B. ARCHITECTURE

BUILDING SERVICES – II (AR2254)

Fundamentals of lighting

Lecture - 3

Principles of Light:

Now **what is light? - Light** is the electromagnetic radiation that creates visual sensation on human eyes. That is what we see as light. Now what is electromagnetic radiation? It is a form of radiant energy. It travels in waves. It is made up of vibrating electric and magnetic fields. This waves and fields when we look into, this electromagnetic radiation is an atomic particle. So again, it is an electron. So it is accelerated by an electric field and it moves. So when it moves it produces oscillations and in oscillations, you will have electric and magnetic fields. Now both the fields are travelling at right angles to each other. So there is a bundle of light energy is produced here. So that is what we call as photons.

Now these waves, they have **certain characteristics**. When you talk about waves you have **frequency,** you have **wave length** and you have **energy.** So what is **wave length**? - It is the distance between two consecutive peaks of a wave. If you take this as a waveform, the consecutive peaks whatever you have, the distance between this is called as wavelength. So **frequency** is the number of waves it is taken for a given time. So if you take a second or if you take a minute, how many waves that you can form that is called as frequency. Whenever we talk about waves, it is measured by the number of wave cycles per second. In units, we call it as hertz. Now the shorter wavelength frequency will be having a higher wavelength because the time taken for that one cycle to pass will be very less. So the shorter wave length will have a higher frequency. Now when you take a longer wavelength, the frequency will be low because the cycle will be longer to complete for the particle to move through.

PRINCIPLES OF LIGHT:-Now these **electromagnetic radiations when you see it is on a wide spectrum**. You have various wave lengths and frequencies and that frequencies all put together we call it as electromagnetic spectrum. This spectrum is generally divided into 7 regions in the order of decreasing wave length. This is your entire electromagnetic spectrum. You have various divisions in that, basically 7 divisions. Not only that the centre one, the colourful one, we call it as

visible spectrum, that is the only spectrum that we can see. Now all together the electromagnetic spectrum you have X-rays, gamma rays, radio waves, micro waves , everything is available in that. This is the only part that we see shown in the picture the colourful one that is called as the visible spectrum. Generally the wave length is from 380mm to 700mm. only this spectrum will be sensed by the human eyes that you can see with normal human eyes.

Now when you say that you can see this then comes your **nature of vision**. How do we see light? - or How do we see objects?:-So without light we cannot have sight. Without light we cannot see any objects, it will be dark. The visual ability of humans and other animals is the result of complex interaction of light, the eyes and the brain. So how it is used? The sense of sight is based on the functioning of the eyes. So eye is the basic necessity for sight. So when you take an eye you have 3 main parts. Your iris, your lens and your retina. So these are the 3 main parts. This is your iris, your retina and your lens. Now what happens is why we are able to see light/ objects? Because light travels, it can move through space and reach our eyes. So when it comes to our eyes, first the iris will regulate the light that is coming into our eyes, the size of the wave that is coming inside. So depending on the length of the wave or the density of the wave, the lens will contract and expand to accommodate the light. This lens then whatever it takes in, it will focus it to the backside of the eye. So this eye lens again is under the control of the ciliary muscles, so this forms an image on the retina. The retina is nothing but at the back of the eye we will have a screen kind of thing. This retina has so many optical nerves. It has very light sensitive nerves that will give signals to the brain. Now when you take these nerves you again have two types of nerves, one is the rods and the cones. Rods are more sensitive in dim light. So that is always concentrated away from the central portion of the retina. This central portion of the retina we call as fovea. The cones will be like they are responsible for brighter vision and colour sensitivity. It will distinguish the colours. So this is concentrated on the central fovea. And because of these two rods and cones we have 2 different visions- **photpic vision and scotopic vision**. The **photopic** vision is you can discriminate fine details. So when you see an object the final details you are able to understand it is because of the photopic vision. And it creates sharp images.

