes with clear vision leading to accident risk.

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The types of glare are direct glare, when the bright luminaire is in the field of vision, reflected glare when it is reflected from a glassy surface. Reflected glare causes more annoyance than direct glare though not harmful it creates interference.

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Direct glare is minimized by mounting luminaires well above the line of vision. Disability glare is what impairs the vision which happens very rarely, discomfort glare increases with the time of exposure and one is relieved after a period of rest.

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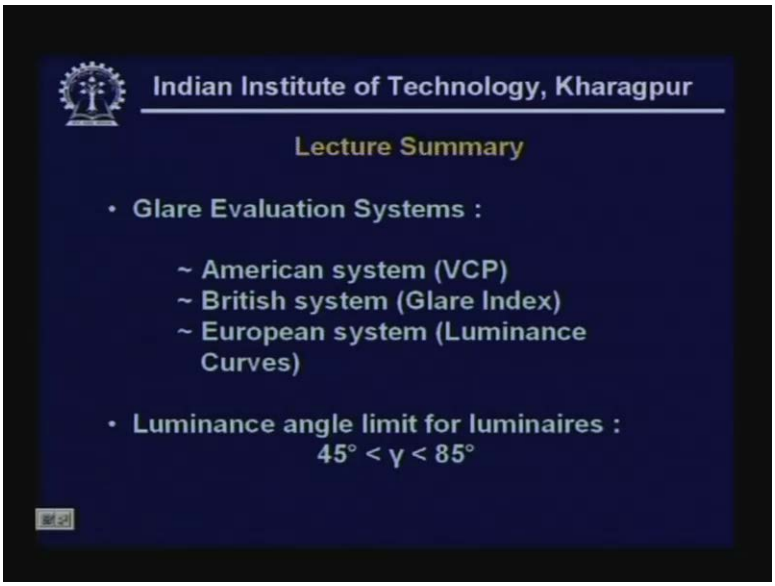

Glare evaluation systems comprise of American system which is visual compare percentage, British system which talks about glare index based on the zone of illumination and the most prevalent European system is luminance limit curves. Luminance curve limit looks for luminance angle between 45 to 85 and based on the curves one evaluates the glare.

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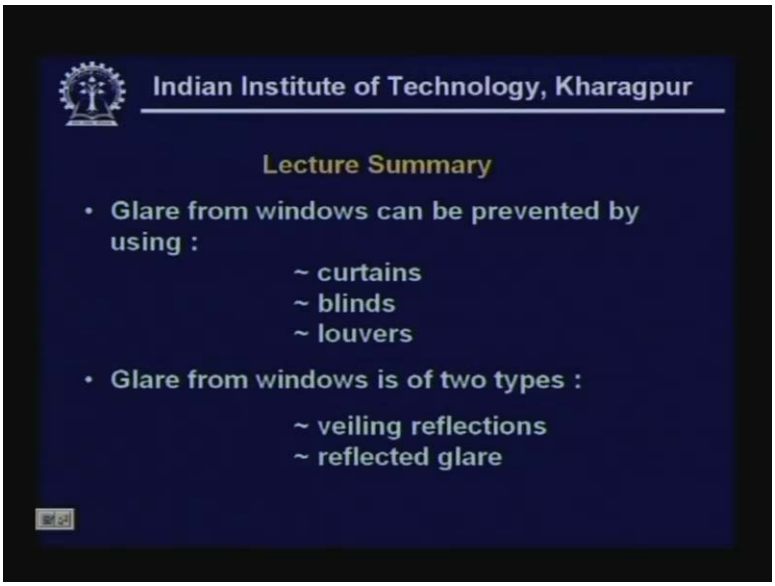

Glare from windows is always prevented by using curtains, blinds, louvers is of two types, there could be reflected and veiling reflections that is light trying to percolate in between the curtains or blinds.

