Illumination Engineering and Electric Utility Services
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Lecture No. # 11
Illumination Systems – I

Yeah, welcome to the next lecture on illumination engineer and electrical utility services.

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This is the eleventh in series, titled illumination systems I. Having understood the need for illumination and having understood that the requirement for artificial illumination systems arises from the fact that the life cycle or the activities of the human beings are centered around the sunlight, the natural radiation and all our systems are trying to get the spectrum as close to the spectrum that due to sunlight. And having understood the way sun light functions and looking at the way the human eye response to these light, we had a look at the various possible systems that could be used to get the artificial lights. And any of these artificial sources had to use some kind of a physical phenomena and having got these sources, it becomes necessary to look at the complete lighting system which we call illumination systems.

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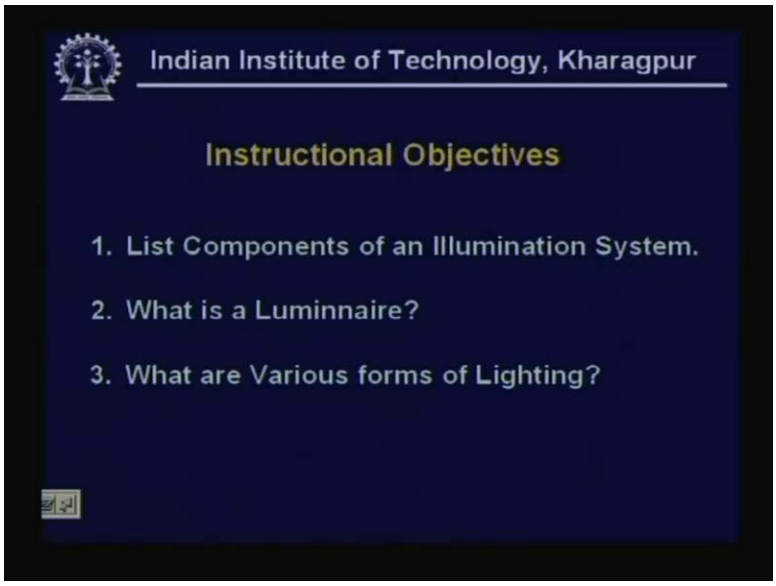

So the instructional objectives for the lesson could be listed as, list the components of an illumination system. That is apart from the source yes, there is a source which can give certain life flux but we have to make it available on the surface or the task surface or the object of interest. Recall that human eyes are most responsible for acquisition of information and it is through eyes that more than 80% of the information is acquired by the human beings. Now in this context of trying to have the light available on the task surface, a luminaire becomes important. So, the next instructional objective would be what is a luminaire and what are the various forms of lighting.

Look at the spectrum of activities that we have. We have activities broadly categorized as what goes on inside a building, home, office which we can call as interior lighting. As against this we have activities outside which could be commuting from place to place using the high ways. Streets, roads which could come under the category of highway or street lighting. Second thing could be sports which should come under the sports lighting and we also have lighting requirements for our manufacturing processes which we can call it as an industrial lighting. So this is what could be addressed in various forms of lighting.

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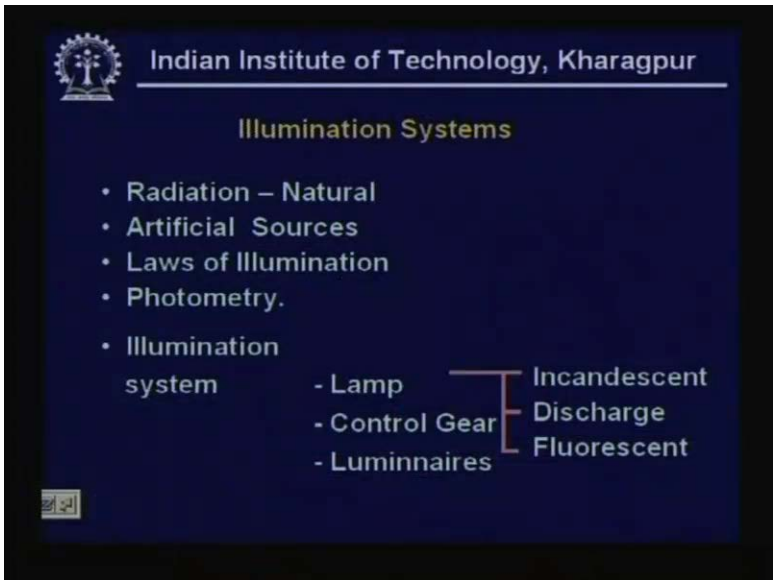

So illumination systems are being looked after the thing to be borne in mind is the natural radiation due to sun is what enables us to perceive things and eyes are enabling us to perceive, we had a complete look at how eye sensitivity depends or how eye response to the light and we find that the peak response of human eye is very close to the peak energy content in the visible spectrum of natural light. Incidentally if you want to classify a light due to a solar radiation, it can be classified as three major zones. One, the ultra violet, two, the visible zone spread over violet to red and then the infra-red. So there comes the need to establish a similar light. In doing this we use artificial sources, in fact the whole course is about that. So we find that there are certain physical processes that are responsible for getting these.

The fundamental process had been the process of incandescence that is materials being maintained at a higher temperature, incandescent lamp in fact evolved from the original wax candle or oil lamp, gas lamp to today's incandescent lamp. Now that is the material is being maintained at a higher temperature in that higher the temperature better is the illumination index and the advantage of this has been that it produces a near uniform or a continuous spectrum. On the other hand the other physical processes like electroluminescence which essentially concession having a discharge luminous discharge in a gas or a metal vapor by application of an electric field is what we call electroluminescence and based on this we have neon signs which are used mainly for display or advertising and then sodium vapor lamps, mercury vapor lamps.

The major lacuna of these discharges is that they are not continuous spectrum. They are line bands or you have band spectra are predominant over a particular zone of the visible red spectrum and hence you do not get uniform white light, the way we get in an incandescent lamp and over and above this, we have a third physical process which we call fluorescence which we are using extensively. It exploits the fact that there is a certain amount of radiant energy available in a mercury vapor discharge in the ultra violet zone which when observed by certain chemicals known as phosphors can be reradiated in the visible spectrum and that is called fluorescence. And we saw the need for moving from incandescent to florescence has come from another

important requirement on illumination sources in the sense they are to be economical or it needs to be reduced or increase the light flux for every watt of energy consumed and that is where we set the… Efficacy of light sources is talked about in terms of lumens per watt and that is how we move from though in case of a discharge lamps, we get a line spectrum or a band spectrum we find in the view of their higher efficacy they are preferred. Now in trying to assess all this, it needs to understand the laws that these systems follow just as any other physical system the illumination or the light flux also follows the certain laws. We have a square law, inverse square law of illumination and that's how we looked into the laws of illumination and no system is complete unless you are able to measure and that is where the principles of photometric where discussed.

