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# *UNIT-4*

# *ILLUMINATION FUNDAMENTALS*

## Introduction:

Light is the prime factor in the human life as well as activities of human beings ultimately depend upon the light. Where there is no natural light, use of artificial light is made. Artificial lighting produced electrically, on account of its cleanness, ease of control, reliability, steady out put, as well as its low it is playing an increasingly important part in modern every day life. The science of illumination engineering is, therefore, becoming of major importance.

### Nature of light:

Light is a form of radiant energy. Various forms of incandescent bodied are the sources of light and the light emitted by such bodies depend upon the temperature of bodies. Heat energy is radiated into the medium by a body which is hotter than the medium surrounding it. The heat of the body, as seen, can be classified as red hot or white-hot. While the body is red-hot the wave length of radiated energy will be sufficiently large and the energy available is in the form of heat. When the temperature increases the body changes from red-hot to white-hot state, the wave length of the energy radiated becomes smaller and smaller and enter into the range of the wave length of the light.

**Colour:** The sensation of colour is due to the difference in the wave lengths of the light radiations. Visible light can have wave lengths of the light between 4,000A and 7,500A and the colour varies in the way as shown in the figure.

### Relative sensitivity:

The sensitivity of the eye to the lights of different wave lengths varies from person to person and according to the age. The average relative sensitivity is shown in the fallowing figure. The high have greatest sensitivity for wave lengths of about 5,500A: that is yellow-green can be seen under such poor conditions of illumination when blue or red can not be see under dim illumination, the sensitive curve shifts as shown by the shaded region in the fallowing figure. Therefore, violate disappears first and red remains visible. Yellow disappears last as the illumination becomes very dim. As each colour disappears, it becomes a grey shade and finally black. The sensitivity of eye to yellow-green radiation is taken as unity or 100% and the sensitivity to other wave lengths is expressed as a fraction or percentage of it. The relative sensitivity at a wave length $\lambda$ is written k $\lambda$ and is known as ***relative luminosity factor.***



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## Illumination:

Illumination differs from light every much, though generally these terms are used more or less synonymously. Strictly speaking light is the cause and illumination is the result of that light on surfaces on which it falls. Thus the illumination makes the surface look more or less bright with certain colour and it is this brightness and colour which the eye sees and interrupts as something useful or pleasant or other wise.

Light may be produced by passing electric current through filaments as in the incandescent lamps, through arcs between carbon or metal rods, or through suitable gases as in neon and other gas tubes. In some forms of lamps the light is due to fluorescence excited by radiation arising from the passage electric current through mercury vapour.

Some bodies reflect light in some measure, and when illuminated from an original source they become secondary source of light. The good example is the moon, which illuminates earth by means of the reflected light originating in the sun.

## Terms used in illumination:

The modern lighting schemes and the selection of fittings and type of lamps require knowledge of the terms and quantities in general use for such purposes. Therefore, the fallowing definitions are given in simple form to facilitate easy identification and reference.

**Light:** It is defined as the radiation energy from a hot body which produces the visual sensation upon the human eye. It is usually denoted by Q, expressed in lumen-hours and is analogous to watt-hour.

**Luminous flux:** it is defined as the total quantity of light energy emitted per second form a luminous body. It is represented by symbol F and is measured in lumens. The concept of luminous flux helps us to specify the output and efficiency of a given light source.

**Luminous intensity:** luminous intensity in any given direction is the luminous flux emitted by the source per unit solid angle, measured in the direction in which the intensity is required. It is denoted by symbol I and is measured in candela(cd) or lumens/steradian.

If **F** is the luminous flux radiated out by source within a solid angle of $\omega$ steradian in any particular direction then $I = \frac{F}{\omega}$ lumens/steradian or candela (cd).

**Lumen:** the lumen is the unit of luminous flux and is defined as the amount of luminous flux given out in a space represented by one unit of solid angle by a source having an intensity of one candle power in all directions.

Lumens = candle power $\times$ solid angle = cp $\times$ $\omega$

Total lumens given out by source of one candela are $4\pi$ lumens.

**Candle power:** Candle power is the light radiating capacity of a source in a given direction and is defined as the number of lumens given out by the source in a unit solid angle in a given direction. It is denoted by a symbol **C.P.**


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$$\text{C.P.} = \frac{lumens}{\omega}$$

**Illumination:** When the light falls upon any surface, the phenomenon is called the illumination. It is defined as the number of lumens, falling on the surface, per unit area. It is denoted by symbol E and is measured in lumens per square meter or meter-candle or lux.

If a flux of **F** lumens fails on a surface of area **A**, then the illumination of that surface is $E = \frac{F}{A}$ lumens/$m^2$ or lux

**Lux or meter candle:** It is the unit of illumination and is defined as the luminous flux falling per square meter on the surface which is every where perpendicular to the rays of light from a source of one candle power and one meter away from it.

**Foot candle:** It is also the unit of illumination and is defined as the luminous flux falling per square foot on the surface which is every where perpendicular to the rays of light from a source of one candle power and one foot away from it.

1 foot-candle = 1 lumen/$ft^2$ =10.76 meter candle or lux

**Candle:** It is the unit of luminous intensity. It is defined as $\frac{1}{60}$ th of the luminous intensity per $cm^2$ of a black body radiator at the temperature of solidification of platinum ($2{,}043^0$K).

**Mean horizontal candle power: (M.H.C.P)** It is defined as the mean of candle powers in all directions in the horizontal plane containing the source of light.

**Mean spherical candle power: ( M.S.C.P)** It is defined as the mean of the candle powers in all directions and in all planes from the source of light.

**Mean hemi-spherical candle power: (M.H.S.C.P)** It is defined as the mean of candle powers in all directions above or below the horizontal plane passing through the source of light.