Now **scotopic vision** you will not have any colour discrimination, so the objects will appear more or less grey.. So this cannot distinguish fine details. It will not give colour neither it will not give fine details. So when there is a change in the environment in the conditions where we are looking at an object, the eye will need a period of time to change. Change in the environment in the sense, you are in a very bright place and suddenly power goes off or it becomes dark. So what happens is the eye will adjust but from light to dark it will take more than 30 minutes to adjust, so that you can see what ever objects are available. But when it is dark to

light it will take only 30 seconds. So in case of a power cut. So when you are at home there is suddenly a power cut for you to get used to the surroundings, the change from light to dark it will take 30 minutes. But when the power comes again you can immediately see the objects, that takes only 30 seconds. So that is the adaptation our eyes have.

Coming to the **measurement of light**:- to measure light you have so many factors like intensity of light, flux, efficiency, light speed and photometry will also be measured. When you talk about all these things when you measure then there is a final output that is the units. So that you will have as two things **physical unit and subjective units**. **Physical unit** is when you measure the light **in terms of energy** because it is again in energy so we will measure in terms of energy units- it is physical units. **Subjective** means **in terms of brightness**, whether it is too bright or too dark. So when you measure in terms of brightness it is called subjective unit.

So when you take, **there are many units when** come across **the measurement of light**. So when you take luminous intensity it is measured in candela. It also has a solidification temperature of 101,325 New tons per metre square of pressure, the speed with which light falls on the surface.

There is another thing **called foot-candle**. Foot-candle is candela whatever we are measuring, it is the amount of light incident on a square foot. You take only the square foot of the area wherever the light has fallen. So that is why it is called foot candle, and the object surface also is one foot distant from the source of the light.

Then there is something called **lux. Lux** is the measurement of illuminance of an objects surface. This light intensity is measured on a surface plane in a particular position. So that is why we call it as illuminance. So 1 lux=1 lumen per metre squared. So what is a lumen? Lumen is a unit for measuring luminous flux. It is the measure of total light of an output of a bulb, whatever output comes from a bulb put together we call it a luminous bulb. Basically the light that is anytime.

End luminous is based on the spot of the light measurement and it is the measurement of light between two points when you take distance of one foot the measurement of light the difference between these two points.

Principles of Illumination:

Efficacy is the ratio of light that is produced and the energy that is consumed. Whatever light is produced whatever the energy you take and how much you produced the ratio is called efficacy. And it is also measured in the no. of lumens divided by the rate of electricity.

Now **illumination** is the distribution of light on a horizontal surface. That is what we call as illumination. So the purpose is it should give light to all the purpose, if you take a room the entire room you should be able to see.

When we talk of **level of illumination** it is the level of illumination on a surface one square metre of an area. The luminous flux we talk about the light that is coming from the source, when it falls on a surface it illuminates the surface and in that surface if you take one square metre you will get the level of illumination. The unit for this is lux = lumens per metre squared.

What is luminance and what is illuminance? - So that we will look in to detail here. This is what luminance. Light is coming on a surface it is reflected to an observer. So what we observe that is called luminance. So emitting a surface for an observer. It is abbreviated as L and its unit is candela per square metre. And illuminance is the measure of the flux on the surface. So we saw the light is falling on the surface so here how much ever light is getting on the surface is called illuminance. That is what we measure as lux.

Then **luminance or photometric brilliance** - So it is when you take a surface, the light is falling in a particular direction, it is not coming in all directions. So the relationship between luminous intensity and the surface when the observer seeing it, so that relationship is called as photometric brilliance. This unit is candela per metre square.