Right from the point of view of standardizing light output, we said intensity of light can be standardized as a candle law. We have seen how a fuse, a perfect black radiator maintained at the freezing temperature of a platinum was chosen as a standard. And now the total light flux coming out of a lamp is what we categorized as lumens. And if we consider the original candle or incandescing lamp we can view it as a point source and if we draw imaginary swear. The total thing that comes out is over the total solid angle of 4 phi radians is what we call 4 phi i lumens where i is the candle power of the lamp at the center.

Now, having defined that way then we look at the effect of this light falling on a source that is talked in terms of the illuminance or luminance intensity which is expressed in lux. And similarly this when reflected from any object, the light in the perpendicular direction is what we call to the plane perpendicular to the light rays is what we call brightness which is again mentioned in terms of a food candles. So having done so much, we look at what should comprise an illumination system. The illumination system therefore comprises of three major things. One is the lamp which is the source, artificial source of light which could be using one of the four physical processes that we have studied. It could be using incandescence in the case of an incandescent lamp, it could be using electroluminescence in the case of a discharge lamp, fluorescence in case of a fluorescent lamp and two the control gear, three the luminaires.

What comprises of the control gear? If you look at the crude sense you need something to hold the lamp and direct the light out of this lamp on to the object of interest. Now the fixture which holds the lamp and its position or it helps in mounting the lamp is what we can call as luminaire and luminaire itself to some extent with the help of the reflecting coating put inside the luminaire which in a colloquial term can be called as shade, we have lamps at home which have shades. They basically direct the light, we normally put them in most, if the ceiling height is very high like the old building, older buildings we would have the light directed downwards otherwise in the modern structures where the ceiling heights are lower, we direct the light upwards to the room which gets reflected and is incident on the object.

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So luminaires not only that means provide support and they also enable electrical connection to lamp or lamps it connect. That means it is a shade or a fixture which gives the physical support and remember all these lamps are being run using electrical power, so there must be connections provided by a way of leads in and leads out. Now we also saw that in case of a discharge lamps, the radiation is by virtue of a gas discharge in the vapor or metal vapor or a gas which is ionized that means there is an electric field. And once electric field discharge takes place there is an arc which is nearly constant current. That means there is a requirement to have a initially higher voltage for the arc to strike and later on it needs to maintain the current. And therefore that calls for certain accessories that is what we call as a control gear and luminaire may have provision to include those things within its container.

Now therefore primarily it provide support and enables electrical connections. It says lamps, all lamps that means in a single luminaire I may be having more number of lamps. One could in fact look at the required amount of illuminance on the object sources and there by work out how many lamps are required and accordingly put. These are part it controls, controls means it sees in which direction the light has to go. Imagine a naked bulb mounted on the wall, the light would go in all directions and if the walls and ceiling are not properly maintained, it may so happen that good amount of light may be absorbed by the walls and only a small portion of the light is received on the tough surface which is there is a wastage of light.

Other thing is it distributes light, in fact the distribution of light over certain restricted zones are having what we call beam spreads or beam angles. We find these have applications in automobile lighting and also in sports lighting. Remember in these kind of applications, depending on the size of the object, sports lighting when we talk of it is the outdoor games and depending on the type of the game athletics is another cup of tea in the sense athletics one may not have to observe a small object that is if you say a game like badminton, a shuttlecock is a smaller object.

So recall from the way eye functions, finer it is more illumination is required that means you need your phobia to come into activity and these are the reasons which, so that is why we say luminaire helps in distributing where it is required that directs the light. Of course, obviously control and direct are synonymous with one another in this context but at the same time one has to see that temperatures are kept within prescribed limits. We do not want any undue temperature rise. The issue is very simple, if you use incandescent lamps they are essentially depending on the material or the filament being maintained at a certain temperature, higher the temperature better is the radiation. We have seen it is proportional to the fourth power of temperature.

Now it has got a direct bearing on the overall design of your electrical system in the sense that the lighting has to be integrated with the ventilation and air conditioning system because together will decide an overall electrical low requirement. And today the scenario is we should look for as many measures as possible in trying to reduce the energy. This apart, one has to look at the ease of installation and maintenance.

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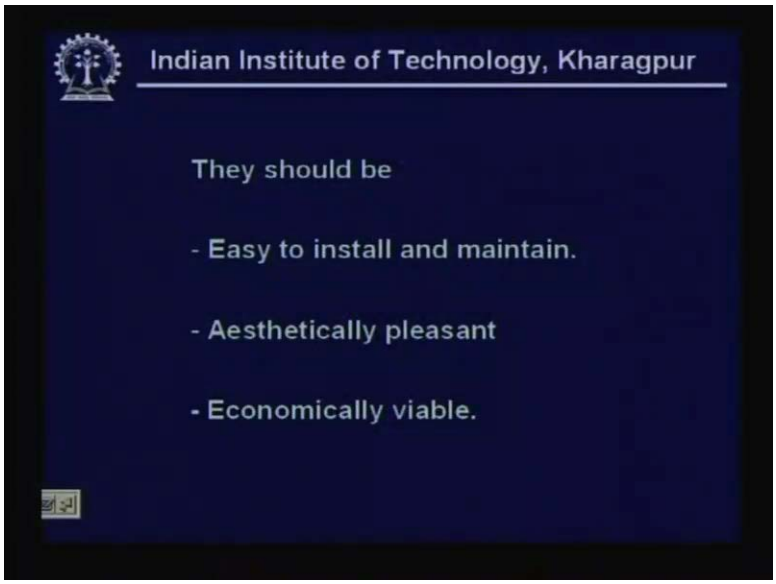

Installation because invariably the sources are kept at a height, so it should be possible to install with minimum of complexity. Second thing maintenance, remember the luminaire depending on the type of environment, let us say we talk of street lights, they have to get to the vagaries of weather that is there can be storms, rains. So any dust deposition on the glass enveloped lamp would make the envelope opaque and thereby reduce the light output and it may be depending on the height, it may be possible to periodically clean or may not be possible. So these are the issues which have to be kept and more the number of loose particles, it becomes more difficult to maintain. At the same time in order to function well and have good psychological impact esthetics has to be kept in mind. In fact it is said unless a lamp itself is an antique piece, it should not draw any attention to itself, the attention should be drawn to the object of interest. Let’s say we are in a display room where we have a model to be displayed then the way the light is directed and controlled and the luminaires are located, it should see that all the light is received on the model being displayed, unless the model itself is a luminaire and in that case it's fine it

can. And the cost cannot be ignored as we have being saying from the beginning economics plays quite a good amount of impact and it should be viable and in fact this the installation and maintenance together with the economics are highly interlinked and all systems should be economically viable. The lighting could be commercial or it could be general.

