Illumination Engineering and Electric Utility Services
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Lecture No. # 03
Eye and Vision – 1

Welcome to this third lecture on illumination engineering and electric utilities. This lecture is titled eye and vision one.

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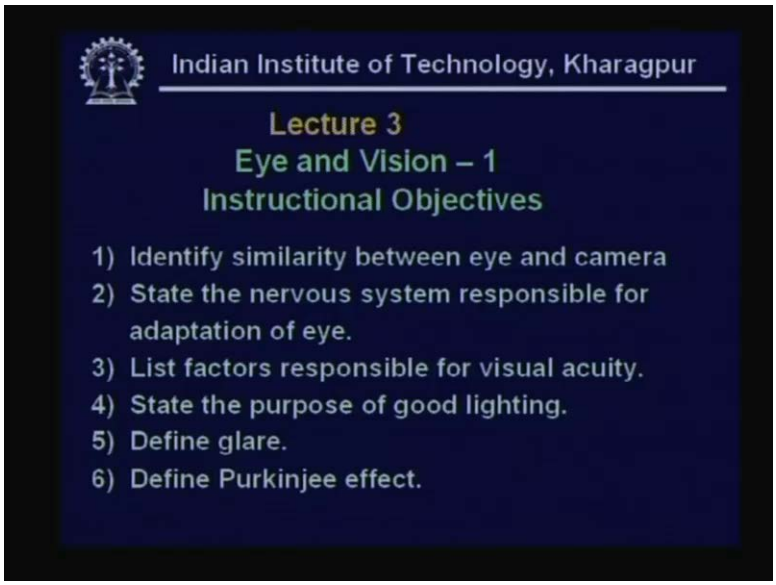

The instructional objectives for this lecture are to identify similarity between eye and camera, two state the nervous system responsible for adaptation of eye, three list the factors responsible for visibility or visual acuity, four state the purpose of good lighting, five define glare, six define what is known as Purkinje effect. So we begin with the lecture three titled eye and vision one and we have looked at the instructional objectives. This lecture I mean on eye and vision is divided into two parts, part 1 and part 2 and recall that in the last lecture we had a look at various physical phenomena that could be utilized to obtain artificial illumination namely the incandescence, electro luminance, flow of phosphorescence, florescence and central to all of these was the effect of incandescence or dependence on temperature. And we had also looked at what was known as color temperature and how various artificial illuminating sources could be categorized in terms of the color temperature which is essentially the temperature at which a black body has to be maintained to obtain radiation similar to that obtained from an artificial source.

Having said that about in the last lecture, we look at how the important organ of the body that is responsible for perceiving things has already brought out in lecture 1. The 85% of information acquisition is through the sense of vision and the most important organ of the body is eye. Today

we have a look at the eye, in fact the first instructional objectives talks about the similarity between eye and camera.

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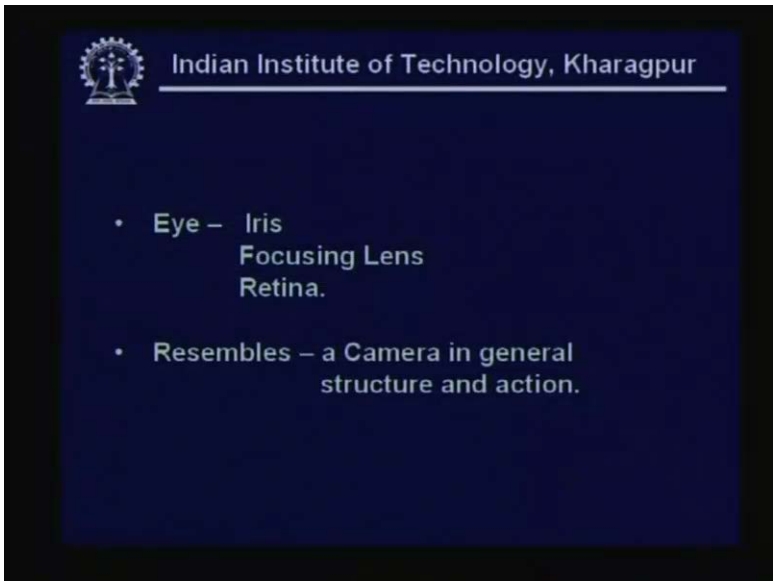

Let's see what constitutes an eye. If you look at the organ eye, it has got three major components namely iris or the opening through which light enters the eye then there is a focusing lens which focuses the incoming light on to the screen at the back which is termed retina in a human eye. So eye consist of three components one iris, two focusing lens, three a retina. This may be seen that it is similar to a camera which is taking a picture. If you recall a camera has an opening through which the reflected light from the object to be photographed is captured and the negative of the image is placed on a film and in doing this there is an optical lens that is used. So functionally and structurally eye and camera are very much similar and the activities can be looked at, the similarities could be looked at in this manner.

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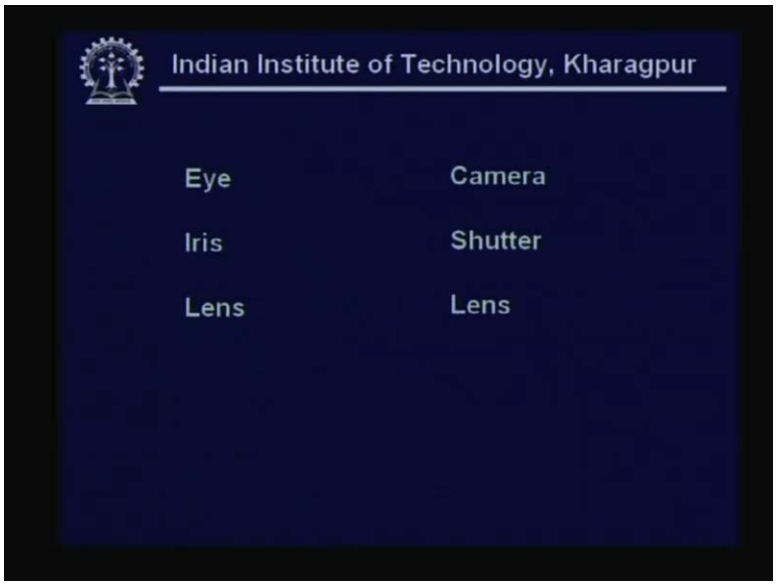

The iris, the opening in the eye or which is also termed pupil which permits entry of light is similar to your shutter in a camera. Just as the optical lens is there in a camera the eye has a lens which focuses the incoming light and enables us to see. And the process of seeing is enabled by formation of the image on the retina. So what do we find? They are highly identical, iris is similar to shutter, lens has an analogue lens in the human eye and film of a camera is analogues to retina or retina is the screen on which the image is formed. In fact though optical images formed in the retina, it is through our brain that we see. There are set of nerves located on the retina which enabled communication to the brain that what is being viewed.

