G.PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY: KURNOOL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CLASS/SEM: IV.B.Tech I-SEM **SUB: UTILISATION OF ELECTRICAL ENERGY**

UNIT-I

Light	It is defined as the radiant energy from a hot body that produces the visual sensation upon the human eye. It is expressed in lumen-hours and it analogous to watthours, which denoted by the symbol '*Q*'.
Color	The energy radiation of the heated body is monochromatic, i.e. the radiation of only one wavelength emits specific color. The wavelength of visible light lies between 4,000 and 7,500 Å.
Luminous flux	It is defined as the energy in the form of light waves radiated per second from a luminous body. It is represented by the symbol 'φ' and measured in lumens
Plane Angle	A plane angle is the angle subtended at a point in a plane by two converging lines .It is denoted by the Greek letter 'ϑ' (theta) and is usually measured in degrees or radians $\therefore \text{Plane angle}(\theta) = \frac{\text{arc}}{\text{radius}}.$
Solid angle	Solid angle is the angle subtended at a point in space by an area, i.e., the angle enclosed in the volume formed by numerous lines lying on the surface and meeting at the point.It is usually denoted by symbol 'ω' and is measured in steradian. $\therefore \text{Solid angle}(\omega) = \frac{\text{area}}{(\text{radius})^2}.$
Luminous intensity	Luminous intensity in a given direction is defined as the luminous flux emitted by the source per unit solid angle. It is denoted by the symbol '*I*' and is usually measured in 'candela'. Let '*F*' be the luminous flux crossing a spherical segment of solid angle 'ω'. Then luminous intensity lumen/steradian or candela $\text{Luminous intensity } (I) = \frac{\phi}{\omega}$ lumen/steradian or candela.
Lumen	It is the unit of luminous flux. It is defined as the luminous flux emitted by a source of one candle power per unit solid angle in all directions. Lumen = CP × ω Total flux emitted by a source of one candle power is 4π lumens
Candle power (CP)	The CP of a source is defined as the total luminous flux lines emitted by that source in a unit solid angle.
Illumination	Illumination is defined as the luminous flux received by the surface per unit area.It is usually denoted by the symbol '*E*' and is measured in lux or lumen/m2 or meter candle or foot candle. $\text{Illumination, } E = \frac{\text{luminous flux}}{\text{area}}$ $= \frac{\phi}{A} = \frac{CP \times \omega}{A}$ lux.
Lux or meter candle	It is defined as the illumination of the inside of a sphere of radius 1 m and a source of 1 CP is fitted at the center of sphere.

Brightness	Brightness of any surface is defined as the luminous intensity pen unit surface area of the projected surface in the given direction.
Mean horizontal candle power	MHCP is defined as the mean of the candle power of source in all directions in horizontal plane.
Mean spherical candle power	MSCP is defined as the mean of the candle power of source in all directions in all planes.
Mean hemispherical candle power	MHSCP is defined as the mean of the candle power of source in all directions above or below the horizontal plane.
Reduction factor	Reduction factor of the source of light is defined as the ratio of its mean spherical candle power to its mean horizontal candle power.
Lamp efficiency	It is defined as the ratio of the total luminous flux emitting from the source to its electrical power input in watts. $\therefore$ Lamp efficiency $= \frac{\text{luminous flux}}{\text{power input}}$. It is expressed in lumen/W.
Specific consumption	It is defined as the ratio of electric power input to its average candle power.
Space to height ratio	It is defined as ratio of horizontal distance between adjacent lamps to the height of their mountings.
utilization factor	It is defined as the ratio of total number of lumens reaching the working plane to the total number of lumens emitting from source.
Maintenance factor	It is defined as the ratio of illumination under normal working conditions to the illumination when everything is clean.
Depreciation factor	It is defined as the ratio of initial illumination to the ultimate maintained illumination on the working plane.Its values is always more than 1.
Waste light factor	When a surface is illuminated by several numbers of the sources of light, there is certain amount of wastage due to overlapping of light waves; the wastage of light is taken into account depending upon the type of area to be illuminated.
Absorption factor	Normally, when the atmosphere is full of smoke and fumes, there is a possibility of absorption of light. Hence, the total lumens available after absorption to the total lumens emitted by the lamp are known as absorption factor
Reflection factor	When light rays impinge on a surface, it is reflected from the surface at an angle of incidence .