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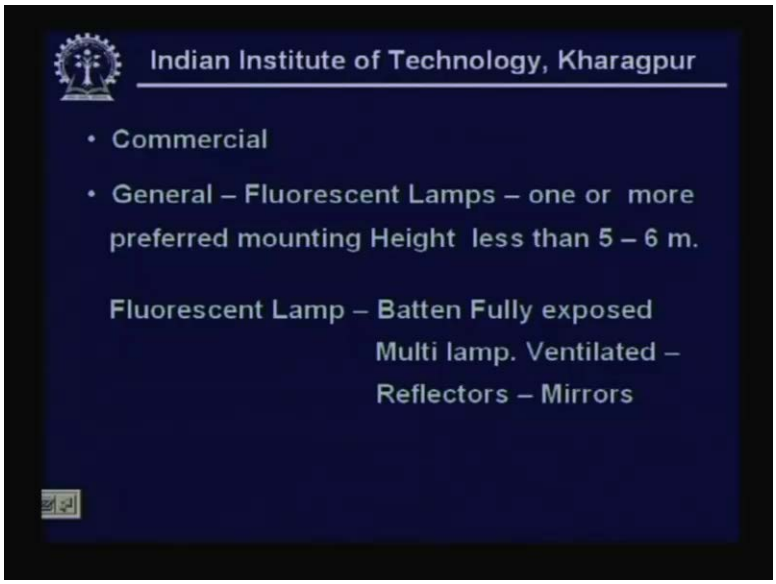

Now most of the times commercial lighting when we talk about luminaires, we have depending on the application. Let's say in a show case the requirement is to show certain products. So their requirements could be different but in general office or interior lighting we normally have fluorescent lamps. Fluorescent lamps could be one or more and typically they are mounted at a height of 5 to 6 meters whereas these fluorescent lamps as all of us are familiar in our residences and hostels, we have fully exposed batten, they are simply mounted on a batten with the two enhold lamp holders I mean the enholders and whereas it could be an enclosed multi lamp kind which is called ventilated with reflectors. These reflectors could be mirrors and that is the other.

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The issue is there it could be difference in control which depends on the luminous intensity of the lamps employed and how one wants to distribute the light and the number of lamps that are involved. Here let us recall what we learnt in loss of illumination. If we consider an incandescent lamp, we find the radiation or the due to point source at any point on the task surface can be related to I over d square where d is the distance between the point and that is point of observation and point of source which means it keeps on varying inversely with square of the distance. So if we use incandescent lamps this has to be borne in mind. One aspect which I must mention is that in designing over the entire task area, we try to maintain nearly same level of illuminance that is the lux levels with hardly difference over any point less than 30% okay. So that being kept, we need to locate the lamps accordingly and you can. On the other hand if we have as against a point source a line source, a typical example of a line source is a tube light or a fluorescent lamp we find it is the distance between the point of observation and is inversely with the distance.

Now imagine you can get the similar structure by having number of incandescent lamps placed one after the other over a vertical, over a length of a line. And as against this supposing we create what we call a sheet of light or a plane source radiation. In fact we see large conference rooms and large work rooms where discussions are to be held, one tries to create a sheet of light over the task area. This is very much true of a conference room where you have a large oblong table and you have on top of the table. See the distinct advantage is that when you try to create using set of lamps, luminaires so design that you get a sheet of light. How do we have achieved this?

Now we have a luminaire that means luminaire is nothing but a physical support which is similar to our shade which in case of a incandescent lamp has got a conical structure. Now that has a reflecting coating or a mirror is placed and then the number of lamps are fixed below which a diffuser is placed. Once you have a diffusing exterior envelope, the entire light gets diffused and forms a sheet of light. So you may be having let’s say over certain area, number of fluorescent lamps included within this luminaire.

Now designer should always aim at locating lamps on this. So with the help of reflectors and there are what are called louvers with openings. See you can have diffusers, you can have louvers commonly what we find a louvers with slanted fins or vanes this is being used. So control direct and reflect and as a result we try to see that as much of the light flux that comes from the source is allowed to fall on the object of interest. If we take a simple batten type of a fluorescent lamp, there is virtually no control, light goes out in all directions and whatever comes below or on the task that is what is available for the task.

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The next most common thing is enameled reflectors. I told you even the simplest of the luminaires which we talked call as lamp shades are nothing but enamel coated metal conical reflectors. The next best would be to have mirror reflectors and you could have louver type of shields at the bottom. Basically the two purposes which a shield does is which enables which prevents any dust entering and also acts as an opening for the enclosed lamp assembly for the light to go out and you could be using opalescent shades that is it gives an opaque nature that is a diffusing shade which will enable.

Now the principle to be borne in mind is this, if we had a point source depending on the distance the light available on the task varies inversely as the square of the distance that means there is a barring to the mounting height. There is an optimal mounting height if you are using point sources and it varies as square. As against this if we use fluorescent lamps which can be thought of as a line sources, the mounting height dependency is there but is inversely proportional to the mounting height. On the other hand with the help of various luminaires along with the diffusing shades, it is possible that we get nearly plane source of radiation or a sheet of light which is independent of the mounting height. That's what we look for especially in office lighting because and the reflectors enable and of course as I told you depending on certain applications we can orient it in a desired solid angle.

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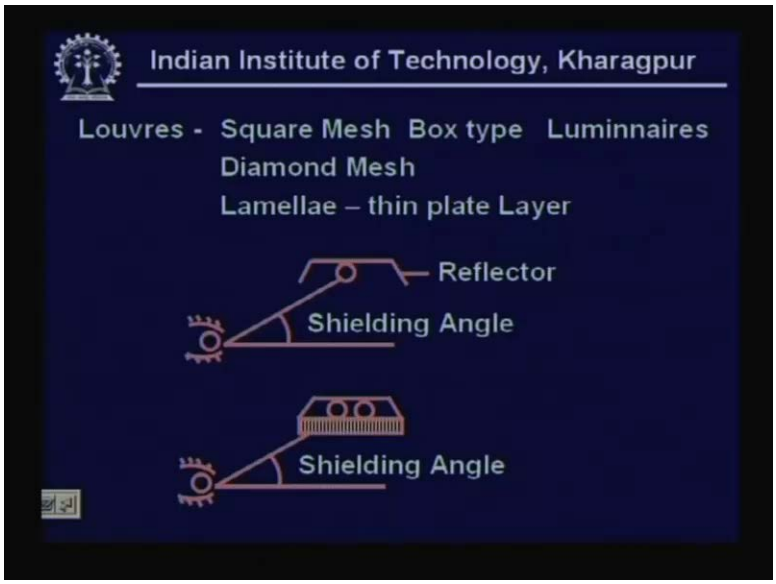

The louvers themselves could be having the square mesh or a diamond mesh or thin layers, this depends on the type of luminaires you have. They could be the issue is again what one uses depends on the ease of maintenance and some knowledge of the local conditions becomes very important. Now all this holds good essentially for what we call office lighting or interior lighting. We have one other category where it is very important is the industrial lighting and the street lighting where normally the mounting heights are reasonably high number one, number two they are prone to more what you call vagaries of weather, three what we look for is that in those applications, it is not necessary to really go into fine details or be able to reproduce the colors or meaning to say that have good colour rendering and that is where one may not really bother so much.