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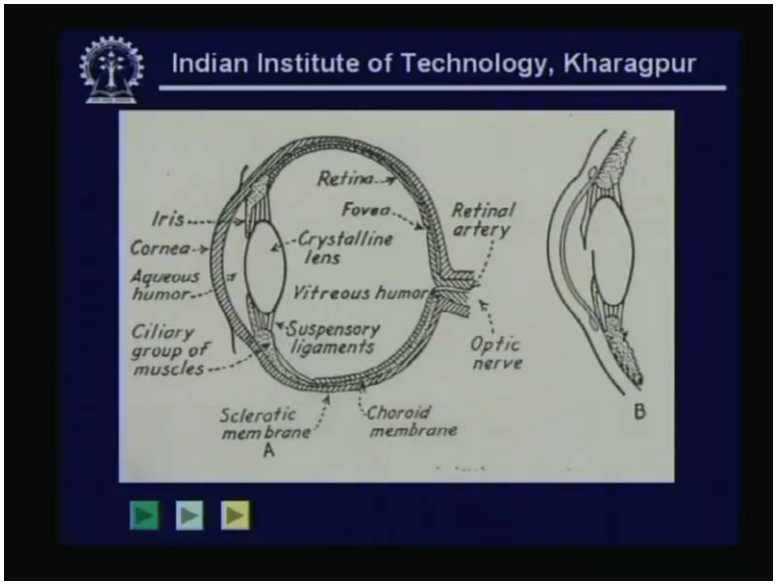

This picture here shows the complete structure of an eye. As already told the three major components are essentially iris which is also termed as pupil that permits light. Lens, it is crystalline lens that focuses the images then retina is this creed at the back and you may see in fact the nerve connecting the retina to the brain is shown in the picture which is known as optic nerve. Although, the figure shows many other muscular membranes and group of muscles that are there. For our understanding, it's not important to know all these things but suffice it to say the three components of importance as far as we are concerned are iris, the lens and the retina.

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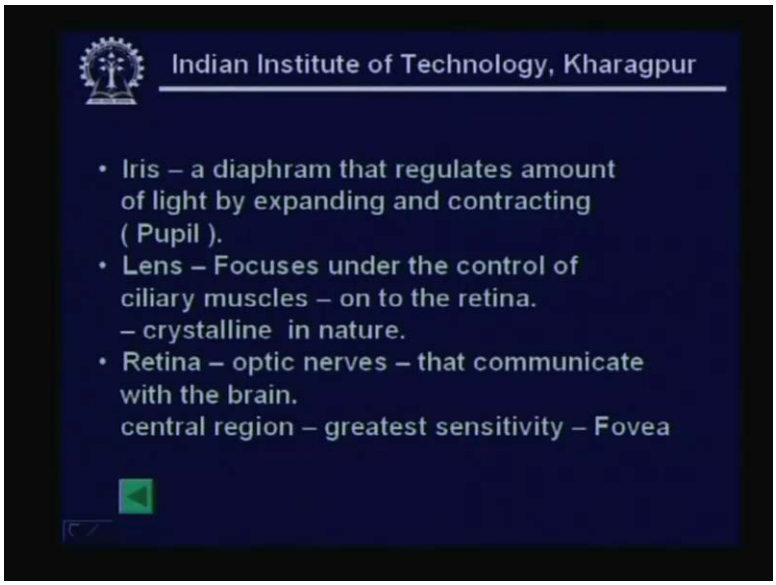

Now what is iris? Iris is a diaphragm that regulates the light entering the eye and it is obtained by expanding and contracting the pupil. We have seen the pupil supported by a set of muscles by and it is able do that, so iris is the most important end component which enables light to be brought into the human eye. Then you have lens which is crystalline in nature, this focuses on to the retina. Now this lens is distinctly different from a lens in a camera in the sense that it is somewhat flexible, it can became concave, convex, flat depending on the environmental illumination conditions and the requirement of the object to be viewed and the distance to the object of the absorber.

And therefore this lens can change its shape unlike the lens in a camera and is controlled by the group of ciliary muscles which we saw in the lens. Then this screen in this case analogues to the film in a camera is the retina which is connecting to the brain through set of optic nerves and they communicate with the brain through this set of nerves. Now in the retina there is a central region where the sensitivity to vision is a maxima and is termed fovea. In fact a little while from now, we will absorb then this is the region which is responsible for the fine details.

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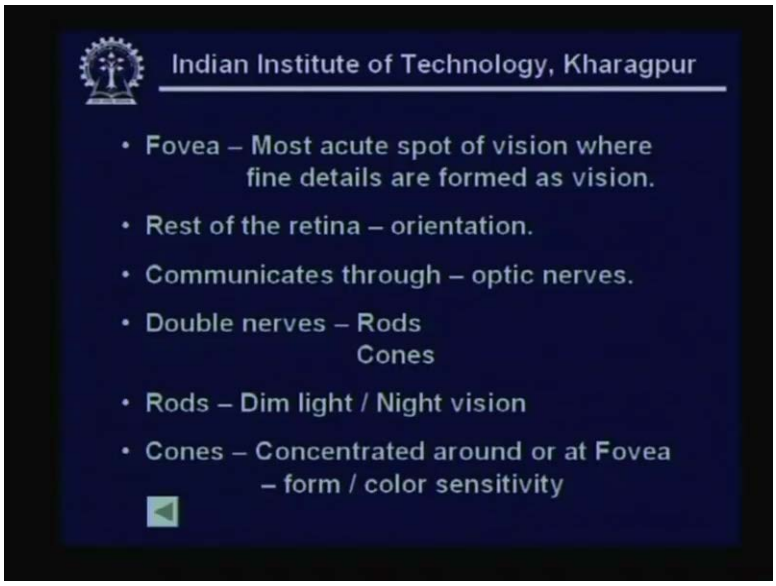

Let's look at the eye once again. Fovea is the most acute part as already told, it's fine details are formed for the observation and the rest of the retina essentially takes care of orientation and the communication with the brain. In fact I said earlier also the scene is done through the brain, though the optical light is collected through the iris lens retina system but the feeling of the image formed there is with the help of the brain and this communication is done through optic nerves. Now these nerves, there are two set of nerves. Now as we know our eye is comfortably able to take care, taking images in low light as well as high light. It is able to see things at close quarters as well as power of distance and this is possible through two set of nerves and they are called rods and cones.

Now rods are a set of nerves that enable us in seeing in dim light or night vision where as cones are concentrated in the central region which we termed as fovea. Remember that this is the spot where the eye visibility or visual sensitivity is at a maximum is therefore cones are concentrated around the fovea and when we move away from the fovea, the number of cone cells is limited and they are responsible for form oblique color sensitivity. The vision obtained with the help of the cone cells is what we call photopic vision and it is necessary for discriminating very fine details and it is very useful for critical observation and therefore what we find since that's patch of retina has got maximum sensitivity, it is very densely packed with cone cells and therefore is able to transmit sharp images.

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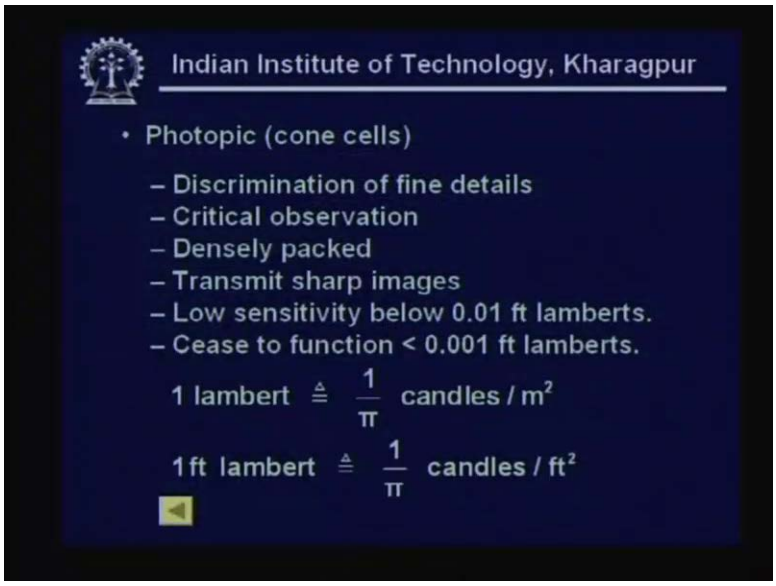

It is remembered that is like having large number of processes that are able to pick a signal and transmit. So if you have a large number, you have a higher strength that is what is happening. You are able to get more details and you are able to get the fine form with the help of this. However these cells do not respond for illumination levels which are less than 0.01 foot lamberts. We will see what is foot lambert is a little while from now. The point to be noted is that the cone cell vision does not work below 0.01 foot lamberts and completely ceases to a function anywhere below 0.001 point foot lamberts. That is although the vision would continuously go off from cone cells to rod cells at a point 0.001 foot Lambert.