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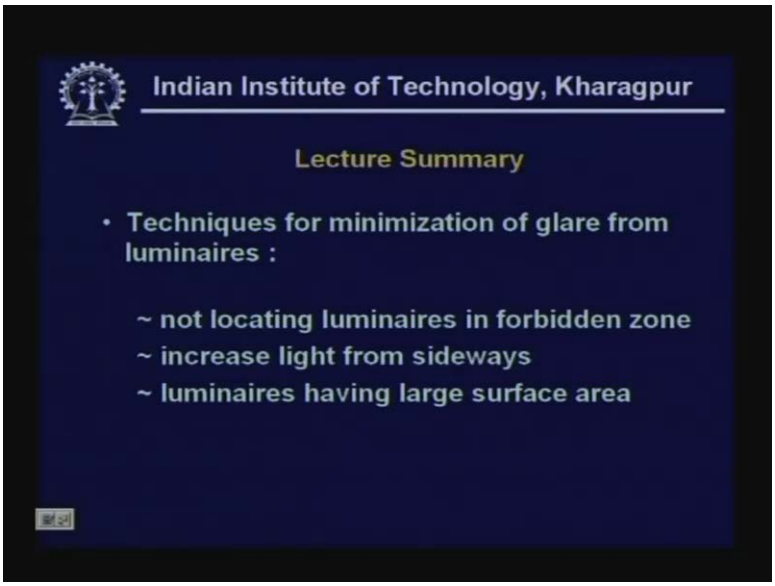

Techniques for minimization of glare from luminaires never locate them in forbidden zone, increase the light from sides and employ low luminaires but large surface area luminaires.

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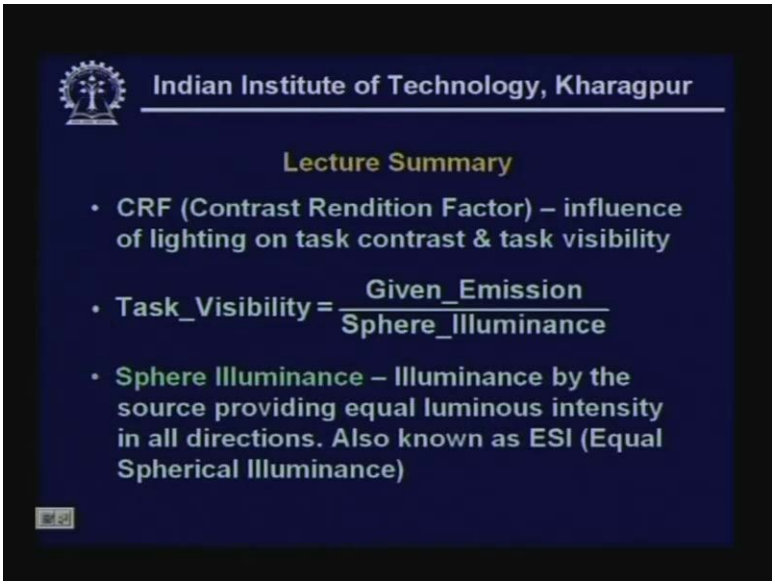

Contrast rendition factor influence lighting on task contrast and task visibility which is defined as the given emission to the sphere illuminance and sphere illuminance being the source providing equal luminous intensity in all directions ESI.

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Three categories of lighting are important that in general lighting, local lighting and combination so that an appropriate glare is avoided. In fact a suitable combination of general and local reduces glare to a very large extent.