Now coming up to **visual task** we have all the slides and everything now how are we going to, we saw how the eyes are perceiving the light .How we are going to utilize to perform a task. So when you take a visual task the primary purpose of lighting system is to give enough illumination so that you can do some work. Task it means any work you are planning to do. And you should be able to do efficiently and accurately. So that the concept of visual task conventionally it is the total sum of all the things that had to be seen at the given moment. So when you take a visual task whatever things you need to see to complete that particular task. So that the character will be changed from moment to moment, it is not the constant one it will not remain the same. So in determining whether illumination is adequate for a task we have to consider the nature of the task. I told you it is not going to be

the same. The light required for reading and writing is different from the light required for the cooking. The task will differ and the nature of the task differs so the illumination will also differ. So you depending on the performance output that you are require from the task the lighting has to designed. So when you take visual task, the amount of illumination required will be calculated based on the size of the task and all its component parts. The time it takes to see the task or view the task and the brightness of the task itself and the contrast of the brightness and the colours with the task whatever task we have performed, whatever colours we are going to be handling in that particular task that one in relation to the surroundings. So the contrast of the brightness and colours will be there for consideration. Apart from these consideration will also have age and subnormal vision, the person who is handling that task depending on the person's age and subnormal vision and depreciation of the lighting system and the source of light which is going to provide depreciation will be there for any lighting system that has to be taken into consideration.

Then **supplementary lighting:-** This is like when there is a special need apart from the general lighting you will give an additional lighting , that is called as supplementary lighting. You will have higher foot candles on a particular task.

And then **Glare:** - Glare is generally when you have higher illumination level which is more than the required light, you'll have a glare. You have foot candle recommendation for a particular task, this task you should have only this much foot candle. So that kind of a restriction we have. That is provided because you have a glare free illumination can be produced for the task.

Again coming to **units of light**, we saw measurement of light. When you measure light, what are the units that come into the picture. When you measure what will be the final unit**. Luminous flux: -** Luminous flux in the sense I told you it is the total light emitted by a light sourced from all directions. So that is luminous flux. This is abbreviated as F and its measurement is Lumen.

Then **luminous intensity**. It is how much you measure like how much luminous flux is given from a source in a particular direction. So that is luminous intensity. It is abbreviated as L. The measurement is candela.

Then you **have solid angle**: - Solid angle is how large the object appears to an observer from a particular point. So that is what we call it is angle. An angle that is formed by the point you see here, this is the source from where it is originating. Now this is the object, from depending on the point of source the object size may differ. So this angle which creates the hook puts the object into a view that is called as solid angle. It is represented by the symbol omega Ω and the measurement is called as steradian.

There is another thing called **utilization factor**, this is generally a proportion of the luminous flux, that is the light that is emitted and when it reaches the working place, so how much you receive there. So it is basically a proportion or a ratio and it gives the effectiveness of a lighting scheme. So when you design a particular lighting scheme you will consider utilization factor as a main factor. So when you consider this utilization factor it is has various again coming into the picture- light output ratio of the luminaire, flux distribution of the luminaire, luminaire is your light fixture, then the room proportions- see the same light depending on the size of the room will have a different utilization factor. And the room reflectance the materials that is in the room that is reflecting the light. And Spacing or mounting height ratio where to fix the fixture. So all these things will have a major impact on the utilization factors.

Then comes your **depreciation factor.** I told you we have some depreciation for the light source. It is the ratio of the illuminance produced after you install at some particular time to when it is installed new. The difference of the illuminance it can give, the light it can produced, when it was new and after a period of time. So there will definitely be a difference and that difference will be the depreciation factor. So what causes this depreciation is the fall in lamp luminous flux with hours of use. So when you keep on using a particular light source, there is going to be a fall that is decrease in the flux that is the light that is emitted. And there is deposition of dirt on the luminaire, so wherever you are using the luminaire, there is going to be a layer of dust on it. And the reflectance of room surface over time. Even though the reflectance is going to be the same for the material, even the material reflectance rate will change over a period of time. So based on this, whatever light that is being emitted will have a difference over time. So that is depreciation.