CONCEPTS

LAWS OF ILLUMINATION

Mainly there are two laws of illumination.

1. Inverse square law.

2. Lambert's cosine law.

Inverse square law

This law states that 'the illumination of a surface is inversely proportional to the square of distance between the surface and a point source'.

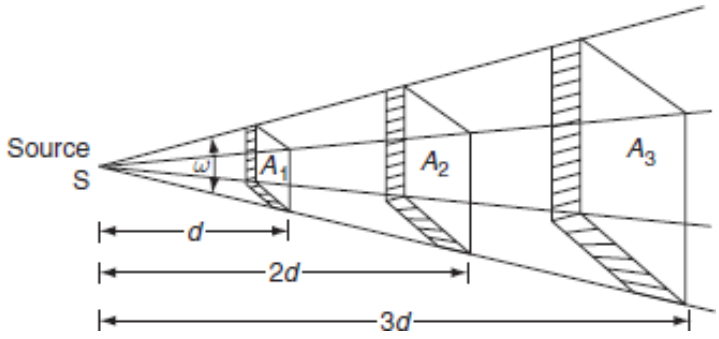
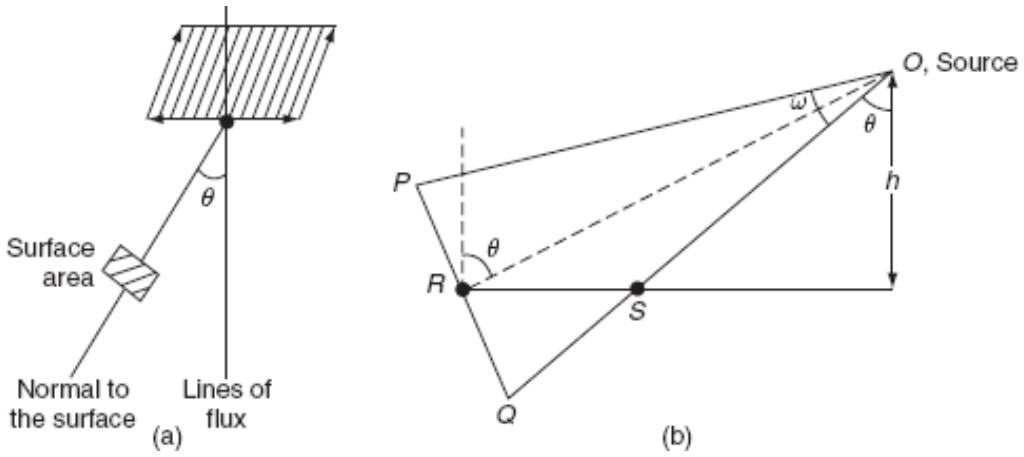


Fig.1.1 Inverse square law

Lambert's cosine law

This law states that 'illumination, *E* at any point on a surface is directly proportional to the cosine of the angle between the normal at that point and the line of flux'.



$$E_{RS} = \frac{I}{d^2}\cos\theta = \frac{I}{h^2}\cos^3\theta$$

Fig.1.2 Lamberts Cosine Law

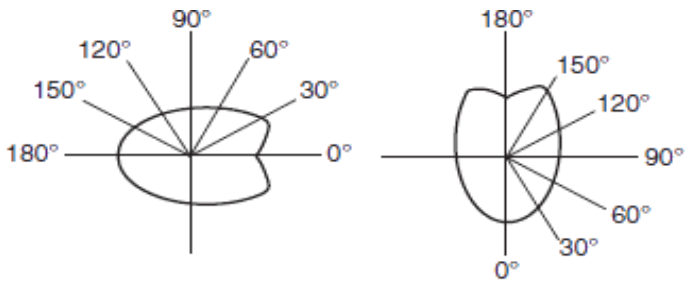
where *d* is the distance between the source and the surface in m, *h* is the height of source from the surface in m, and *I* is the luminous intensity in candela.