What is this foot Lambert? Foot Lambert is essentially amount of light falling on a surface area defined as, you can see that the one Lambert is defined as 1 over by candles per meter square. When we talk of the standardization or quantification of illumination, we will observe that unit of illumination or light flux is talked in terms of a light output from a standard wax candle. Therefore you will find that it is talked in terms of candles and therefore one Lambert by definition is 1 over pi candles spread over a surface of 1 meter square likewise if the area of the space is talked in terms of fba system that is second system, 1 over pi candles per feet square it corresponds to one foot Lambert.

So the point what we have observed is the cone cells which are densely packed in the fovea region enable us to discriminate fine details and transmit very sharp images or do not or not very sensitive below 0.01 foot lamberts and completely cease functioning that is they do not respond at all for any illumination which is less than 0.001 foot lamberts. Here one Lambert has been defined as a light flux incident on a surface area which is 1 square meter producing 1 over pi candles. Moving further, as against the cone cell vision, we have rod cell vision. Recall we said there are two set of nerves that are communicating for the image formed on the retina to be visible to us, one is cones other are rods.

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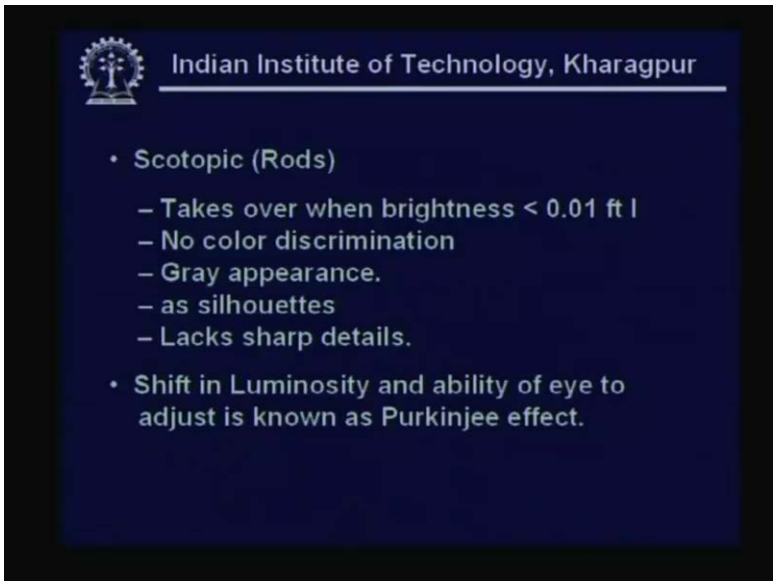

And the rod of vision is what we called scotopic vision and it is in fact takes over whenever fact takes over, whenever brightness is less than 0.01 foot lamberts we said cone cells do not or low sensitivity have low sensitivity below 0.01 foot lamberts. Therefore however since they work with very low intensity brightness or illumination, they have little color discrimination and most of the time rod vision is somewhat gray in appearance and often times we see the images as silhouettes. We do not get fine details and sharp details are absent and the ability of eye to shift from rod to cone is what we call Purkinje effect.

In fact all of us are comfortably changing from one to other without our knowledge and that is what we call Purkinje effect, in fact unlike the lens in a camera which is rigid. Now once you choose a particular camera with the particular focal distance, it's not possible for you to change the type of images that are produced. On the other hand depending on the illumination levels, depending on the object of interest, our eye is able to adjust and perceive the object of interest.

Now whenever there is increase of intensity of illumination, what happens? The pupil size decreases so that lesser, so that you get clearer images with greater and fine details and fine details with greater and fine details would mean which set of nerves are responsible. It is the cones cells in the foveal region, the fine details as already brought to you is due to scotopic vision which is essentially due to the cone cells and we get this happens often. All of us have noticed once we go into bright sun light, we tend to close our eye lids thereby decreasing pupil size or the iris size.

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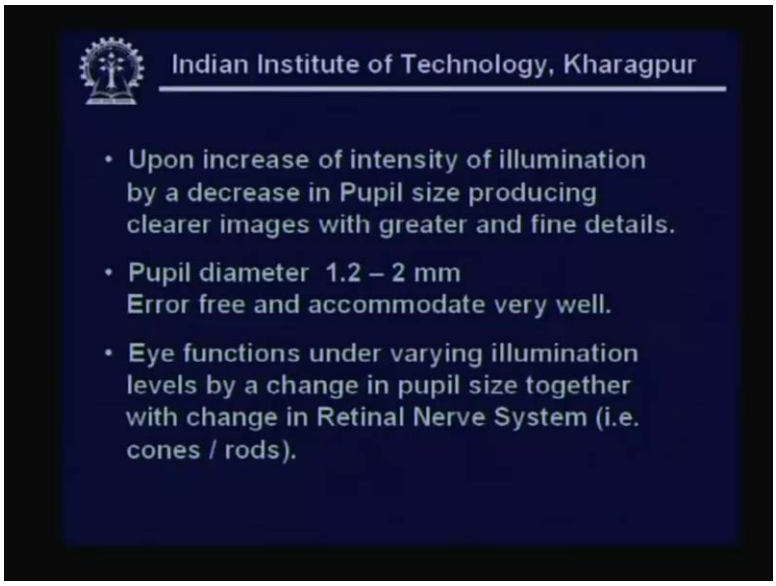

Now pupil diameter has a capacity of changing from 1.2 to 2 mile meters, a typical average human pupil and it accommodates very well. Now therefore our eye has excellent ability of functioning and varying illumination levels, it changes the pupil size and thereby together with the pupil size and shifting the set of nerves responsible for observing from cones to rods, we said cones are predominately located in the foveal region whereas rods are spread around in the retina away from the foveal region and therefore the clear distinct images are obtained only when the images are formed on the foveal region. So whenever you need to observe clearly and get fine details, one has to make the pupil small or decrease the pupil size and this is more so observed when there is a bright light.