So there are two kinds of a luminaire shown here. The top one shows see this could it shown it could be viewed as a fluorescent lamp the circle did denoting that with the pure reflector, the other one with a louver placed below which is being shown in the form of a square mesh. Now in addition to this, we will observe that these luminaires will have what are called as certain ventilating mechanisms. So that the heat does not build up and temperatures do not rise unnecessarily because remember no matter what type of source you use, there is some amount of heating involved. In fact we saw the discharge lamps could be using either cold cathode or hot cathode. Cold cathode would need higher voltages as against hot cathode lamps.

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Now these are either recessed in the ceiling or mounted on the surface. When they are mounted on a surface these are the two issues otherwise since normally unless if you are trying to create a sheet of light it depend on the mounting height. So they could be suspended, when you will suspend they are called down lights, okay. The other application therefore I was telling you the air handling becomes very important ventilation. So it shows three different ways of allowing the air handling. The top could be having slots cut as shown in figure to the left most, this particular type of luminaire having this is called plenum or you could be having ducts as a single duct and twin duct type of air handling. That is you can have air going in and coming out so that the temperature of the luminaire does not rise very high.

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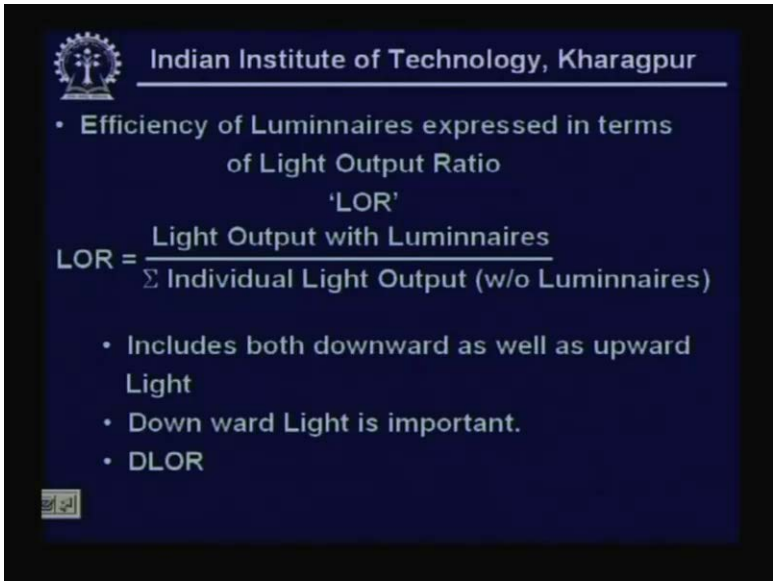

Now the issue comes how does one express the efficacy of these luminaires. There is one factor which we call as the light output ratio. This is defined as light output with luminaires by sum of the individual light output without luminaires. Obviously when you talk of such an index it should be very clear to the user where he is talking of depending on the task. This is abbreviated as LOR and normally when we talk of LOR, it includes both downward as well as upward light but normally downward light is important, bearing in mind most of the lamps are mounted either in the reassess or suspended from the roof or on the surface of the walls and we are either sitting at a table and working or on the floor. So therefore when you are looking at the luminaire, you look at the DLOR that is the index which is of importance.

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Now remember if we direct the light upwards it illuminates indirectly by reflections. The advantage of that is at no point there can be a glare, we defined glare. Glare is the effect of intense light in the line of vision and this has to be avoided because this effects our ability of the human eye to adjust. Human eye has got a very good adjusting ability. Now if we use plane enamel reflectors, the LOR could be lower if you want to improve you can use mirrors. In fact if you see the modern day luminaires especially meant for large complex office lighting or industrial lighting and even the street lighting luminaires they come with mirror reflectors, keeping glare into consideration. The next issue which I said is industrial luminaires. Now depending on the height, essentially it depends on the height. Height of an industrial bay depends on the type of manufacturing process and the volume of the material that they have to handle.

Now therefore the industrial interiors reaching up to about 6 meters they can be lit using fluorescent lamps with matt white reflectors. Again the idea is the maintenance difficulties are much more in an industrial environment. Environment is more hazardous and more scope for pollution and that's the reason why you do not go in for really sophisticated systems whereas what we call high bay luminaires are used whenever there is height beyond 6 meters and there invariably it is the discharge lamps.

We have already mentioned discharge lamps are used on two accounts, one because they operate with high luminous efficacy that's the most important thing. There is no doubt colour rendering is bad, in case of a mercury it is better but in case of a sodium vapor which is predominantly used again between sodium and mercury, the choice of sodium has come because of a high utilization ratio.

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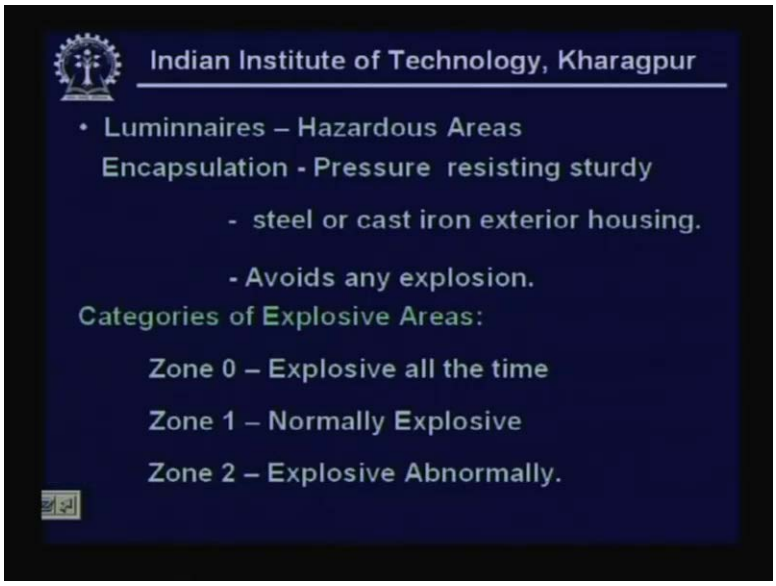