POLAR CURVES

The luminous flux emitted by a source can be determined using the intensity distribution curve. The luminous intensity or the distribution of the light can be represented with the help of the polar curves. The polar curves are drawn by taking luminous intensities in various directions at an equal angular displacement in the sphere. A radial ordinate pointing in any particular direction on a polar curve represents the luminous intensity of the source when it is viewed from that direction. Accordingly, there are two different types of polar curves and they are:

1. A curve is plotted between the candle power and the angular position, if the luminousintensity, i.e., candle power is measured in the horizontal plane about the vertical axis, called 'horizontal polar curve'.

2. A curve is plotted between the candle power, if it is measured in the vertical plane and the angular position is known as 'vertical polar curve'.Figure shows the typical polar curves for an ordinary lamp.



(a) Horizontal polar curves (b) Vertical polar curves

Fig.1.3 Polar Curves

TYPES OF SOURCES OF ILLUMINATION

Usually in a broad sense, based upon the way of producing the light by electricity, the sources of light are classified into following four types.

Electric arc lamps

The ionization of air present between the two electrodes produces an arc and provides intense light.

Incandescent lamps

When the filaments of these lamps are heated to high temperature, they emit light that falls in the visible region of wavelength. Tungsten-filament lamps are operating on this principle.

Gaseous discharge lamps

When an electric current is made to pass through a gas or metal vapor, it produces visible radiation by discharge takes place in the gas vapor. Sodium and mercury vapor lamps operate on this principle.

Fluorescent lamps

Certain materials like phosphor powders exposed to ultraviolet rays emits the absorbed energy

into visible radiations fall in the visible range of wavelength.

INCANDESCENT LAMP

These lamps are temperature-dependent sources. When electric current is made to flow through a fine metallic wire, which is known as filament, its temperature increases. At low temperatures, it emits only heat energy, but at very high temperature, the metallic wire emits both heat and light energy. These incandescent lamps are also known as temperature radiators.

Choice of material for filament

The materials commonly used as filament for incandescent lamps are carbon, tantalum, tungsten and osmium. The materials used for the filament of the incandescent lamp have the following properties.

o The melting point of the filament material should be high.

o The temperature coefficient of the material should be low.

o It should be high resistive material.

o The material should possess good mechanical strength to withstand vibrations.

o The material should be ductile.

CONSTRUCTION :

Figure shows the construction of the pure tungsten filament incandescent lamp. It consists of an evacuated glass bulb and an aluminum or brass cap is provided with two pins to insert the bulb into the socket. The inner side of the bulb consists of a tungsten filament and the support wires are made of molybdenum to hold the filament in proper position. A glass button is provided in which the support wires are inserted

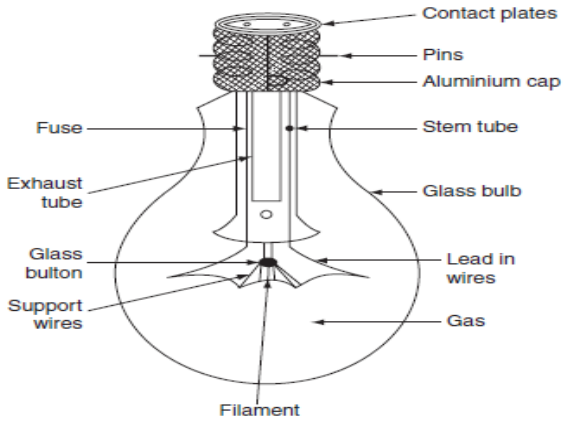


Fig.1.4 Incandescent lamp

OPERATION

When electric current is made to flow through the fine metallic tungsten filament, its temperature increases. At very high temperature, the filament emits both heat and light radiations, which fall in the visible region. The maximum temperature at which the filament can be worked without oxidization is 2,000°C, i.e., beyond this temperature, the tungsten filament blackens the inside of the bulb. The tungsten filament lamps can be operated efficiently beyond 2,000°C, it can be attained by inserting a small quantity of inert gas nitrogen with small quantity of organThe variations in normal supply voltages will affect the operating characteristics of incandescent lamps.