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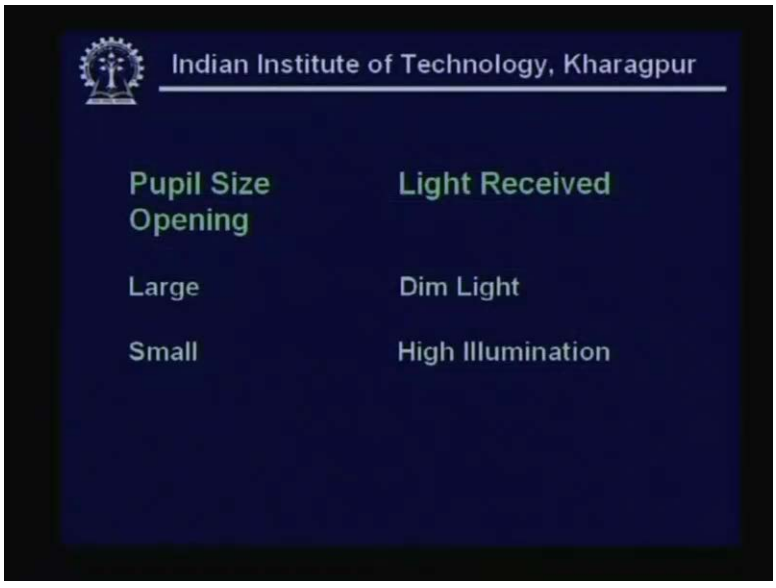

See, we can relate the pupil size and light received, as you can see this, pupil size is very large when it is dim light, in fact all of us have noticed this. When we have to walk in a dark street, we tend to open our eyes much wider so that we are able to clearly observe the person coming in the opposite direction. The other observation to be noted there is when the pupil opens so large, it is the rods which are responsible because you can see the image is formed away from the foveal region and therefore it is the rod cells that are responsible and hence the image appears more grease it's not. So color reproducibility to the brain is much lower than when cone cells are involved and you do not get the details. You see the person coming, you may not be able to know exactly what he is observing, you will see the person coming towards you on the dark road. On the other hand when there is intense illumination, you will find the pupil opening becomes very small. This also we have noticed very clearly and we are able to see very clearly what is placed in front of you.

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So these variations are unconsciously taken care by our eye without any annoyance or discomfort. All this is possible because the lens which is crystalline in nature is controlled by these muscles, ciliary muscles which can change the shape of the lens depending on the illumination level and depending on the need for your object to be viewed. And this ability of the eyes is what scientist call as adoptability or accommodation. So in fact this is what one says and it is believed that human eye is a chromatic and the dispersive power in terms of the optical distance is believed to be little greater than water that means what it means is it does not change the color of the incoming signal.

Now if you see carefully for a near vision, the eye is able to focus very easily to blue color. On the other hand for red it is going to strenuous. Now here I must say that we should recall the complete visible spectrum which spreads over from violet to red as the focal length increases, not focal length wave length increases. The for vision we are able to focus easily to red and focusing to a blue color becomes difficult. Remember the red has very high wave length compared to

blue, so these abilities bearing in mind one could once again have a look at how our eye functions.

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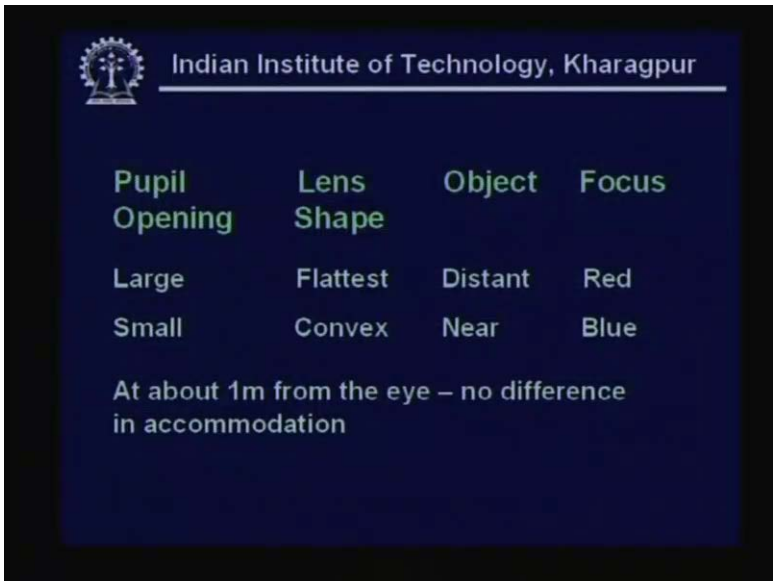

The first row it talks about how the pupil opening becomes very large and when you are looking at a distant object, it becomes easy by virtue of the distance involved because of large wave length for red color, it's easy to focus to red and in trying to do this when the pupil opening becomes very large lens becomes very flat. The shape of the lens is flattest. I told you unlike the camera lens, the human lens has ability of changing its shape, it can become concave, convex or it's the most concave or flattest when you are trying to see a distant object. We know when we open our eye wide that is when it behaves like that.

On the other hand when the opening is very small, the lens becomes highly convex and it is focused in fact you remember when you are trying to see an object under microscope, we tend to do that, you close your eye lids just as I am doing here and it becomes easy to focus to blue because blue has a shortest wave length and it is able to reach or the images are formed right on the retina. Now it's absorbed through research that there is a distance of about 1 meter from the eye when there is no difference whether the light is high or dim and you are able to focus to all colors equally, so that is the very crucial distance. What I mean is we found that per distant object, it's easy to focus in red color objects. For near objects it's easy to focus on a blue color thing but there is a mid-way where it doesn't matter on at what point along the visible spectrum the incoming light is and that is the point which is one meter away from the eyes. In fact this is the figure which shows the luminosity of eye with respect to visible spectrum.

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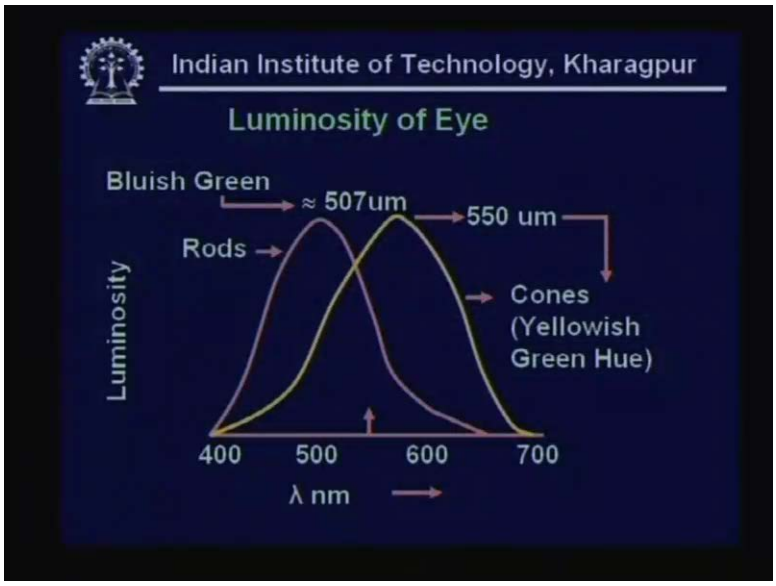

There are two curves corresponding to the rod vision and the cone vision. Recall when we saw the luminosity, luminosity is ability of our eye to perceive the light. We have said the entire light can be categorized into three zones, one the ultra violet visible spectrum and the infra-red. Similarly in the visible spectrum it expands over the wave lengths of 400 to 700 nanometers. Now the red curve here corresponds to the rod vision which has a peak sensitivity around bluish green. Recall that rod vision is effective when you are trying to see distant objects. Rod vision is when you are trying to have the distant objects or when the in dim light, when the pupil is very wide open that is when you are bluish green I mean this zone is where you have the maximum luminosity. As against this, this is around 500 second, 507 nanometers. On the other hand the cone cells have a maxima around 550 nanometers, its yellowish green hue would be the color. The curve pertaining to cone vision is orangish on this diagram. There is a small error in the diagram, it should have been 507 nanometers, it is written as micro meters should be nanometers, 550 nanometers not 550 micro meters.