**Reduction factor:** Reduction factor of a source of light is the ratio of its mean spherical candle power to its mean horizontal candle power.

i.e reduction factor = $\frac{M.S.C.P}{M.H.C.P}$

**Lamp efficiency:** It is defined as the ratio of the luminous flux to the power input. It is expressed in lumens per watt.

**Specific consumption:** It is defined as the ratio of the power input to the average candle power. It is expressed in watt per candela.

**Brightness or luminance:** When the eye receives a great deal of light from an object we say it is bright, and brightness is an important quantity in illumination. It is all the same whether the light is produced by the object or reflected from it.

Brightness is defined as the luminous intensity per unit projected area of either a surface source of light or a reflecting surface and is denoted by L.



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If a surface area A has an effective luminous intensity of I candelas in a direction θ to the normal, than the brightness ( luminance) of that surface is

$$L = \frac{1}{A\cos\theta} \text{ candela/m}^2 \text{ or nits}$$

Nit is defined as the candela per square meter. Bigger unit of brightness ( luminance) is Stilb which is defined as candelas per square cm. lambert is also the unit of brightness which is lumens/cm$^2$. Foot lambert is lumens/ ft$^2$.

**Glare**:- The size of the opening of the pupil in the human eye is controlled by its iris. If the eye is exposed to a very bright source of light the iris automatically contacts in oreder to produce the amount of light admitted and prevent damaged to retina this reduces the sensitivity, so that other objects within the field of vision can be only inperfectly seen. In other words glare maybe defined as brighteness with in the field of vision of such a character as the cause annoyance discomfort interference with vision.

**Space height ratio**:- it is defined as the ratio of distance between adjacent lamps and height of their mountains.

Space height ratio=$\frac{\textit{horizontal distance between two adjacent lamps}}{\textit{mounting height of lamps above working plane}}$

**Utilization factor or co-efficient of utilization**:- It is defined as the ratio of total lumens reaching the working plane to total lumens given out by the lamp.

Utilization factor or co-efficient of utilization=$\frac{\textit{total lumens reaching the working plane}}{\textit{total lumens given out by the lamp}}$

**Maintenance factor:** Due to accumulation of dust, dirt and smoke on the lamps, they emit less light than that they emit when they are new ones and similarly the walls and ceilings e.t.c. after being covered with dust, dirt and smoke do not reflect the same output of light, which is reflected when they are new.

The retio of illumination under normal working conditions to the illumination when the things are perfectly clean is known as maintenance factor.

Maintenance factor = $\frac{\textit{illumination under normal working conditions}}{\textit{illumination when every thing is clean}}$

**Depreciation factor:** this is merely reverse of the maintenance factor and is defined as the ratio of the initial metre-candles to the ultimate maintained metre-candles on the working plane. Its value is more than unity.

**Waste light factor:** Whenever a surface is illuminated by a number of sources of light, there is always a certain amount of waste of light on account of over-lapping and falling of light outside at the edges of the surface. The effect is taken into account by multiplying the theoretical value of lumens required by 1.2 for rectangular areas and 1.5 for irregular areas and objects such as statues, monuments etc.

**Absorption factor:** In the places where atmosphere is full of smoke fumes, such as in foundries, there is a possibility of absorption of light. The ratio of total lumens available after absorption to the total lumens emitted by the source of light is called the absorption factor. Its value varies from unity for clean atmosphere to 0.5 for foundries.


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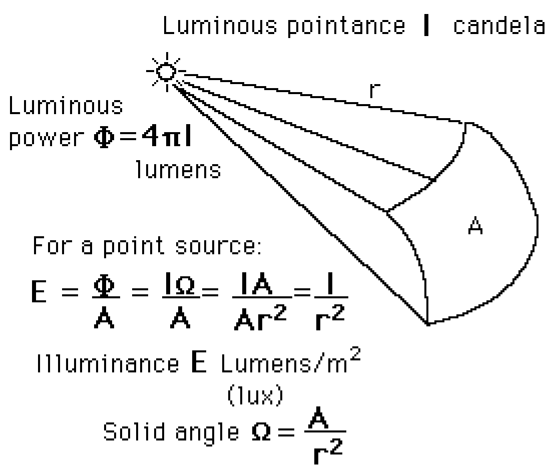
**Beam factor:** the ratio of lumens in the beam of a projector to the lumens given out by lamps is called the beam factor. This factor takes into the account the absorption of light by reflector and front glass of the projector lamp. Its value varies from 0.3 to 0.6.

**Reflection factor:** When a ray of light impinges on a surface it is reflected from the surface at an angle of incidence, as shown in the fallowing figure. A certain portion of incident light is absorbed by the surface. The ratio of reflected light to the incident light is called the **reflection factor.** It's value always less than unity.

**Solid angle:** Plane angle is subtended at a point in a plane by two converging straight lines and its magnitude is given by




$$\theta = \frac{arc}{radious}\ radians$$

The largest angle subtended at a point is 2Π radians.

Solid angle is the angle generated by the surface passing through the point in space and the periphery of the area. Solid angle is denoted by ω, expressed in steradians and is given by the ratio of the area of the surface to the square of the distance between the area and the point.

$$\text{i.e } \omega = \frac{\text{Area}}{(\text{Radious})^2} = \frac{A}{r^2}$$

The largest solid angle subtended at a point is that due to a sphere at its centre. If **r** is the radius of any sphere, its surface area is $4\pi r^2$ and the distance of its surface area from the centre is r, therefore, solid angle subtended at its centre by its surface, $\omega = \frac{4\pi r2}{r^2} = 4\pi$ steradians

**Steradian:** It is the unit of solid angle and is defined as the solid angle that subtends a surface on the sphere equivalent to the square of the radius.