SODIUM VAPOUR LAMP

A sodium vapor lamp is a cold cathode and low-pressure lamp. A sodium vapor discharge lamp consists of a *U*-shaped tube enclosed in a double-walled vacuum flask, to keep the temperature of the tube within the working region. The inner *U*-tube consists of two oxide-coated electrodes,which are sealed with the ends. These electrodes are connected to a pin type base construction of sodium vapour lamp is shown in Fig.

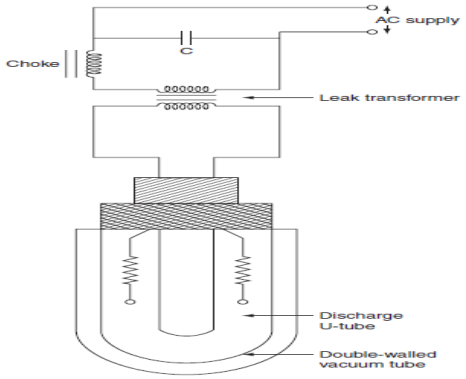


Fig. 1.5 Sodium vapor lamp

This sodium vapor lamp is low luminosity lamp, so that the length of the lamp should be more. In order to get the desired length, it is made in the form of a *U*-shaped tube. This long*U*tube consists of a small amount of neon gas and metallic sodium. At the time of start, the neon gas vaporizes and develops sufficient heat to vaporize metallic sodium in the *U*-shaped tube.

WORKING

Initially, the sodium is in the form of a solid, deposited on the walls of inner tube. When sufficient voltage is impressed across the electrodes, the discharge starts in the inert gas, i.e., neon; it operates as a low-pressure neon lamp with pink color. The temperature of the lamp increases gradually and the

metallic sodium vaporizes and then ionizes thereby producing the monochromatic yellow light. This lamp takes 10–15 min to give its full light output. The yellowish output of the lamp makes the object appears gray.

FLUORESCENT LAMP (LOW-PRESSURE MERCURY VAPOR LAMP)

Fluorescent lamp is a hot cathode low-pressure mercury vapor lamp; the construction and working of the fluorescent lamp are explained as follows.

CONSTRUCTION

It consists of a long horizontal tube, due to low pressure maintained inside of the bulb; it is made in the form of a long tube.The tube consists of two spiral tungsten electrode coated with electron emissive material and are placed at the two edges of long tube. The tube contains small quantity of argon gas and certain amount of mercury, at a pressure of 2.5 mm of mercury. The construction of fluorescent lamp is shown in Fig. Normally, low-pressure mercury vapor lamps suffer from low efficiency and they produce an objectionable colored light. Such drawback is overcome by coating the inside of the tube with fluorescent powders. They are in the form of solids, which are usually knows as phosphors.

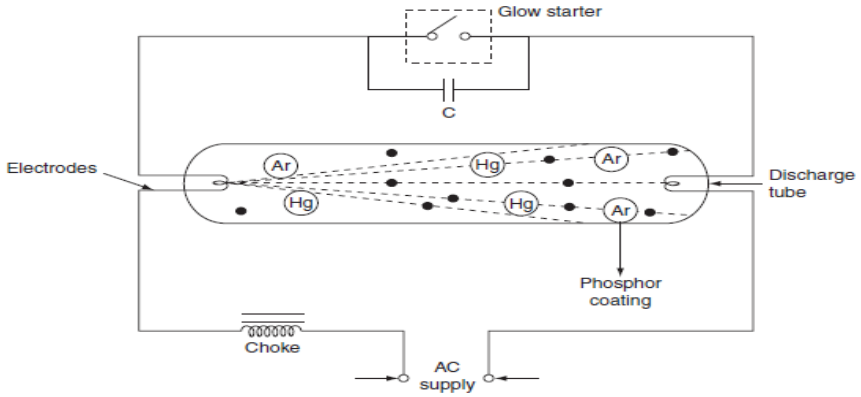


Fig.1.6 Flouroscent Lamp

WORKING

At the time of starting, when both the lamp and the glow starters are cold, the mercury is in theform of globules. When supply is switched on, the glow starter terminals are open circuited and full supply voltage appeared across these terminals, due to low resistance of electrodes and choke coil. The small quantity of argon gas gets ionized, which establishes an arc with a starting glow. This glow warms up the bimetallic strip thus glow starts gets short circuited. Hence, the two electrodes come in series and are connected across the supply voltage. Now, the two electrodes get heated and start emitting

electrons due to the flow of current through them. These electrons collide with the argon atoms present in the long tube discharge that takes place through the argon gas