So, seeing is our primary purpose of lighting. Recall right in the lecture one we have said that it is the ability to see things is the purpose of lighting and our aim has always been to see that artificial lights are as close to as the natural lights. And the good lighting therefore should be in such a way to avoid defective vision. You have seen how eye responds; eye responds in bright light by having what we call cone vision and dim light by having rod vision. Now while looking into, so that is why we are looking at how eye responds to illumination so that whatever system we develop enables us to function without producing any defects in vision. At the same time optimizing the wastage of human resources and enable good seen, in fact as I said in the very first lecture the artificial lighting has enabled us to extend our activity period which was only curtain to sun rise and sun set.

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Now visibility of an object will certainly depend on size of the object, amount of illumination required would depend on how many what details do you need. Do you want to see the periphery of an object or you want to know what exactly are the micro details and therefore visibility would depend on size details of the object and no doubt it depends on the level and quantity of illumination that is incident on the object. The same time one must remember that the background or the contrast color play equal role. We have seen that rod vision has a peak around yellow and cone vision, rod vision has a peak yellow around green and the cone vision has around yellow.

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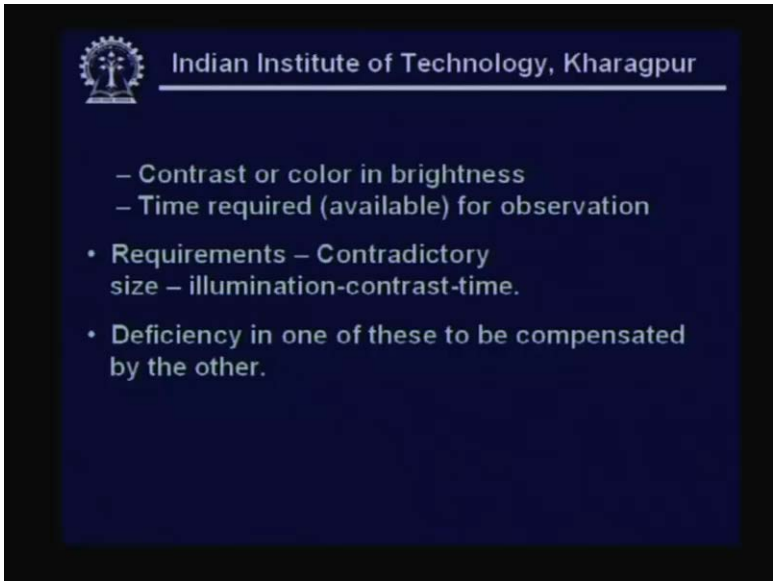

And again the way eye functions is trying to get large number of images, refresh over and over a certain time and then perceive the object and if the observation time is not adequate, it may not be possible for us to view. So, therefore it also depends on the observation time and if we look at the requirements, we find that they are highly contradictory. The three major or four major factors that are responsible are the size of the object, illumination requirement, contrast and time of observation. If you see contrast vis a vis illumination are highly contradictory, size versus time again becomes contradictory. Now one has to design the illumination system in such a way that deficiency in one is compensated by the additional input in the other, this has to be kept in mind. Now finally the visibility will certainly depend on, the visibility will certainly depend on the nature of eye defects one has and that also apart from the defects there is what is called fatigue. The fatigue can be physical, could be optical and the third factor that may be hamper your visibility is distraction.

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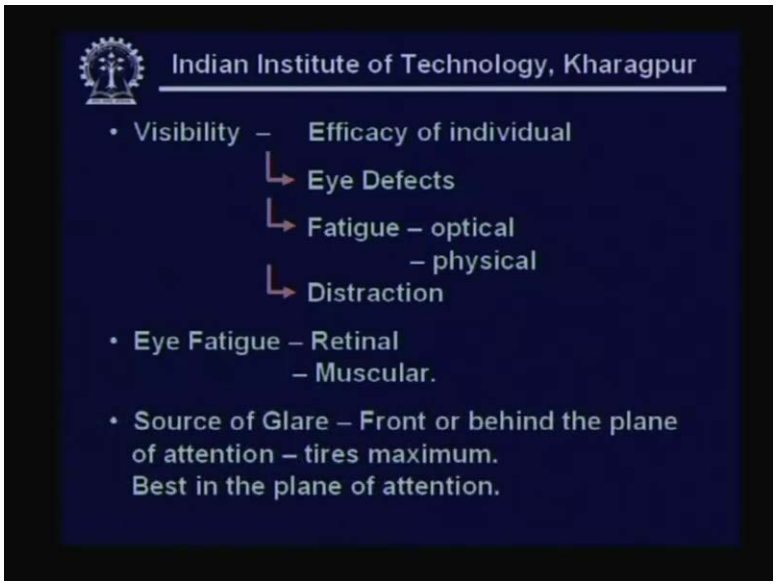

Remember that efficacy of an individual to perform depends on the visibility and the visibility itself depends on the nature of defects the eye has. One is defects that are already there, two is fatigue, the optical system does get fatigue. See as it happens every system, every man made system has fatigue involved. Then the third thing is distraction like when we are talking, I mean when we are discussing certain thing in a class and somebody talks something else that distracts the main line of thought. That's, now coming to the eye fatigue there are two major natures of fatigue, one is retinal other is muscular. See the second, then the next important point that comes is the glare. All of us have experienced glare at some point or the other, in fact class room are one place where glare has been experienced to a very large extend because of bright light falling on some portion of the board, some of the students are unable to see from certain angle. The source of the glare, if it is either behind or in front of the plain of observation, here you will see in this slide, the plane of attention is written meaning the plane in which the object to be observed is that.

Now what happens if there is a glare? Glare means it‘s an intense illumination in that plane. If it is behind or in front of the object it means we are distracted from observing the object and in that process eye tends to move. Let’s say move from the plane of glare to the plane of the object. So if it is behind or in front it tries to go back and forth and in the process it gets fatigue. See, the moment you have to move your focus from one plane to other, it calls for lot of muscular adjustments in your brain or eye, eye muscles and that task gives rise to fatigue. It’s believed if any glare that cannot be minimized is best in the plane of attention thereby you will see whenever glare is there as I told you, it will cause the focusing muscles have to go back and forth and lot of strain and fatigue is introduced.

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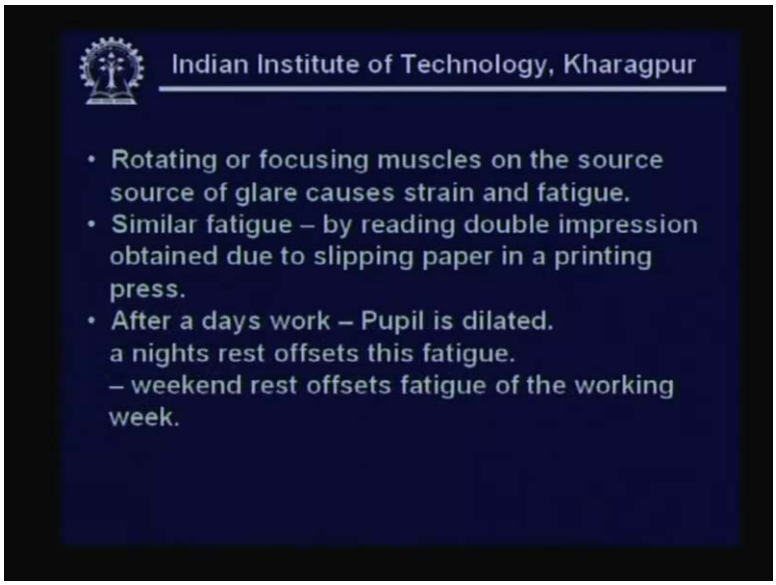

Now in fact this can be explained, I do not know how many of us have seen when the newspaper is being printed in a press and some of the film or pictures one must have noticed. There is double impression obtained when a paper is rolling out of printing press and this gives rise to a similar fatigue. In fact all of us have experienced that after a full day’s work, pupil is dilated and in nights rest in fact becomes very important to offsets this fatigue, in fact those unlike the prehistoric man who had very little to do with exacting eye tasks. Today we are involved with very large of number of eye task and remember that most of us have to do some kind of reading or writing for most of the day which means that our objects of interest are very small in size. It means we are mostly trying to do with fine detailed study and in a natural environment we have not expected to do so much. And therefore all you know it becomes necessary to have a break at the end of a day’s work to offset this fatigue, though pupil which is dilated does not come back fully. At the end of week, you need to take a longer break to overcome this fatigue got in the working week.