**Laws of illumination**:- There are two laws of illumination

1. Law of inverse squares



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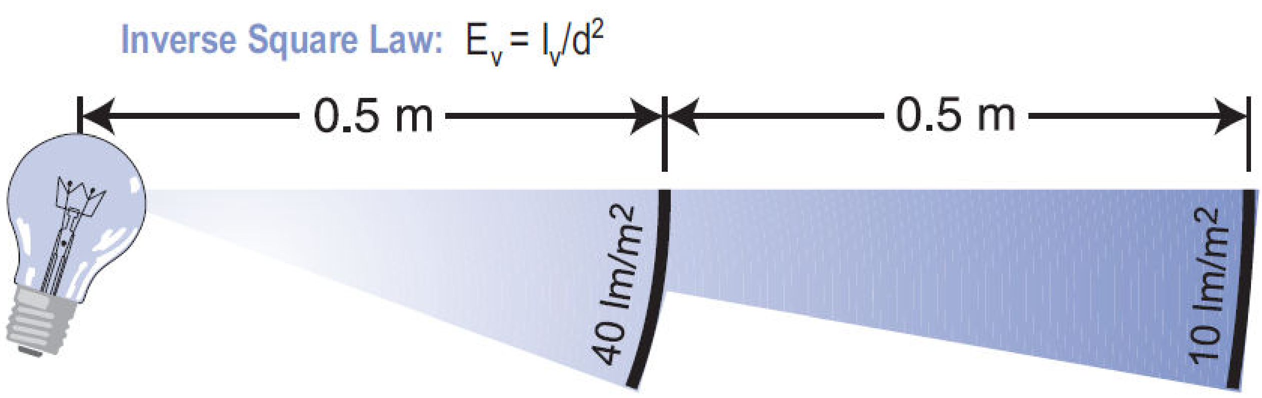
2. lamberts cosine law

**1. Law of inverse squares**:- If a source of light which emits light equally in all directions be placed at the center of the hallow sphere, the light will fall uniformly on the inner surface of the sphere that is to say, each square mm of the surface will receive the same amount of light. If the sphere be replaced by one of the larger radius, the same total amount of light is spread over a larger area proportional to the square of the radius. The amount which falls upon any square mm of such a surface will therefore diminishes as the radius increases, and will be inversely proportional to the square of the distance

A similar relation holds if we have to deal with a beam of light in the form of a cone or pyramid as shown in the fig. if we consider parallel surfaces which cut the pyramid at different distances from the source, the areas of these surfaces are proportional to the square of these distances, and therefore the amount of light which falls on the one unit of the area of these surfaces is inversely proportional to the square of the distances from the source. This relation is referred to as the law of inverse squares. Mathematically it can be proved as follows:




➢ **Polar curves** :-

All over discussions so far were based on the assumption that luminous intensity or the candle power from a source is uniformly distributed over the surrounding surface. But none of the practical type of lamp gives light uniformly distributed in all directions because of its unsymmetrical shapes. It is often necessary to know the distribution of light in various directions to as certain how the candle power of light source varies in different directions. The luminous intensity in all directions can be represented by polar curves. If the luminous intensity is a horizontal plane passing through the lamp is plotted against angular position, a curve known as horizontal polar curve is obtained. If the luminous intensity in a vertical plane is plotted against the angular position, a curve known as vertical polar curve is obtained. The typical polar curves for an ordinary filament lamp are shown in the following fig:



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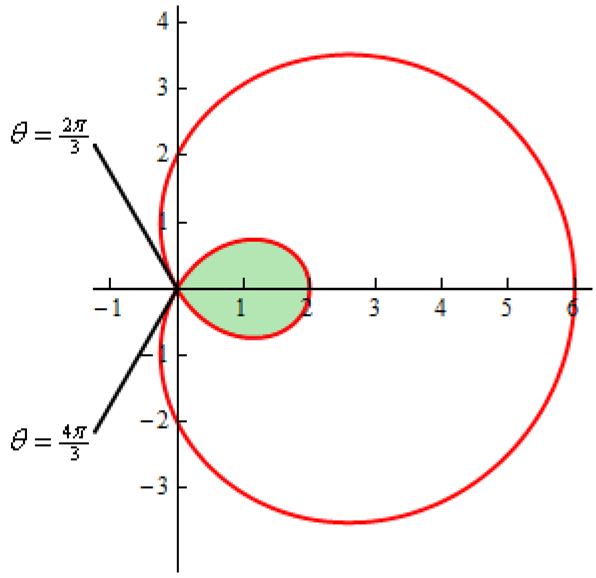


The polar curves are used to determine the mean horizontal candle power ( m.h.c.p.) and mean spherical candle power (m.s.c.p.). these are also used to determine the actual illumination of a surface by employing the candle power in that particular direction as read from the vertical polar curve in the illumination calculations.

The mean horizontal candle power of a lamp can be determined from the horizontal polar curve taking the mean value of the candle power in a horizontal direction.

Mean spherical candle power can be determined from the vertical polar curve by Rousseau's construction.

**Rousseau's construction:** The construction is illustrated in the fallowing figure. A semi circle of any convenient radius is drawn with the pole of the polar diagram as centre. The line CD is drawn equal and parallel to the vertical diameter $YY^1$. Now from this line CD ordinate equal to corresponding radius on the polar curve are set up such as BD = OK, GH= Of and so on. The curve obtained by joining the ends of these ordinates is known as Rousseau's curve. The mean ordinate of this curve gives the m.s.c.p. of the lamp having polar curve given as in the fallowing figure.

$$\text{The mean ordinate of the curve} = \frac{\text{Area CSTGDBHLC}}{\text{Length of CD}}$$

The area under the curve can eighter be determined on the graph paper or found by Simpson's rule.