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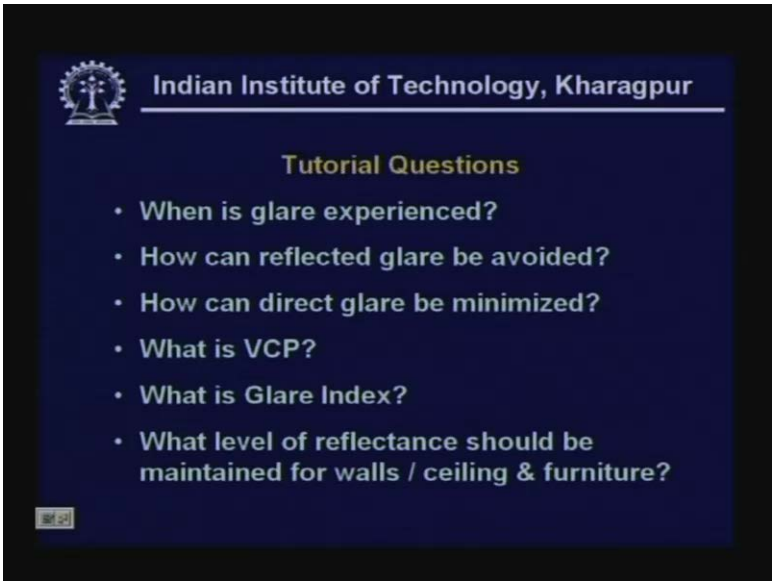

The questions that can be addressed are when is glare experienced? How can reflected glare can be avoided? How can direct glare be minimized? What is VCP? What is glare index? What level of reflectance should be maintained for walls or ceiling and furniture?

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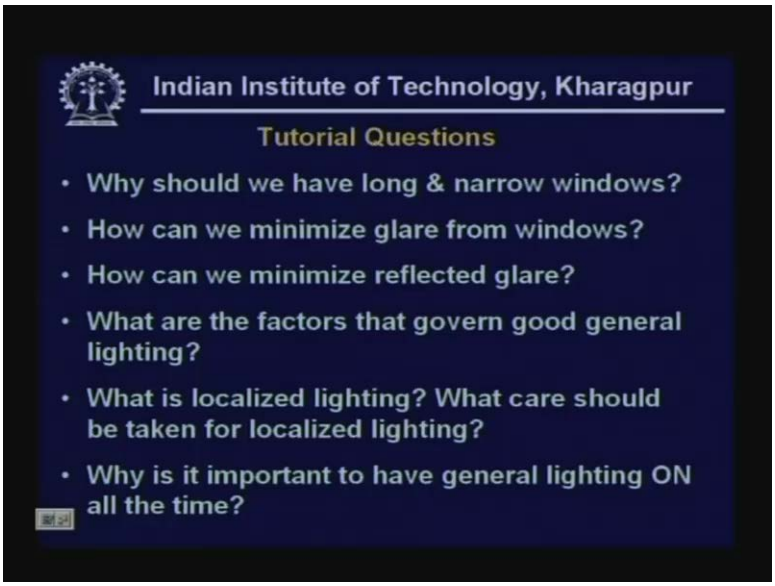

Why should we have long and narrow windows? How can we minimize glare from windows? How can we minimize reflected glare? What are the factors that govern good general lighting? What is localized lighting, what care should be taken for localized lightning? Why is it important to have general lighting on all the time?

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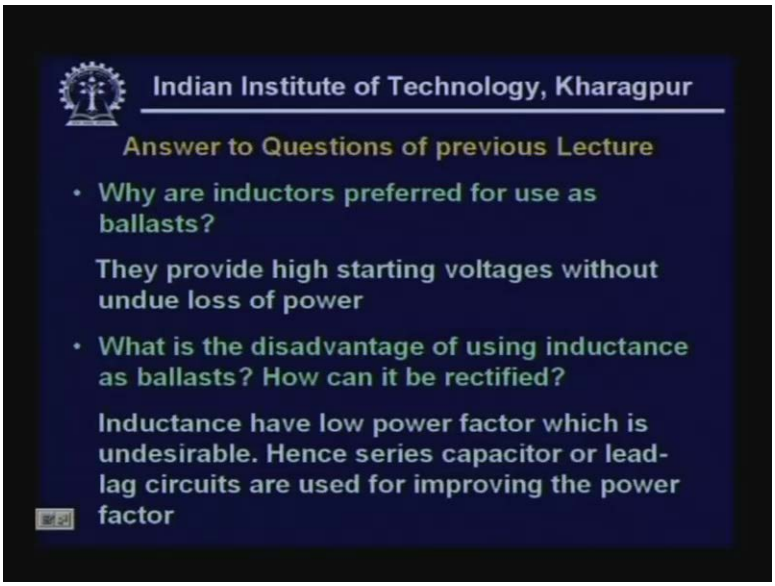