The pupillary changes should not become permanent, when they become permanent that is when we say that there is a shift in your focal point and that is what gives rise to optical fatigue or a permanent fatigue which calls for use of glasses. And this can be avoided if you have good conditions for seeing. Now this is apart, everything has a natural aging cycle.

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So eye defects are known to occur due to age one, two because of use. By using also it does. Abuse, trying to read fine print in dim light is one way of abusing, locating in a wrong angle. And see, the one of the major factor or major ability that gets hampered is the ability of human eye to adjust to various changes which we call accommodation ability or adaptability becomes common in the longer run if you continue without any rest of cover strained muscles. Now defective vision perceive could be because of difference in size may be in the form of different size in the location of images which often times is called refractory errors and these errors can be limited to easy task note.

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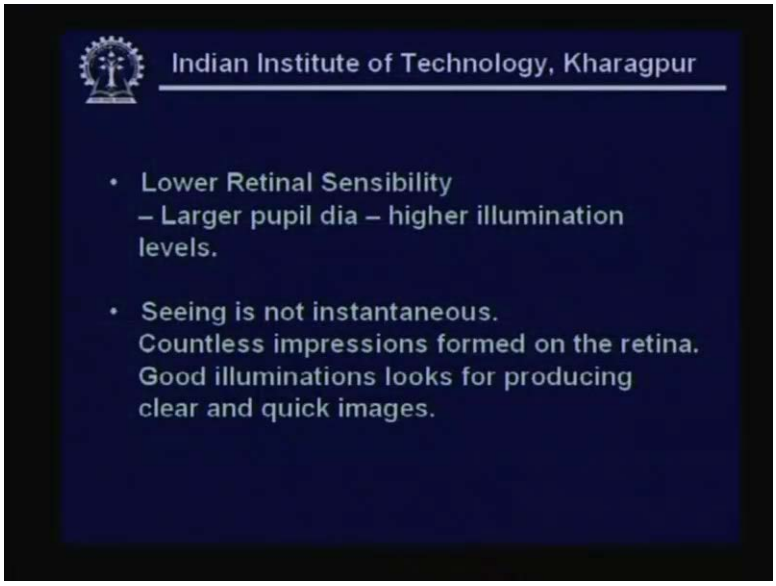

But lower retinal sensibility would mean larger pupil diameter is required and higher illumination levels. And remember behind the whole thing time of, I mentioned that the time of observation becomes important this is because seeing is not instantaneous, there are countless impressions formed on the retina okay and after countless impressions are formed, the eye is able to visualize the object, therefore good illumination looks for producing clear and quick images. Keeping in mind the ability of the eye to focus and adapt, now what we have seen is that in structure and function, eye is very much like a camera. It has that three major components iris or opening which is also known as pupil is similar to the shutter in a camera.

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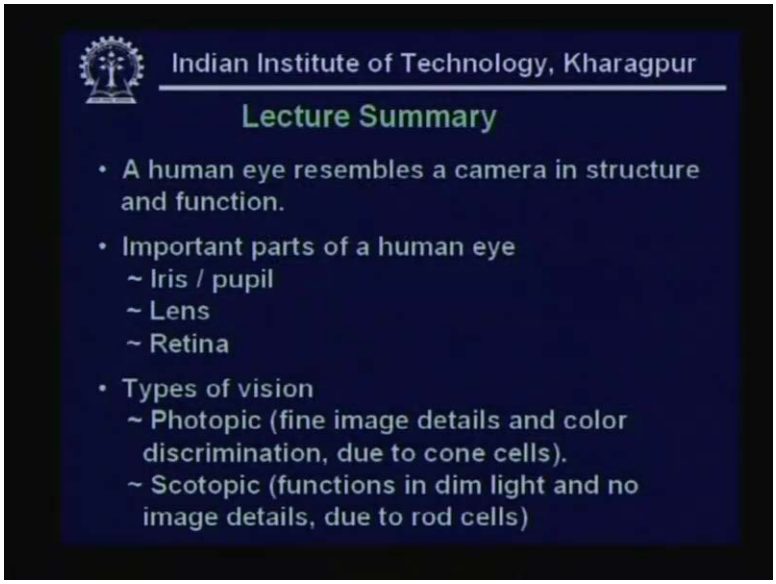

A lens which focuses the incoming light which is similar to lens in the camera, however the difference is depending on the light available, the lens has ability to change it shape. Now whenever there is high level of illumination, the lens becomes convex. When there is low levels of illumination, the pupil widens or opens very wide and the process lens becomes flat which is not the case with the camera. Then the third most important component of the eye is retina where the image is formed and this is similar to the film on which negative of the image to be taken by the camera is formed. The vision perceived is of two kinds, one is photopic which essentially gives fine image details with color discrimination ability due to what we call cone cells, two is scotopic functions in dim light and no image details and this is mainly due to rod cells.

In fact the most of the task which we are doing today involve some form of reading or writing and therefore they fall under the category of the fine image details which means we need to, I have good cone vision and recall that the most important point of the retina that is responsible for photopic vision is the central point where the sensitivity is maximum is the fovea. The cone cells are densely packed there and as you move away from the fovea, the cone cells are lesser and lesser in number and therefore in high illumination or when you need to observe fine details, the lens becomes convex and the focal point is placed right on fovea. Therefore any in coming light beam or the light race reflected from the object are terminated in a convex manner converge onto the fovea. On the other hand when the light is dim you have scotopic where the lens becomes flat

and parallel rays of light fall on the retina and hence the images are grey in nature, it do not get fine details.