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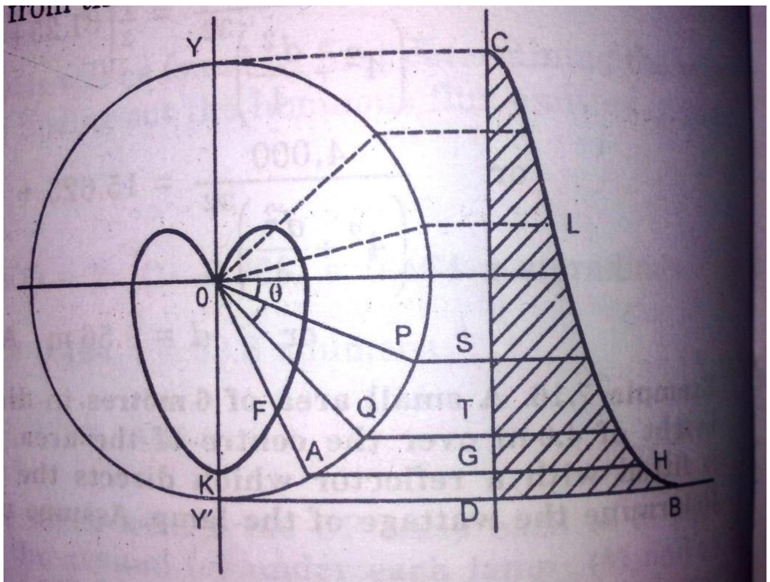
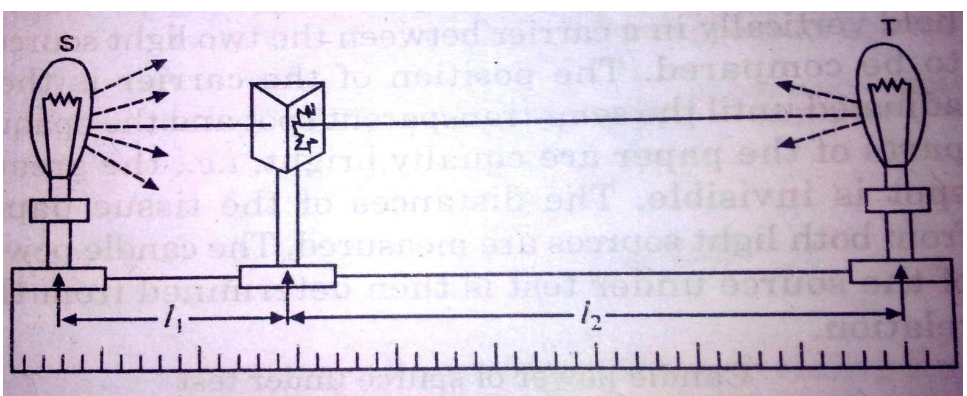


Rousseau's Construction

**Photometry**: -

The candle power of a source in any given direction is measured by comparison with a standard or substandard source employing photometer bench and some form of photometer. The experiment is performed in dark room with dead black walls and ceiling in order to eliminate the errors due to reflected light.



Measurement of Candle Power

The photometer bench consists essentially of two steel rods which carry the stands or saddles for holding the two sources, the carriage for the photometer head and for any other operators employed in making measurements. One of the bar carries a bar strip, graduated in centimeters and milli-meters the carriages which slides upon the bench have expect that carrying the photometer head, a circular table which can be rotated in a horizontal plane and clamped in any position. The circular table is provided with a scale graduated in degrees round its edge so that the angle of rotation of lamp from the direction of the axis of bench can be measured. The bench should be rigid so that the source is being compared may be free from vibrations and carriage holding the photometer head should be capable of moving smoothly and with every little effort. The photometer head acts as a screen for comparison of illumination of the standard source and the source under test. There are different types of photometers, which can be used for the purpose. Some of them are described here.

The principle of the most methods of measurement is based upon the inverse square law.



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The standard source, whose candle power is known (say S) and the source under test whose candle power is to be determined, are set on the bench at a distance apart with some type of screen in line with, and between, them as shown in the above figure. The photometer head or screen id moved in between the two fixed sources until the illumination on the both sides of the screen is same. If the distance of the standard source S and source under test T from photometer head are $l_1$ and $l_2$ respectively then according to inverse square law.

$$\frac{\text{Candle power of source under test}}{\text{Candle power of standard source}} = \frac{l_2^2}{l_1^2}$$

$$\text{Candle power of source under test} = S \times \frac{l_2^2}{l_1^2}$$

- **Integrating sphere**:-

It is a source of apparatus which is now commonly employed for measurements of mean spherical candle power. In this method the sphere is used to measure the total flux radiated by the lamp, which when divided by 4π gives as m.s.c.p. Since in this method the flux radiated in all directions is taken into account, so this method is better than that described in which it was assumed that the candle power distribution is same in all vertical planes, an assumption which may not always be justifiable.

The integrating sphere consists of a hallow sphere whose diameter is large compared to the lamp to be tested having a smooth inner surface with a uniform coating of white paint. If the lamp is hung inside the sphere, the light is so diffused an uniform illumination is produced over the whole surface. A small window of translucent glass provided at one side of the sphere is illuminated by reflecting light from the inner surface of the sphere. The small screen is inserted in between the lamp and window in order to prevent the light from the lamp reaching the window directly.

- **Source of light**:- According to the principle of operation of light source maybe grouped as follows:

1. **Arc lamps**: - Electric discharge through air gives intense light. This principle is utilized in arc lamps.

2. **High temperature**: - Oil and gas lamps and incandescent filament type lamps, which emit light when heated to high temperature.

3. **Gaseous discharge lamps**: - Under certain conditions it is possible to pass electric current through a gas or metal vapour, which is accompanied by visible radiation. Sodium and mercury vapour lamps operate on this principle.

4. **Fluorescent type lamps**:- Certain materials, when exposed to ultra violet rays, the absorbed energy into the radiation of longer wave length lying within the visible range. This principle is employed in fluorescent lamps.