Luminaires in hazardous areas need special requirements, there could be it should be encapsulated and there should be pressure resistant and they should be very sturdy. Normally they have a steel or a cast iron exterior housing and the so design that they can prevent any explosion what so ever and therefore depending on the, there are certain categories of explosive areas have been identified a card zone 0 is 1 where there is a scope for explosion all the time. Zone 1 which is normally explosive not all the time, zone 2 if it is abnormally explosive that is it is as though there is some finite chance. Let us look at it this way, I can say may be about 10% of the times, zone 2 is explosive more than 60, 70% of the times zone 1, 100% of the time is zone 0. That's how accordingly luminaires have to be designed to encapsulate that there is no ingress of any poisonous gas into, remember this is at a high temperature, filaments are at high temperature there could be a discharge. So any poisonous explosive gas getting in can create an explosion.

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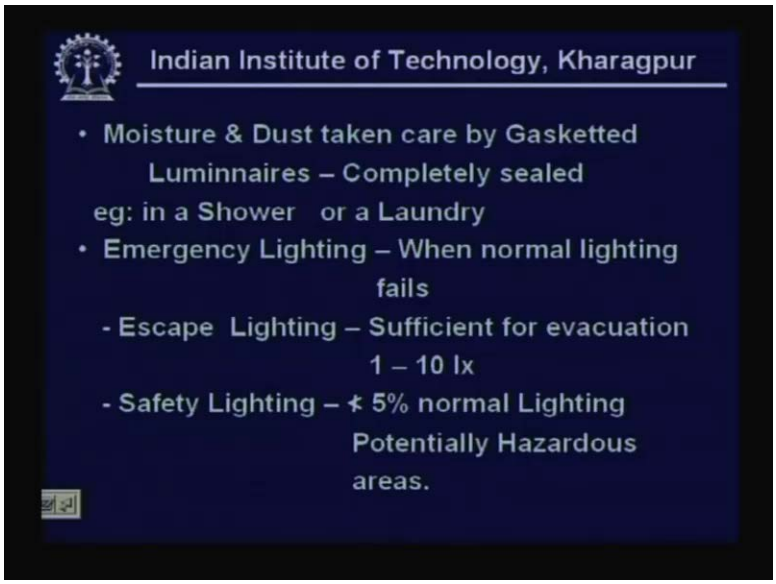

Moisture and dust of course can be handled by having gaskets. See luminaire has a glass enveloped through which a light is coming out, this is should be gasket. See inside the house one may have open luminaires with just fins. The other important area where one requires completely shield luminaires are in the shower or laundry where water is used. Now the other categorization of lighting needs to be done before we look at these illuminance systems. One is emergency lighting, you need certain minimum lighting even when the normal lighting fails so that you are able to move around and take care of your basic activities without any unsafe accidents. This is what we call emergency lighting and then that is a lighting which we tried to provide in circulation areas, in fact the usage of 5 watt lamps at home as night lamps or bed lamps is essentially to see that we have. Now there it's not an emergency lighting it is what we can categorizes as safety lighting or in fact we see escape lighting is what is mentioned here.

Escape lighting is a minimum lighting to be able to locate the exit passages. In fact we have observed these that these exit passages are often provided by guided lights or fluorescent lights or indicators in fact. Safety lighting is normally not less than the 5% of the normal lighting in potentially hazardous areas that is very important. So there is scope in certain areas where one may meet with an accident and in those areas, one has to see that it is never below 5% of them. Let us say we need about say 20, 30 lux in the normal operation, the general lighting requirement in an interior. So it should not be below 3 lux so that you will in the hazardous areas.

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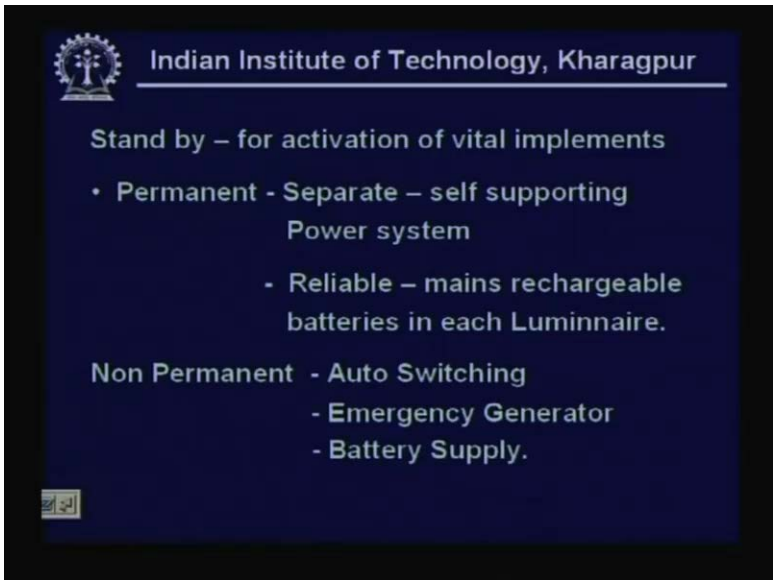

This apart, we do have stand by for activation of vital implements and permanent separate self-supporting power system. This becomes part of your requirement from the utility. So all this emergency lighting requires that there is a self-supporting power system. We will look into that and those why we are looking at it at this point of time is that sometimes these days the luminaires themselves are provided with reliable batteries which are mains rechargeable, they act as a stand by supply, this is provided. The other issue is you have switching on some power to emergency generator or a battery supply. So all this the utility system designer can low. So you see lighting itself has to be there. There is a certain functional lighting, this is an emergency lighting because in the event of an emergency you need and there is certain basic lighting from the safety point of view.