There are two other things**-Mean horizontal candle power and Mean spherical candle power**. This is like the candlepowers, the luminous the light that is emitted in all directions in the horizontal plane, which has the source of light. So if the source of light is going to be fixed on the wall so the horizontal plane for the light or the source and how much it can give in all directions. That is horizontal candlepower.

When you take mean **spherical candlepower**, it is the mean or average of the thing on all panes. We are not talking about horizontal, we are talking about horizontal, vertical both any other planes that we have. All the planes put together what is the mean or average of the candlepower you will have. So that is your mean spherical candle power.

There is another unit called **brightness: -** Brightness is actually an attribute, it's for a visual perception you can see the brightness. You cannot actually take it as a physical thing. So it will be like the source being very radiated or reflecting light. It

is a very subjective quality of light. It is the perception elicited by the luminance of a visual target. So it is actually perception of your sight. So there is nothing physical there.

Then you have something called **Glare:-** Glare is the opposite of brightness if you can take it like that is simply put. So it is the difficulty in seeing an object in the presence of bright light. If you have very bright, you will not be able to, you are feeling very difficult to see an object that is what we call it as glare. It is caused by a significant ratio of luminance between the task and the glare source. So the luminance that is coming out of the task and the glare source there is a ratio difference. So that is what is glare. And it can be divided into two types, we have **discomfort glare and disability glare**. **Discomfort glare** will be you have instinctive desire to get away from it. So if you are directly looking at the sun or a bright light you have tendency to look away from it. So that we call it as discomfort glare, you feel discomfort to look at the glare. So driving westward on a sunset will be a very good example for it. **Disability Glare** is caused by the inter-reflection of light within the eye ball. So there is a disturbance within the eyeball so this will reduce the contrast between the task and the glare source. When the glare is very intense, you cannot see anything, your vision is totally impaired. So this is what we call it as dazzle. We say dazzling light. Dazzling means it is so bright that you cannot see anything. So that is what we call it as disability glare.

Illumination and lighting:

Now we are moving onto another part of **illumination and lighting**: - So now we were talking about electric source and source of light and all those things. So what is this electric light source. This is a device, an electric device. It produces the light. So the light is a visible light again. This is visible light and this light flows by means of an electric current. So many things are there. You have an electric device, it produces electric light, the light is a visible light and it is flowed by electric current. So the most common form of artificial lighting that is what we generally use in modern society. So artificial lighting is a very common form of electric light source. And this light source will have a replacement component. That is what we call it as lamp.

Now there are **various types of electric light sources**. We can classify it majorly into 3 types, one is the **incandescent,** the other is your **electrical discharge** and then you have **light emitting diodes**. Incandescent is this works like there will be

a filament inside your lamp and that will be heated up, it will glow and there will be a black body radiation from the heat of the filament. Electric discharge is a current will be passing through a gas present inside the lamp. When current is passed through this gas, the gas will split and it will glow that will give you light. Light emitting Diode is a current will be sent through a semi conductor, this will emit photons, and that photon emission is what we see as light.

Now when you take **incandescent bulbs**, what happens here is why we call it incandescent? Incandescence is the phenomena where solids and liquids when they are heated, they emit visible radiation. And the temperatures of these heating is generally above 1000k. This phenomenon is what we call it as incandescence. When this is followed in bulbs we call those bulbs as incandescent bulbs. This is the basis of light generation in a filament lamp. Like I told you the filament will be heated up. So when electric current passes through a thin tungsten wire the temperature will rise to around 2,500 to 3,200 Kelvin and depending upon the light and its application you have a light will be emitted. But incandescent bulbs the temperature limit is only 2,700 Kelvin. Above that the filament will evaporate and the temperature will become very excessive. So the large part of the radiation that is emitted in incandescent bulb, it does not give light. It gives too much heat in the source. So filament lamps are more effective to use as a heating devices and heating devices in the sense it can be used for a print drying, food preparation or any animal rearing you can use this. Food preparation in the sense you the thing that we use in the microwave oven, we use these filament lamps and that is the thing that is going to heat your food. So It is used as a heating device.