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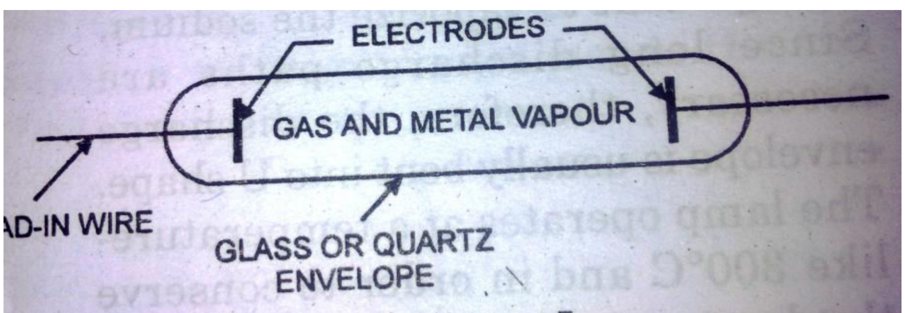
## UNIT-5

## VARIOUS ILLUMINATION METHODS

### GASEOUS DISCHARGE LAMPS:

Incandescent lamp suffers from two disadvantages –low efficiency and coloured light. The gaseous discharge lamps have been developed to overcome these draw-backs.

The basic principle of a gas discharge lamp is illustrated in the following fig. Gases are normally poor conductors , specially at atmospheric and higher pressure ,but application of suitable voltage , called the ignition voltage , across the two electrodes can result in a discharge through gas, which is accompanied by electro –magnetic radiation . The wave length of this radiation depends upon gas, its pressure and the metal power used in lamp. Argon gas and sodium and mercury vapours are commonly employed in the manufacture of gaseous discharge lamps.




*Gaseous Discharge Lamp*

Once the ionization has commenced in the gas, it has the tendency to increase continuously accompanied by a fall in the circuit resistance i.e. gaseous discharge lamp possesses a negative resistance characteristics. In order to limit the current to a safe value use of a choke or ballast is made. The choke performs the dual functions of providing the ignition voltage initially and limiting the current subsequentially. Since due to use of choke the power factor becomes poor (0.3-0.4) , therefore in order to improve the power factor of the gaseous discharge lamp use of a condenser is made. The light spectrum obtained is, however discontinuous (i.e. it consists of one or more coloured lines). The colour of the light obtained depends upon the nature of the gas or vapour used

Discharge lamps are of two types:

i. Those which give the light of the same colour as produced by the discharge through the gas or vapour such as sodium vapour , mercury vapour and neon gas lamps.
ii. Those which are the phenomenon of fluorescence and are known as fluorescent lamps. In these lamps the discharge through the vapour produces ultra violet waves which cause fluorescence in certain materials called as phosphor . The inside of the fluorescent lamps is coated with a phosphor which absorbs invisible ultra- violet rays and visible rays . example is fluorescent mercury vapour –tube.



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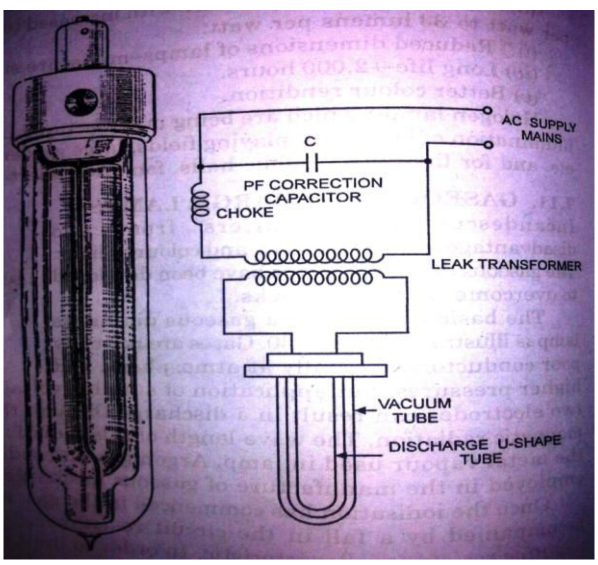
The gaseous discharge lamps are in general , considered superior to metal filament lamps. However, they suffer from the following draw backs.

a. High initial cost and poor power factor.
b. Starting is somewhat complicated requiring starters in some cases and transformer in others.
c. These take time to attain full brilliancy.
d. Ballasts are necessary for stabilizing the current since such lamps have negative resistance characteristic.
e. Light output fluctuates at twice the supply frequency. The flicker causes stroboscopic effect.
f. These lamps can be used only in particular position.

1) **Sodium vapour lamp (SV LAMPS) :** scientists have long been familiar with the fact that high luminous efficiencies could be obtained by the use of sodium vapour as a source of light . The development of a practical lamp of this type, however, was delayed since ordinary glass cannot withstand the chemical action of hot sodium. with the development of special resistant glass, the sodium vapour lamp has now reached the practical stage.




Principally the sodium vapour consists of a bulb containing a small amount of metallic sodium, neon gas, and two sets of electrodes connected to a pin type base. The presence of neon gas serves to start the discharge and to develop enough heat to vapourize the sodium. Since long discharge paths are necessary, therefore the discharge envelope is usually bent into ‘U’ shape. The lamp operates at a temperature like $300^0$ in order to conserve the heat generated and assure the lamp operating at normal air temperature the discharge envelope is enclosed in a special vaccum envelope designed for this purpose. The lamp must be operated horizontally, or nearly so, to keep the sodium well spread out along the tube, although some special lamps may be operated vertically, lamp cap up. Care should be taken in handling these lamps, particularly when replacing inner U-tube , for if it is broken and sodium comes in contact with moisture fire will result.

The sodium lamp is only suitable for alternating current, and therefore requires choke control. This requirement is met by operating the lamp for a stray field step-up –tapped transformer with an open circuit secondary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voltage of 470 to 480 volts. The uncorrected power factor is very low, about 0.3 , and a capacitor must be used to improve the power factor .

When the lamp is not in operation , the sodium is usually in the form of solid deposited on the side walls of the tube, therefore at first when it is connected across the supply mains the discharge takes place in the neon gas and gives red-orange glow. The metallic sodium gradually vapourizes and then ionizes, thereby producing the characteristic mono-chromatic yellow light, which makes object appear as grey. The lamp will come up to its rated light output is approximately 15 minutes. It will restart immediately should the power supply be momentarily interrupted since the presence of vapour is quite low and the voltage sufficient to restrike the arc.