Stroboscopic effect

For 50-Hz frequency supply of the alternating current, a discharge lamp will be extinguished twice in a cycle and 100 times per second (for 50-Hz supply). A human eye cannot identify this extinguish phenomenon, because of the persistence of vision. If this light falls upon a moving object, the object appearing like slow moving or fast moving or moving in reverse direction, sometimes stationary. This effect is due to the extinguishing nature of the light of the lamp. This effect is called as '*stroboscopic effect*'.

TYPES OF LIGHTING SCHEMES

Usually, with the reflector and some special diffusing screens, it is possible to control the distribution of light emitted from lamps up to some extent. A good lighting scheme results in an attractive and commanding presence of objects and enhances the architectural style of the interior of a building. Depending upon the requirements and the way of light reaching the surface, lighting schemes are classified as follows:

1. Direct Lighting,

2. Semindirect Lighting,

3. Indirect Lighting,

4. Semi-Indirect Lighting, And

5. General Lighting.

1.Direct lighting schemes

Direct lighting scheme is most widely used for interior lighting scheme. In this scheme, by using deep reflectors, it is possible to make 90% of light falls just below the lamp. This scheme is more efficient but it suffers from hard shadows and glare. Hence, while designing such schemes, all the possibilities that will cause glare on the eye have to be eliminated. It is mainly used for industrial and general outdoor lighting

2.Semidirect lighting schemes

In semidirect lighting scheme, about 60–90% of lamps luminous flux is made to fall downward directly by using some reflectors and the rest of the light is used to illuminate the walls and ceiling. This type of light scheme is employed in rooms with high ceiling. Glare can be avoided by employing diffusing globes. This scheme will improve not only the brightness but also the efficiency.

3.Indirect lighting schemes

In this lighting scheme, 90% of total light is thrown upwards to the ceiling. In such scheme, the ceiling acts as the lighting source and glare is reduced to minimum. This system provides shadowless illumination, which is very useful for drawing offices and in workshops where large machines and other difficulties would cause trouble some shadows if direct lighting schemes were used.

4.Semi-indirect lighting schemes

In semi-indirect lighting scheme, about 60–90% of light from the lamp is thrown upwards to the ceiling and the remaining luminous flux reaches the working surface. Glare will be completely eliminated with such type of lighting scheme. This scheme is widely preferred for indoor lighting decoration purpose.

5.General lighting scheme

This scheme of lighting use diffusing glasses to produce the equal illumination in all directions. Mounting height of the source should be much above eye level to avoid glare.

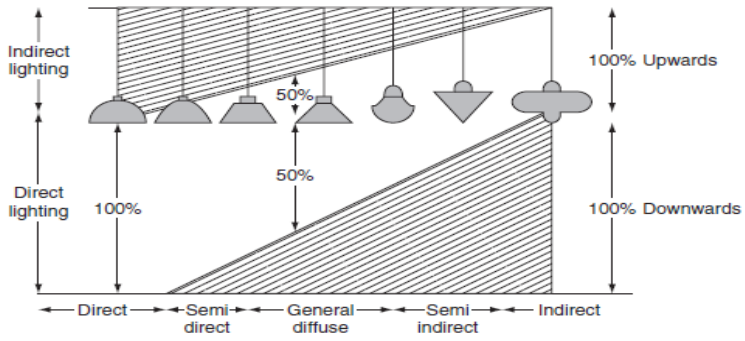


Fig.1.7.Types of Lighting Schemes

DESIGN OF LIGHTING SCHEMES

The lighting scheme should be such that:

o It should be able to provide sufficient illumination.

o It should be able to provide the uniform distribution of light throughout the working plane.

o It should be able to produce the light of suitable color.

o It should be able to avoid glare and hard shadows as much as possible.

While designing a lighting scheme, the following factors should be taken into consideration.