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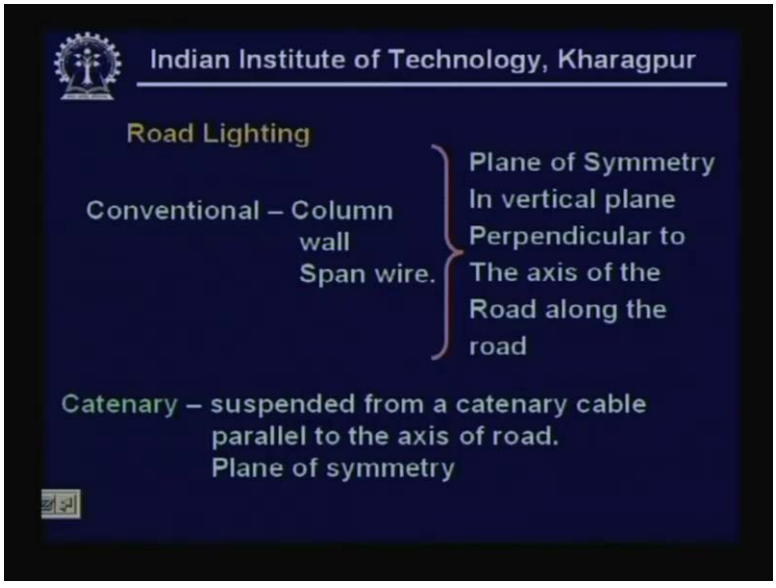

All this has to be assured and now coming to the road lighting, there are various ways you have column of lights that is you have lamps placed mounted on the poles on one side of the road or either side of the road across. Now supposing if there are some walls, you mount them on the walls or you have it as a form of a catenary on the middle of the road suspended by the two poles on the either side. The important is that you have a plane of symmetry in the vertical plane which is perpendicular to the access of the road along the road that's the important. This applies to street lighting or highway lighting. As I was telling you that there could be a column or a span on either side or both sides or a catenary, these are the ways to do this.

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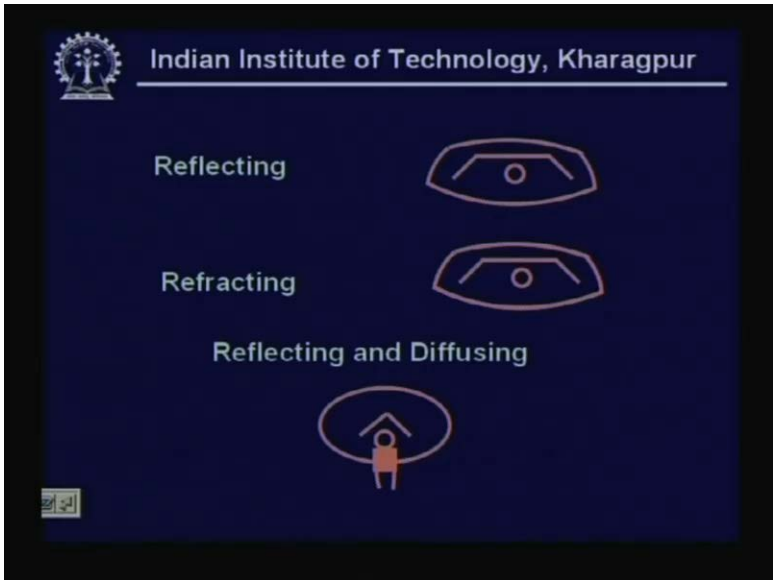

Now this shows a picture of a reflecting luminaire. Now since here we are showing it for a road lighting application which is completely enclosed because it is subject to vagaries of the weather. The circle denotes your lamp, there is a reflector or the luminaire per say and then the enclosure which could have a, bottom could be glass and in order to see that dust or moisture does not get in we will have a gaskets provided. This is a refracting in the sense that the outer envelope will not be transparent glass but it is an opaque thing so that if the light diffuses it comes. This may not be suitable as a normal street light but it is an ornamental lighting of path ways and paths can be which when it is made at low heights where the light falls in the sight of vision and hence avoids glaring. This is both reflecting as well as diffusing. This shows a typical luminaire used in what we call post top lanterns, you can see the circle depicts the lamp and the triangular thing is the reflector. The overall egg shape dome is there which is translucent opaque thing which diffuses. So you have reflecting, refracting and diffusing kind of a thing. Now the difference between the interior luminaires, industrial luminaires and the exterior luminaires is that the luminaires in industrial environment and the external environment need to have taken care of dust and moisture ingress.

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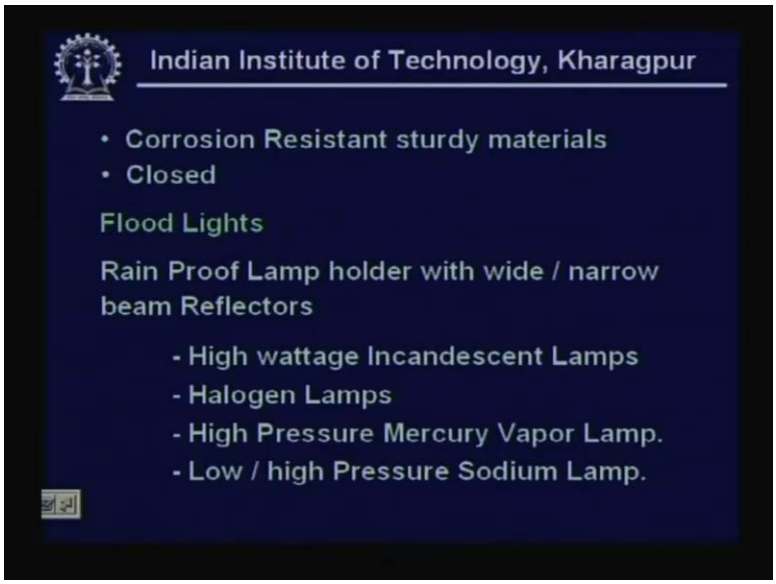

Therefore they are used with corrosion resistant sturdy materials and they are completely enclosed. Flood lights is another application which in fact is what is used especially in sports lighting, they have rain proof holder with wide or narrow beam reflectors. This beam depends on the application. When they are used for certain narrow zone, it will have a narrow beam. They are invariably a very high wattage incandescent lamps or halogen lamps. The halogen lamps we said are nothing but using certain metal halides, it only improves the life of an incandescent lamp because it avoids blackening which is prevalent with your normal incandescent lamps. High pressure mercury vapor lamps are also used for flood lighting and these days even low pressure sodium vapor lamps.

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Spot lights or down lights these are used essentially for studios and performances and this they used along with screens, reflectors and you know in theaters one needs to create different colors, so one can use filters colored envelopes and closed lamps. Now the issue is their control is involved essentially they are all electrical accessories. The outer screen can be controlled with the help of motors and down lights or spot lights are essentially suspended from the top.