The efficiency of a sodium vapour lamp under practical conditions is about 40-50 lumnes/watt . The major application of type of lamp is for high way and general out door lighting where colour discrimination is not required, such as street lighting, parks, railyards, storage yards etc. Such lamps are manufactured in 45, 60, 85, and 140watt ratings. The average life is about 3000 hours and is not affected by voltage variations. At the end of this period the light output will be reduced by 15% due to ageing.

The lamp fails to operate when

(i) The filament breaks or burns out.

(ii)The cathode stops to emit electrons,

(iii)The sodium particles mat concentrate on one side of the tube,

(IV)The lamp tube is blackened owing to sodium vapour action on the glass, in which case the output will be reduced.

**HIGH PRESSURE MERCURY VAPOUR LAMP(MV LAMPS):**

The extension use of the mercury vapour lamp depends entirely upon the versatility of the mercury vapour as regards pressure, temperature, voltage and other characteristics, each change resulting in a lamp of different spectral quality and efficiency.

The mercury vapour lamp is similar in construction to the sodium vapour lamp. It consists of a discharge envelope enclosesd in an outer bulb of ordinary glass. The discharge envelope may be of hard glass or quartz. The space between the bulb is partially or completely evacuated to prevent heat losss by convection from the inner bulb. The outer bulb absorbs harmful ultra-violet rays. The inner bulb contains argon and a certain quantity of mercury. In addition to two main electrodes a starting electrode is connected through a high resistance is also provided. The main electrodes are made of tungsten wire in the shape of helices. In this case no separate heater is required for the cathode which is heated by the constant bombardment of the heavy mercury ions.

The lamp has to heavy auxiliary equipment for use with standard mains voltage, and the necessary connections are shown in following fig. The choke is provided to limit the current for a safe value. This choke lowers the power factor, so a capacitor is connected across circuit to improve the power factor. These lamps must be operated vertically, since if they horizontally convection will cause the discharge to touch the glass bulb, which will fail. Lamps


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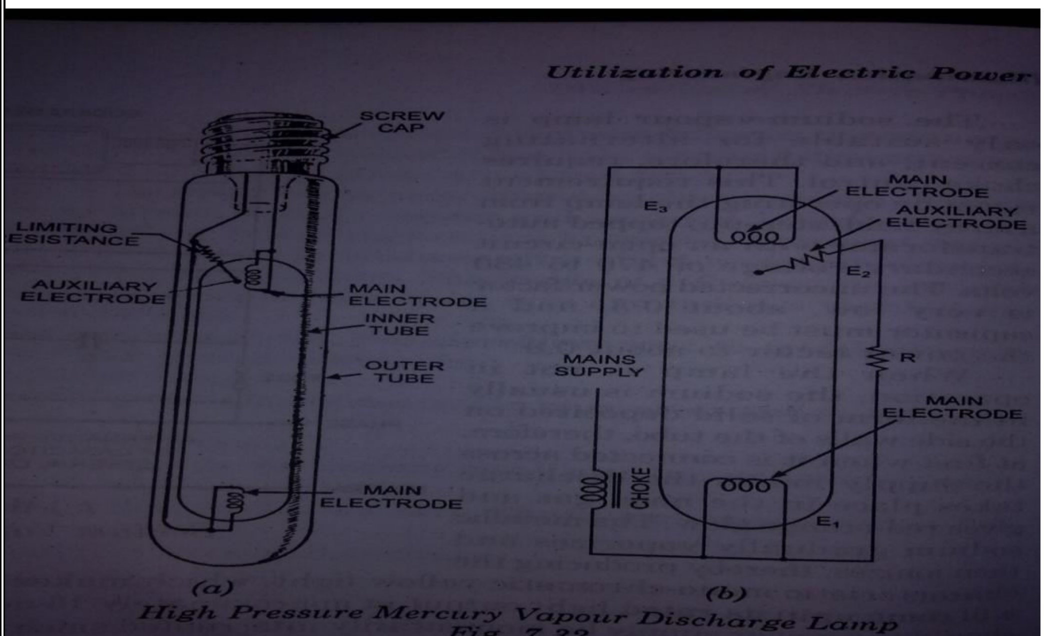
which are intended to operate horizontally are fitted with a magnetic device which will hold the luminous column central.




When the supply is switched on, full mains voltage is applied between the auxiliary electrode and neighbouring main electrode; this breaks down the gap and a discharge through the argon takes place. This enables the main discharge to commence. As the lamp warms up, mercury is vapourised, increasing, the vapour pressure and the luminous column becomes brighter and narrower . The lamp requires 4 or 5 minutes to attain full brilliancy. If the supply is interrupted, the lamp must cool down and the vapour pressure be reduced before it will start. This takes 3 or r4 minutes. The temperature of operation inside the inner bulb is about $600^0$c. It gives greenish blue colour light, which causes colour distortion. The efficiency is about 30-40 lumens/watt. These lamps are manufactured in 250 and 400 watt ratings for use on 200-250 volts a.c. supply mains. The pressure of vapour in lamps is 2-3 atmosphere. lamps of this type are used for general industrial lighting, railway yards, ports, work areas , shopping centers ,etc, where greenish blue colour light is not objectionable.

The lamp described above is M.A. type. Another type, which is manufactured in 300 and 500 watt rating for use on a.c. as well as d.c. supply mains, is M.A.T type. This is similar to M.A. type except that choke is not used as a blast. Space between two tubes instead of being evacuated contains a tungsten filament in series with a discharge tube which acts as a blast. When the supply is switched on, it operates a s filament lamp, its full output being given by the outer tube. . At the same time the discharge or inner tube beings warming up and at a particular temperature a thermal switch operates cutting a part of the filament and there by increasing the voltage across the discharge tube. The filament contributes a considerable portion of red rays. The combination of red rays from the filament and the blue radiations from the discharge tube produce a useful colour. As the filament acts as a resistance, the overall power factor of the lamp is about 0.95 and therefore capacitor is not required.