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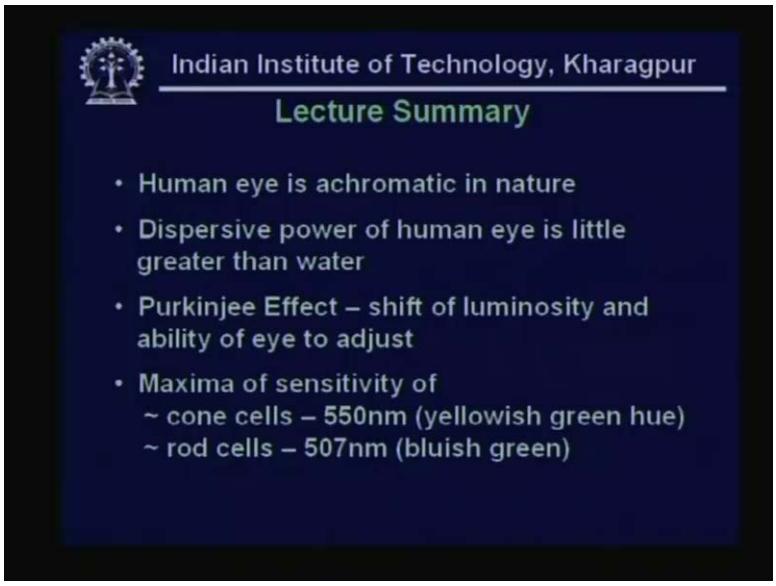

As already said the human eye is achromatic in nature and the dispersive power of the human eye is a little above the water. And the ability is a ability of shifting luminosity and to adjust to varying levels of illumination and focusing which we call accommodation and adaptation is also known as Purkinje effect. We have already seen that cone cells which are responsible for fine details and color vision which are located on fovea have a maximum sensitive at the wave length of the 550 nanometers which corresponds to yellowish green hue whereas rod cells which are responsible for the dim light or night vision are responsible for or having a peak around 507 nanometers with bluish green zone. So good lighting therefore should aim to prevent defects in vision, should optimize the resources and be able to improve conditions of visibility.

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Visibility of course as already told to you, this is from the observers point of you depends on the size and what details we are interested? Are we interested in outline of the object or what is written on that depending on that, two it depends on the level or quality of illumination. The contrast color it is very well known, if I write on a white board with may be light orange color pen then it could be hardly visible. On the other hand if I take a black board with white object, it will be much better so that is where the contrast comes. Secondly, last point that comes into mind is available time. We said the vision is by not instantaneous there are countless impressions obtained and it is the average of that which is perceived as the object image therefore time becomes very important.

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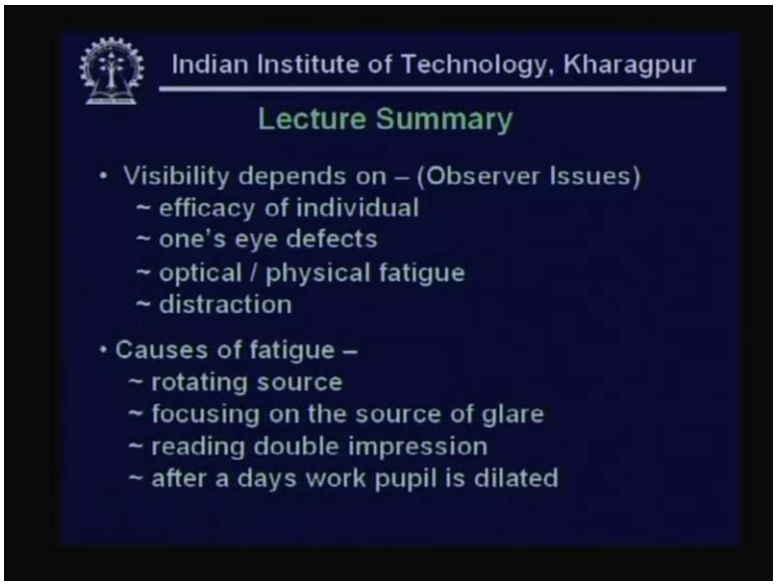

Now it also affects visibility in fact effects of efficacy of individual, I said right in the beginning that artificial illumination has enabled to extend our activities levels round the clock, round the year and good conditions can in fact improve the efficacy of or functionality. It also depends on the eye defects one has which again depends on the fatigue. Fatigue could be in the sense retinal or muscular and over a day there is a dilation in the pupil because of its fatigue set up and the fatigue would mean… What does fatigue do? Fatigue essentially effects the accommodation ability and visibility is no doubt, it depends on the distraction like any other thing I mean any activity that's going on is always disturbed by a, distraction is like noise. And some of the fatigue could be, some of causes attributable to fatigue are its source itself is moving or a rotating source and presence of glare. Often times if the glare is present ahead of the object plane of vision or behind, in trying to look at the object in the presence of the glare, the eye tends to move back and forth. And this is akin to reading a paper that's being printed in a press leading to double impression, so that has to be kept in mind. These are some of the causes of fatigue and in fact the fatigue due to a day's work is always produced by the nights rest and similarly the fatigue in a working week is taken care by the rest obtained at the end of the week.

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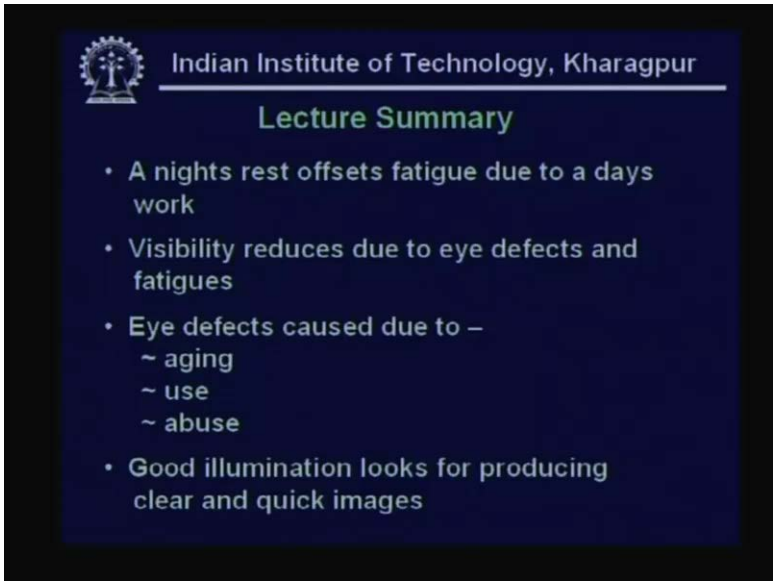

The eye defects as covered in the lecture are obtained, one due to aging which is natural. Most systems age then using, due use also there is some aging. Abuse, abuse is one technique I mean abuse is one reason for most things to get become defective. And with all this one must remember that we would like to have an illumination system for producing clear and quick images, keeping in mind how the eye functions. So we will now take up some tutorial questions. In the next lecture two will cover some quantifiable one parameter with which one could assist the vision and thereby look at the illumination system.

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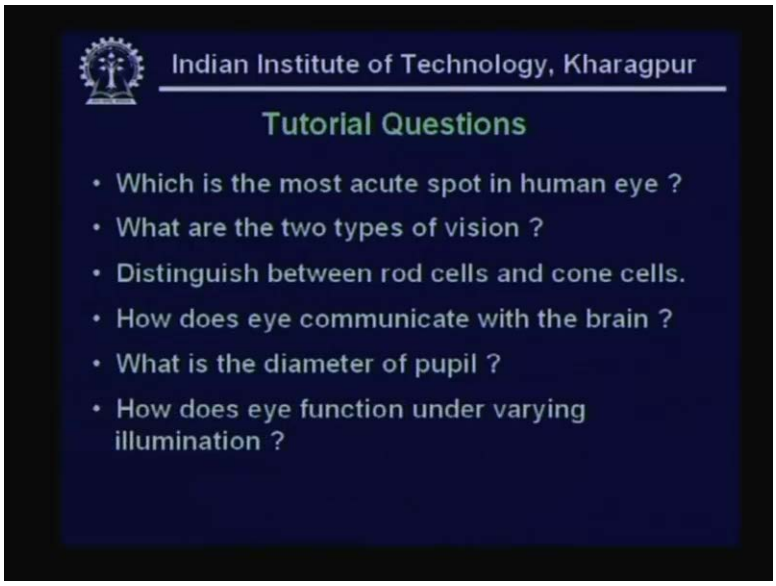

The first question is which is the most acute spot in human eye? What are the two types of vision? Three, distinguish between rod cells and cone cells. How does eye communicate with the brain? What is the diameter of pupil? How does eye function under varying illumination levels? Why is the color, red color used for a traffic signal to stop?