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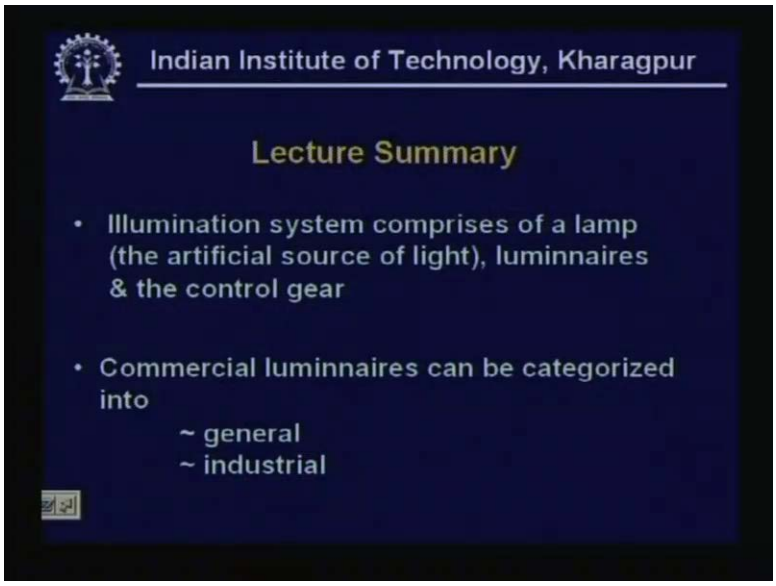

So in effect one could look at the summary of the lecture on illumination systems as that illumination system comprises of a lamp that is the artificial source of light luminaires and the control gear. Now here there are certain control gears such as the ballast, starters in case of the discharge lamps and fluorescent lamps and certain applications like street lighting can have varying levels of intensity depending on the time of the day. For all this will be covered in the subsequent lesson. Commercial luminaires can be categorized as general and industrial.

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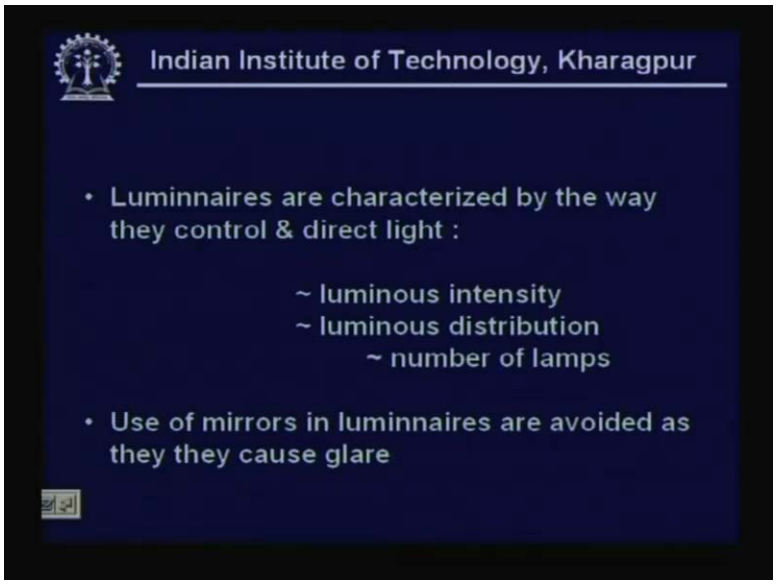

And luminaires are characterized but the way they control and direct the light which depends on the intensity distribution and number of lamps. The difference is depending on the application although at home a single luminaire may have only one lamp. Most general applications have more than one lamp and the three basic issues are one luminaire which supports with a reflector which reflects directs a light towards where it is to be and depending on the environment either it is enclosed or has louver through which light comes on to the task surface. Use of mirrors to be avoided but if used along with diffuses is fine.

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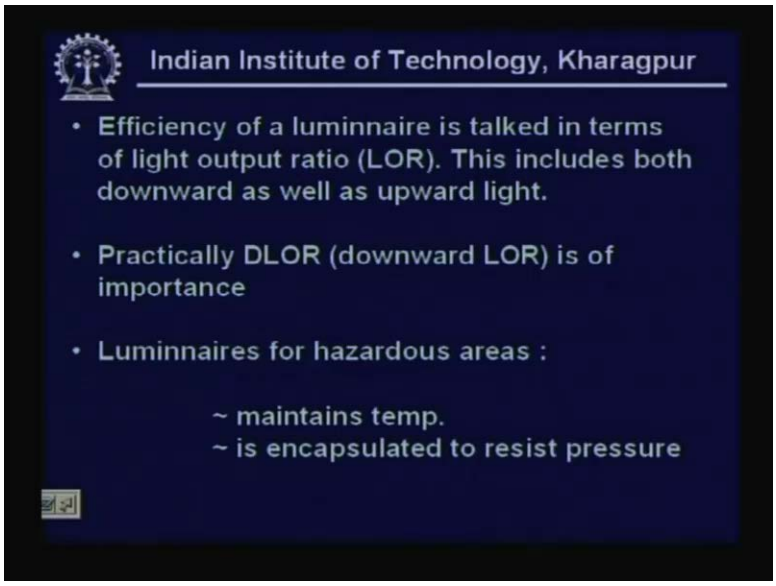

Now the efficiency of a luminaire is talked in terms of the light output ratio which we defined as the light output with luminaire to the sum total of the light output of the system without luminaire. Normally downward luminaire is downward light output ratio is of importance because most lamps are mounted at a height and the task is at the table of required thing. For hazardous areas one has to be very careful that they maintain temperature, so they have to be sturdy and encapsulated to resist any pressure variations.

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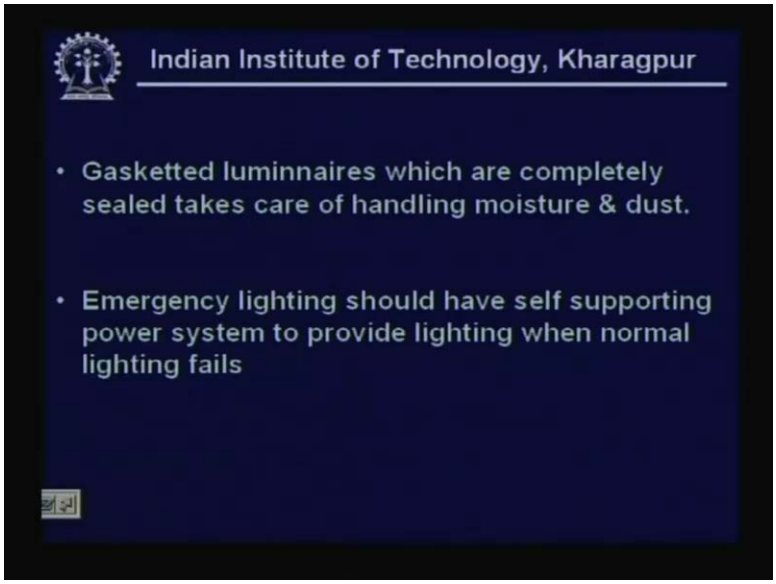

And wherever moisture is involved gasket should be provided and completely shield so that dust or moisture does not take place. Now for the sake of having different emergency lighting or safety lighting, one should have self-supporting power system when normal lighting fails.