Lower wattage lamps, such as 80 and 125 watts, are manufactured in a different design and using high vapour pressure of about 5-10 atmosphere. These are known as M.B. types. These operate in a manner similar to M.A. type except that resistance in series with starting electrode is large and outer



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bulb is of quartz, in order to withstand high temperature so that these lamps can be used in any position.

**MERCURY IODIDE LAMP:**

These lamps are similar in construction to high temperature mercury vapour lamps but in addition to mercury, a number of iodides are added which fill the gaps in the light spectrum, and thus improve the colour characteristics of the light. Their efficiency is also higher (75-90 lumens/watt). A separate ignition device, in addition to the choke, is required for the mercury iodided lamp. Such lamps are suitable for application in the fields of flood lighting, industrial lighting and public lighting.

**NEON LAMPS:**

It is cold cathode lamp and consists of a gas bulb filled with a neon gas with a small percentage of helium. These lamps give to orange pink coloured light. Electrodes are of pure iron and are spaced only few mm apart so that lamp can be made for voltages as low as 110 volts a.c. or 150 volts d.c. For use on a.c. the electrodes are of equal size. On d.c. the gas glows near the negative electrode, therefore negative electrode is larger in size. The efficiency of neon lamp lies between 15-40 lumens/watt. Owing to discharge of gas between the electrodes in the form of an arc, it may cause the current drawn by the lamp to increase indefinitely. This is prevented by connecting a high resistance of few thousand ohms in series and mounting it in the cap. The lamp of this type is of the size of an ordinary incandescent lamp. The power consumption is of the order of 5watts.

Neon lamps are used as indicator lamps, night lamps, for determination of polarity of d.c. mains in larger size as neon tubes for the purpose of advertising.

**NEON TUBES:**

The popularity of high voltage neon lighting arose almost entirely from its use in adversiting, for signs, or in decorative treatment of buildings, but later the lighting field become important. The neon tube, which is used in varying lengths upto about 8 meters, may be bent almost any desired shape during manufacture . It consists of a length of glass tubing containing two electrodes, normally cylindrical in shape, of iron , steel, or copper.

The true neon tube contains neon, but the term is now used also for tubes with fillings of other rare gases. By varying the composition of glass and adding different substances to neon gas different colours such as orange, red, yellow and green etc. are obtained. The diameters of tube vary and common sizes of 10,15, 20, and 30mm carry currents of 25, 35,60,150mA respectively. Voltage required may vary from 300v to 1000v per meter of tube length for starting and discharge a striking voltage, about $1\frac{1}{2}$ times this value is required. Such voltage is obtained by making use of step up transformer having a high leakage reactance so that it gives a dropping characteristics. The usual operating voltage is 6000 volts.

The tubes are mounted either on a wooden frame or a metal base. These are matched with step –up transformers by connecting suitable transformers by connecting suitable tappings for the rated current. Connections between letters are made by nickel wires, the glass tubings being slipped over them.



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The power factor of neon tubes is quite low and is improved by using capacitors. The capacitors can, however, be placed only on the low voltage side of the transformer

## FLUORESCENT TUBES:

Fluorescent lighting has a great advantage over other light sources in many applications. The tubes can be obtained in a variety of length, with illumination in a variety of colours. It is possible to achieve quite high lighting intensities without excessive temperature rise and owing to the nature of light sources, the danger of glare is minimized. The efficiency of the fluorescent tube is about 40 lumens per watt, about three times the efficiency of an equivalent tungsten filament lamp. The fluorescent tube consists of a glass tube 25m.m in diameter and 0.38m-1.52m in length. The inside surface of the tube is coated with the thin layer of fluorescent material in the form of a powder.

The coating materials used depend on the colour effect desired and may consists of a zinc silicate, cadmium, silicate or calcium tungstate. These organic chemicals are known as ***phosphorus*** which powder transforms short wave invisible radiation into visible light. By mixing the various powders light of any desired colour including day light can be obtained. The tube contains small quantity of argon gas at a pressure of 2.5mm of mercury and one or two drops of mercury. It is provided with two electrodes coated with electron emissive material. A starting switch is provided in the circuit, which puts the electrodes directly across the supply mains at the time of starting, so that electrodes may get heated and emit sufficient electrons. A stabilizing choke is connected in series with it, which acts as a ballast.

Fluorescent tubes are available in the fallowing sizes

| Length | wattage |
|---|---|
| 38 cm | 14W |
| 46 cm | 15W |
| 61 cm | 20W |
| 100 cm | 25W |
| 122 cm | 40W |
| 152 cm | 65W |

The starting switches are of two types, namely thermal type and glow type.

### Thermal starter type:

The thermal starter is a current operating device and consists of two metallic strips and a heater coli. The bimetallic strips are in contact with each other when the lamp is not in operation. When the supply is switched on, the two electrodes get connected in series through the thermal switch the relatively large current raising them to incandesence. The current also flows through the heater element as a result of which bimetallic strips break contact. This causes interruption in the current flowing through the circuit, which further results in a high voltage surge across the electrodes of the tube, which is enough to strike the arc between the electrodes. This arc is then maintained by the normal lamp voltage. The thermal switch is now generally obsolete because of its more complicated construction, greater cost and greater power loss.