1. Illumination level.

2. The size of the room.

3. The mounting height and the space of fitting.

METHODS OF LIGHTING CALCULATIONS

There are so many methods have been employed for lighting calculation, some of those methods are as follows.

1. Watts-per-square-meter method.

2. Lumen or light flux method

3. Point-to-point method

STREET LIGHTING

Street lighting not only requires for shopping centers, promenades,etc. but also necessary for the following.

o In order to make the street more attractive, so that obstructions on the road clearly visible to the drivers of vehicles.

o To clear the traffic easily in order to promote safety and convenience.

The basic principles employed for the street lighting are given below.

1. Diffusion principle.

2. The specular reflection principle.

Diffusion Principle

In this method, light is directed downwards from the lamp by the suitably designed reflectors. The design of these reflectors are in such a way that they may reflect total light over the road surface uniformly as much as possible. The reflectors are made to have a cutoff between 30° and 45°, so that the filament of the lamp is not visible expect just below the source, which results in eliminating glare.

Illumination at any point on the road surface is calculated by applying inverse square low or point-by-point method.

Specular Reflection Principle

The specular reflection principle enables a motorist to see an object about 30 m ahead. In this case, the reflectors are curved upwards, so that the light is thrown on the road at a very large angle of incidence. This can be explained with the help of Fig. An object resides over the road at 'P' in between the lamps *S*1, *S*2, and *S*3 and the observer at '*Q*'.

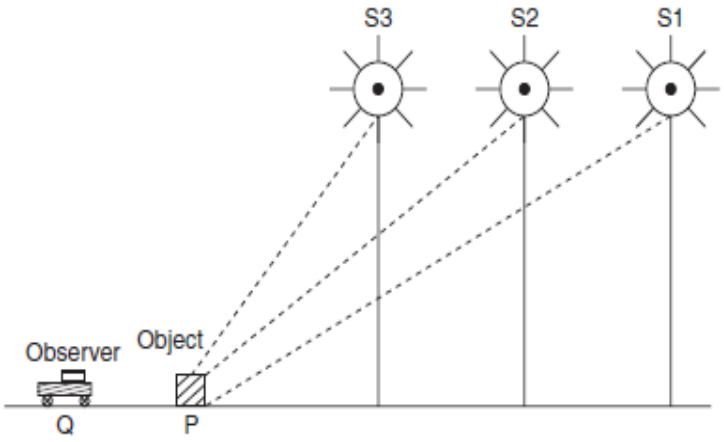


Fig.1.8 Specular reflection for street lighting

Thus, the object will appear immediately against the bright road surface due to the lamps at a longer distance. This method of lighting is only suitable for straight sections along the road. In this method, it is observed that the objects on the roadway can be seen by a smaller expenditure of power than by the diffusion method of lighting.

Area Illumination (lumen/m2)

1. Road junctions and important shopping centers. 30

2. Poorly lighted sub-urban streets. 4

3. Average well-lighted street. 8–15

FLOOD LIGHTING

Floodlighting means flooding of large surface areas with light from powerful projectors. A special reflector and housing is employed in floodlighting in order to concentrate the light emitted from the lamp into a relatively narrow beam, which is known as floodlight projector.This projector consists of a reflecting surface that may be a silvered glass or chromium plate or stainless steel. The efficiency of

silvered glass and polished metal are 85–90% and 70%, respectively. Usually metal reflectors are robust; therefore, they can be preferred. An important application of illumination engineering is the floodlighting of large and open areas. It is necessary to employ floodlighting to serve one or more of the following purposes.

Important Questions:

1. Explain with a neat diagram the principle and construction of operation of a sodium vapour lamp.

2. Explain with a neat sketch the principle of operation of fluroscent lamps.

3. Explain briefly the principles involued in the design of Street and Factory Lighting installations.

4. Explain with a neat sketch the principle of operation of fluroscent lamps.

5. Explain the following (i)Laws of Illumination (ii) Illumination at a point.

6. Explain types of Lighting schemes and requirements of good lighting scheme

7. Explain with a neat sketch the principle of operation of fluroscent lamps

8. Explain Polar Curves