Some of the questions which were asked in the last, why are inductors preferred for use as ballasts. They provide high starting voltages without undue loss of power. What is the disadvantage of using inductance as ballasts, how can it be rectified? The inductance has low power factor which is undesirable hence series capacitor or lead lag circuits are used for improving the power factor.

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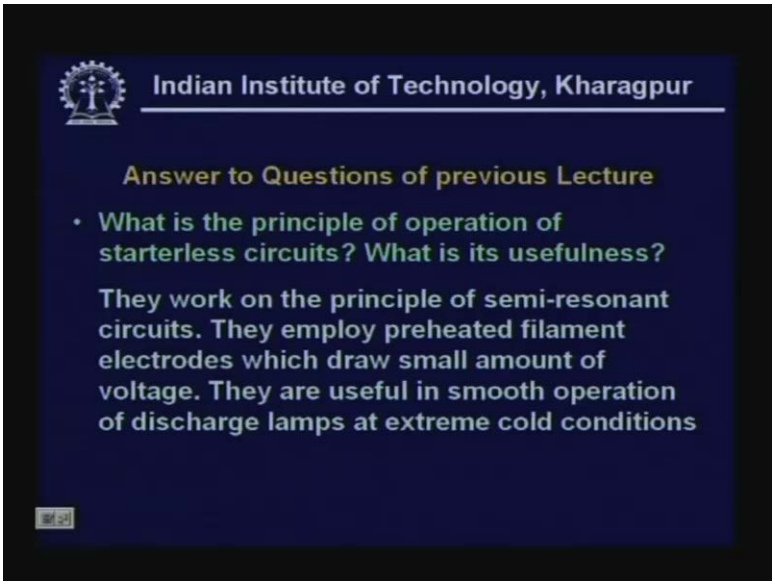

What is the principle of operation of starterless circuits, what is its usefulness? They work on the principle of semi resonant circuits, they employ preheated element filament electrodes which draw small amount of voltage. They are useful in smooth operation of discharge lamps at extreme cold conditions.

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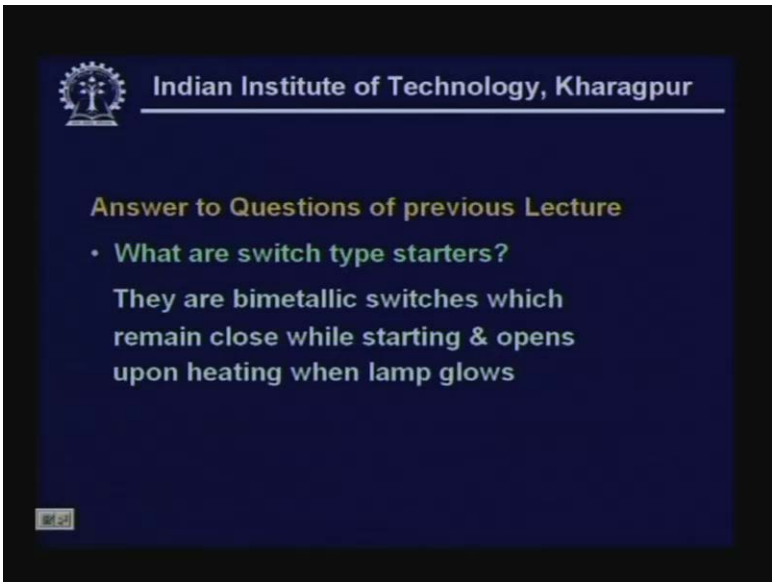

What are switch type starters? They are bimetallic switches which are very commonly used, remain closed while starting and opens upon heating when lamp glows. Thank you.