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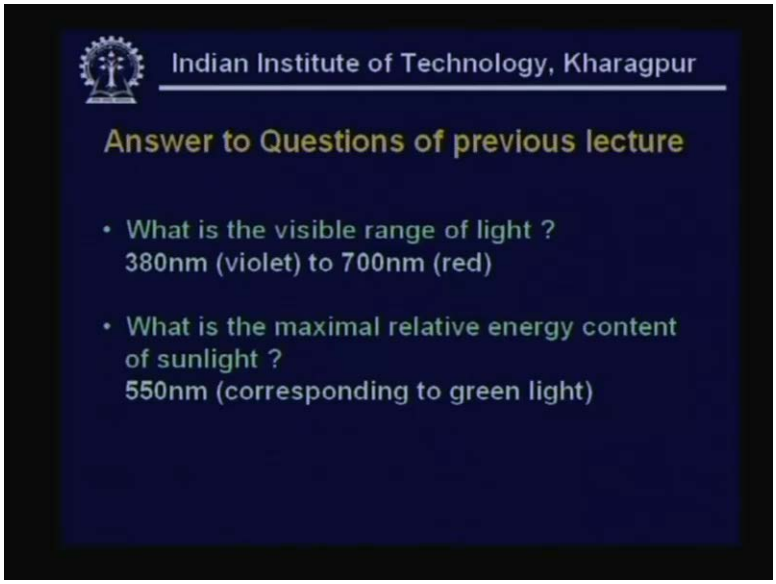

Now before we close let's look at some of the answer to questions in the previous lecture, lecture two on radiation. What is the visible range of light? Visible range of light spans over 380 nanometers corresponding to violet to 700 nanometers corresponds to red. What is the maximal relative energy content of sun light? As can be seen, as seen from the spectrum shown in the

lecture two, the maximal relative energy content corresponds to a wave length of 550 nanometers which is in the green zone.

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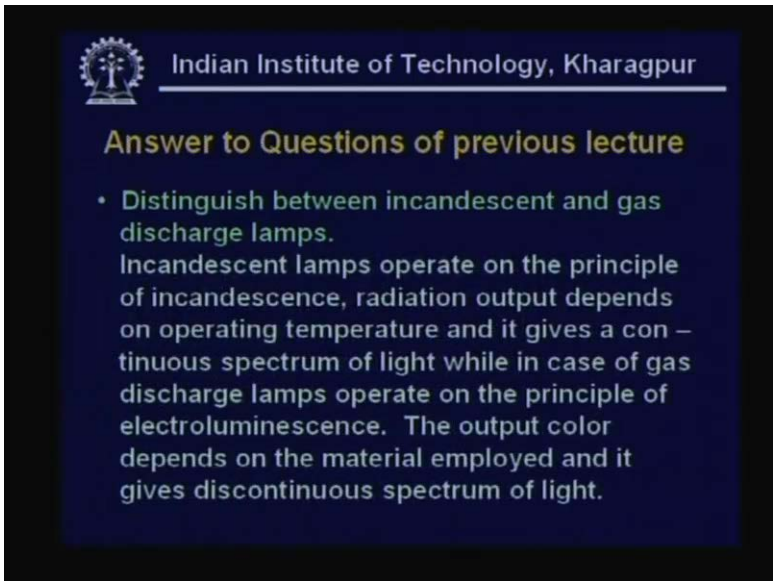

Distinguish between incandescent and gas discharge lamps? Incandescent lamps operate on the principle of incandescence. Recall the incandescence is a process, physical process where radiation output depends on the operating temperature and gives a continuous spectrum while in case of a gas discharge lamp; the principle coming in the play is electroluminescence that is a gas vapor being burnt. And the output color depends on the material employed and gives a bands spectrum or discontinuous spectrum of light.

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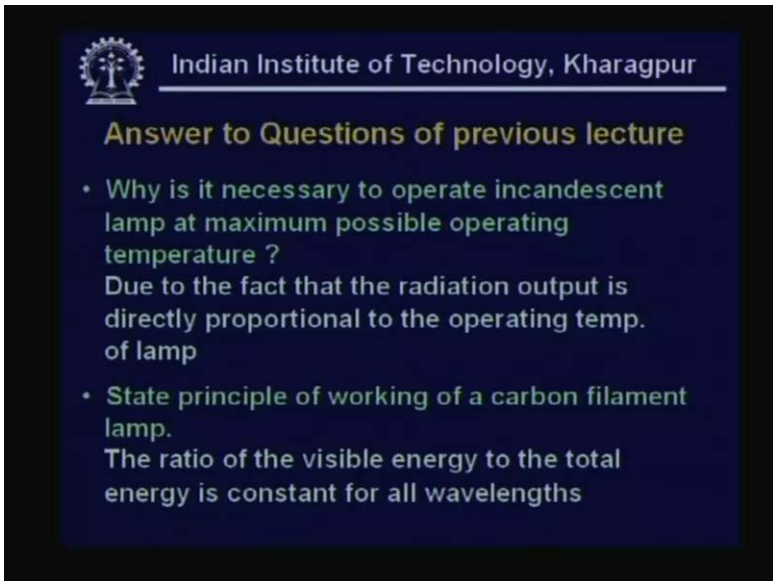

Why is it necessary to operate incandescent lamp at maximum possible operating temperature? Due to the fact that the radiation output is directly proportional to operating temperature of the lamp. This is the reason why in fact we saw this and state principle of working of a carbon filament lamp. The ratio of the visible energy to the total energy is constant for all wavelengths.

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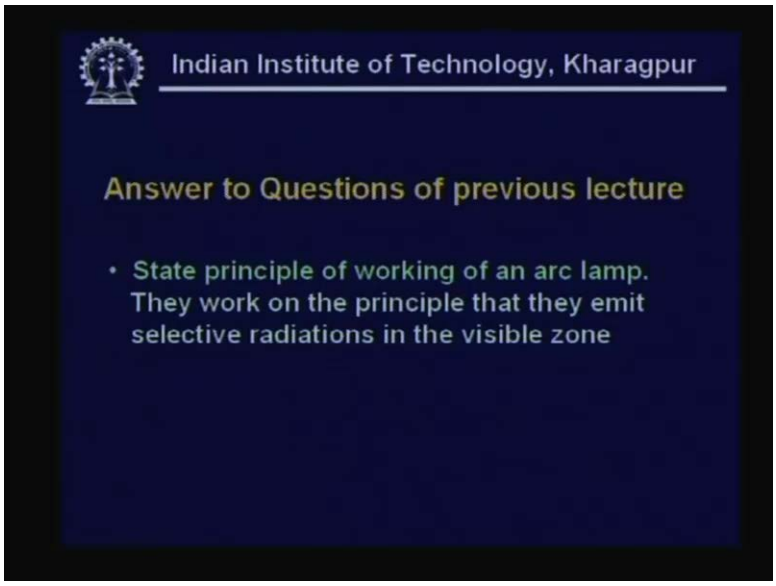

State principle of working of an arc lamp: The arc lamp works in the principle that they work, they emits selective radiations in the visible zone. Thank you.