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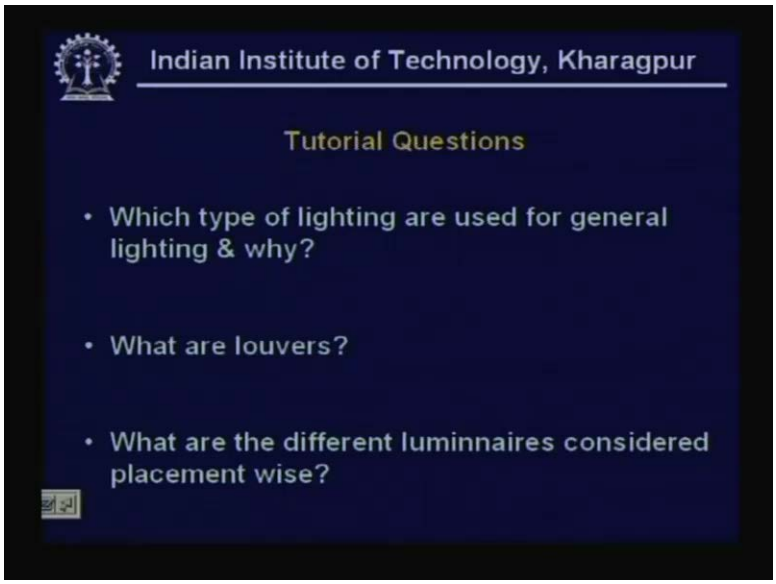

This could be in the form of a rechargeable batteries provided within the luminaire. The questions that may be address which type of lighting are used for general lighting and why? What are louvers? What are the different luminaires considered placement wise?

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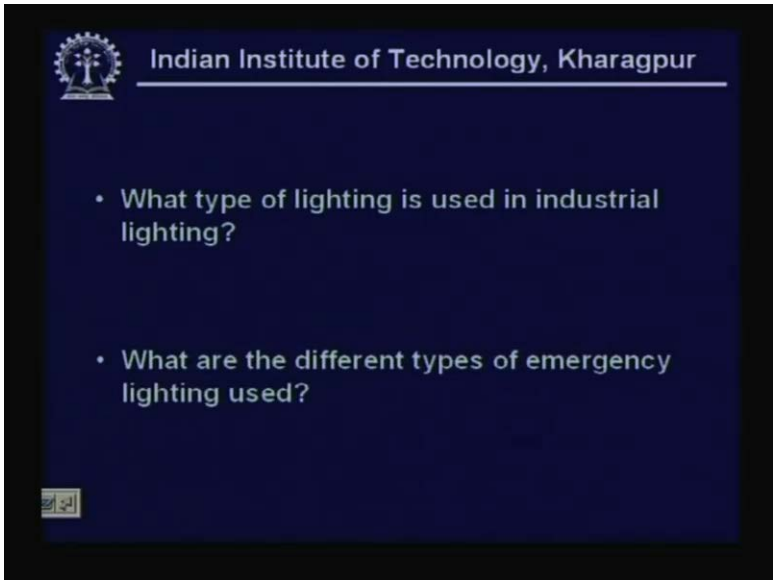

What type of lighting is used in industrial lighting systems? What are the different types of emergency lighting used?

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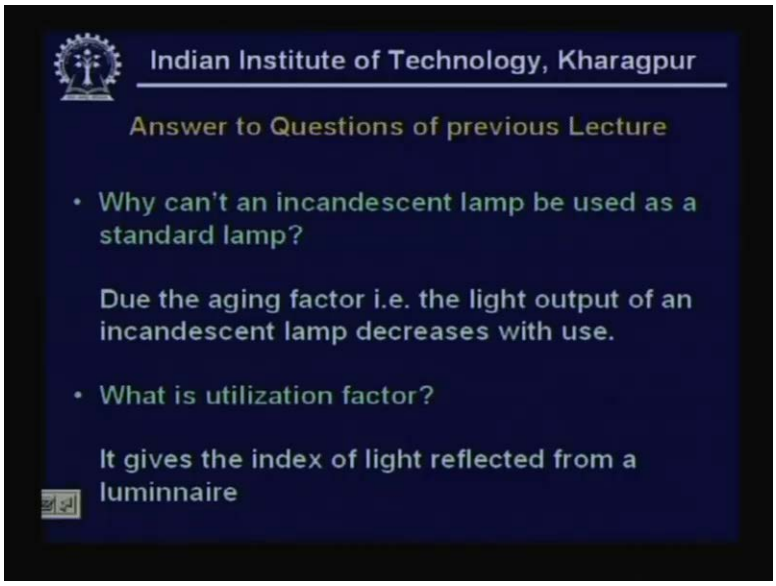

Answer to questions of certain questions in the previous lecture are why can't an incandescent lamp be used as a standard lamp. Due to the aging factor the light output of an incandescent lamp decreases with use. What is a utilization factor? It gives the index of light reflected from a luminaire.

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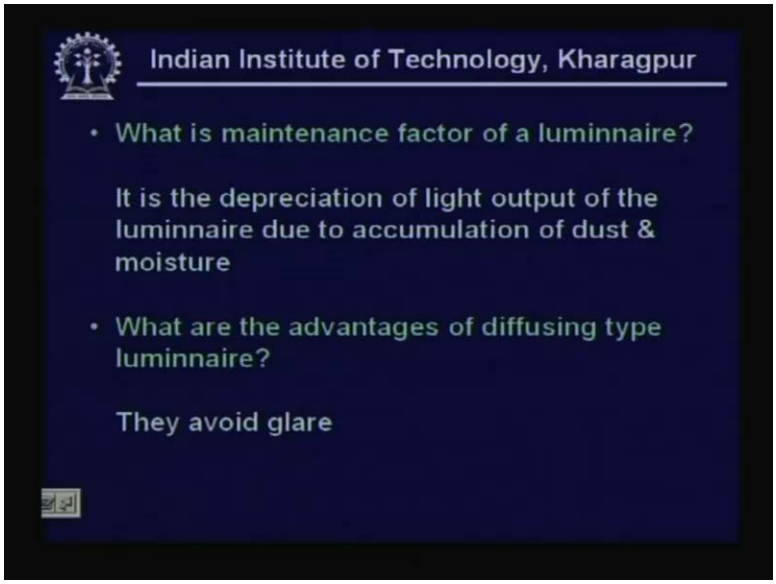

What is a maintenance factor of a luminaire? It is the depreciation of light output of the luminaire due to accumulation of dust and moisture and age. Advantage of using diffusing type of luminaire? They avoid glare. Thank you.