Now again when you take **incandescent bulbs you have several types**. One is a **General service**:- general service is the general light that we use for a house. This is very inexpensive. It is readily available. This will produce a warm yellow-white light and it is emitted in all directions. The source can be clear light or frosted also. This again you can have it **as general light bulb, this** we call as **globe bulb** and this we use it for **decorative t**hings. It can be in a teardrop shape or a flame, or any other shape for decorative purpose we will use that bulb.

Then you have **reflectorised bulbs**. These bulbs will have a reflective coating inside the lighting fixture. So this coating will reflect the light. When the light is emitted in all directions, whatever lights fall on the reflectors will again come back to us, so you will have more brightness coming out of the light. So the light that is produced we call it as R. This R will be double the general light whatever you get. The previous bulb we saw incandescent bulb, whatever light is coming from the general service, R will be double that times. Then you also have a PAR. PAR reflectance will be 4 times the general lighting. So these kinds of light we will use in the recessed lighting or track lighting we will use this type of reflectorised incandescent bulbs.

The next one you have is **tungsten and halogen**. This will produce an even a brighter and whiter light other than any other incandescent bulb. It has a longer life also and it provides more light per watt when you take the electrical consumption also. This one is available in 2 types one is line voltage and a low voltage. Line voltage is your 120 watt and this bulb is used in track lighting, recessed lighting and outdoor spot and flood lights you use this 120 watt. The low voltage is 12 volt which is used in outdoor landscape areas to accent any lighting fixtures or any clove lighting we will use low volt.

Then you have **electric discharge lamp**. Electric discharge lamp is a modern technique. Modern light sources are coming in this technique. It is more efficient a production of light happens here. The lamps will combine the electric discharge with photoluminescence and it will emit light. So this is how it works. So you have a bulb here inside you have a gas and then you have the electrodes coming here. The electricity passes through this an arc will be formed, it will split the gas and an arc will be formed and that will evaporate the gas which is inside and the evaporated gas will have the photoluminescence quality which will emit the light. When you take this type of electric discharge lamps we have major classification as **sodium and mercury**. You have seen sodium vapour lamps and mercury vapour lamps. The characteristics is it gives useful radiation. See you can use any gas but whatever it emits you should be able to see it otherwise it is not useful at all. So only sodium and mercury will fall under the visible spectrum radiation and when you take low pressure sodium vapour is a very commonly used lamp. It has a very high lamp efficacy when compared to any other electric discharge lamps. So here again the small current is passed through sodium gas. When it passes through you will have a faint red discharge and the sodium is evaporated and the result will be a sodium vapour. Now this thing will have a particular light, colour emitted along with it. So that will distort your perception. So that is why we use this only for street lighting.

This is another type of **discharge lamp, high pressure mercury vapour lamp**. So this will have resonant emissions of 185 nanometres to 254. These are in the UV range. So the emission is concentrated in the 5 narrow bands. So the narrow bands will be like blue, violet and green only these colours will be emitted from this. Now there are different types again in this. High pressure the gas will absorb this radiation and will be re-emitted and this spectrum is red deficient. That means that you will not have any red in the spectrum of this light. So the perception will be distorted. Then you have a fluorescent discharge. Fluorescent lamps, the discharge is like in the ultra violet spectrum. So the inside of the lamp will be coated with phosphorous. So that will absorb the wave length and light will be emitted. You have a wide range of colours and wide varieties when it comes to Fluorescent lamps.

Then you have **light emitting diodes**. This is the LED light that is very famous now-a-days, the very current one. You have semi-conductors will be there, that will produce electrons which will give you light. Now this LED will be like a small chemical chip, which you see in this picture, this is the LED light, the semi conductor will emit light. Light emitting diodes need not be only one single thing, together it can form a strip lighting also. Something like in your tube light.