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**GLOW STARTER TYPE:**

The connections of the fluorescent tune incorporating a glow type starter are shown in the above figure. The glow type starter is a voltage operated device and consists of two bimetallic electrodes enclosed in a glass bulb filled with a mixture of helium and hydrogen. Normally the contacts are open. When the supply is switched on, the potential across the bimetallic electrodes cause a similar glow discharge at a small current not enough to heat up the tube electrodes. This discharge is enough, however, to heat the bimetallic strips of the causing them to bend and make contact. The result is a large current through the electrodes, their temperature being raised to incandescence and the gas in the immediate neighborhood is ionized. After one or two seconds the bimetallic strips cool down and the contacts are open. This opening of contacts in series with the choke causes a momentary high voltage, which is sufficient to start the discharge in the main tube. The starter starts to glow as the voltage is now too low. A small capacitor is placed inside the starter to suppress arcing and radio interference.

Now a days starter less circuits are there for instant start or rapid start.

**FLUORESCENT LAMPS FOR DC SUPPLY:**

In the foregoing discussions it has been assumed that the supply to the fluorescent lamps is a.c. if however, the available supply is d.c. some special accessories and circuit modification will be required.

(i) The choke coil has a low impedance in d.c. and therefore, a ballast resistance is connected in series with the choke in order to limit the current.
(ii) On systems below 220v,starting becomes less certain on d.c. only thermal type starters should be used.
(iii) The positive end becomes relatively dark on account of the tendency of mercury vapour to migrate towards the negative end of the tube. In order to avoid this problem a reversing switch in included in the circuit between the supply and the fitting like as shown in the fallowing figure.

In d.c. operation of fluorescent tube there is no problem of power factor correction and no stroboscopic effect. Its disadvantages are low efficiency due to loss in ballast resistance, increased cost of the ballast resistance and reversing switch and less life of the tube.

**Basic Principles of light control:**

When light falls on a surface, depending upon the nature of the surface, some portion of light energy is reflected, some portion is transmitted through the medium of the surface and the rest is absorbed. The ratio of reflected light energy to the incident light energy is known as reflection factor.

There are two basic types if reflection (i) mirror or specular reflection and (ii) Diffuse reflection.


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In case of specular reflection a beam of light is reflected but not scattered, and unless the eye is placed in the path of the reflected beam, the viewer is unaware of the existence of light. Moreover, if his eye is placed in the path of the reflected reflection are silvered mirrors, highly polish metals etc. with diffuse reflection the reflected light is scattered in all directions, and the viewer sees the illuminated surface, not the light source. Surfaces causing diffuse reflection are paper, frosted glass, chalk, dry earth, plaster etc. If a surface that is uniformly illuminated by a beam of light appears to be equally bright when viewed from all possible angles the reflection is said to be perfectly diffuse, perfect mirror surfaces and perfect diffusing surfaces are ideals that do not exist in mature. The reflection from any actual surface is partly secular and partly diffuse, the proportional varying widely. A surface that is almost free from mirror reflection is called a mat surface.

**TYPES OF LIGHTING SCHEMES:**

The distribution of the light emitted by lamps is usually controlled to some extent by means of reflectors and translucent diffusing screens, or even lenses.

The interior lighting schemes may be classified as (i) direct lighting (ii) semi-direct lighting (iii) semi-indirect lighting (iv) indirect lighting and (v) general lighting.

**Direct lighting :** It is most commonly used type of lighting scheme. In this lighting scheme more than 90 % of total light flux Is made to fall directly on the working plane with the help of deep reflectors. Though it is most efficient but causes hard shadows and glare. It is mainly used for industrial and general out door lighting.

**Semi-direct lighting :** In this lighting scheme 60-90 % if the total light flux is made to fall down wards directly with the help of semi-direct reflectors, remaining light is used to illuminate the ceiling and walls. Such a lighting system is best suited to rooms with high ceiling where a high level of uniformly distributed illumination is desirable. Glare in such units is avoided by employing diffusing globes which not only improve the brightness towards the eye level but improve the efficiency of the system with reference to the working plane.

**Semi-indirect lighting :** In the lighting scheme 60-90 % of total light flux is thrown upwards to the ceiling for defuse reflection and the rest reaches the working. Plane directly except for some absorption by the bowl. This lighting scheme is with soft shadows and glare free. It is mainly used for indoor light decoration purposes.

**Indirect lighting :** In this light scheme more than 90% if total light flux is thrown upwards to the ceiling for diffuse reflection by using inverted or bowl reflectors. In such a system the ceiling acts as the light source, and the glare is reduced to minimum. The resulting illumination is softer and more diffused, the shadows are less prominent and the appearance of the room is much improved over that which results from direct lighting. It is used for decoration purposes in cinemas, theatres and hotels etc. and in work shops where 'large machines and other obstructions would cause troublesome shadows if direct lighting is employed.

**General lighting :** In this scheme lamps of diffusing glass are used which give nearly equal illumination in all directions.

**Design of lighting schemes:**


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The lighting scheme should be such that it may,

1. Provide adequate illumination,
2. Provide light distribution all over the working plane as uniform as possible,
3. Provide light of suitable colour and
4. Avoid glare and hard shadows as far as possible.

The following factors are required to be considered while designing the lighting schemes.

I. **Illumination Level :** This is the most vital factor because a sufficient illumination is the basic means where by we are able to see our surroundings, unless they are themselves light sources, since only when illuminated do the objects take on the necessary brightness. It is the task of illumination to give objects a distributed brightness. Body colours have property of reflection light in different degrees. It is this differential brightness which gives essential perception of details. For each type of work there is a range of brightness most favorable to output i.e which causes minimum fatigue and gives maximum output in terms of quality and quantity. Degree of illumination, to be seen and its distance from the observer- greater the distance of the object from observer and smaller the size of the object, greater will be the illumination required for its proper perception and Contrast b/n the object and back ground—greater the contrast b/n the colour of the object and its back ground, greater will be the illumination required to distinguish the object properly. Objects which are seen for longer duration of time require more illumination than those for casual work. Similarly moving objects require more illumination than those for stationary object.

Illumination level required, as per ISI, in various parts of a building is given below

| | |
|---|---|
| **Games or recteation room** | **100** |
| **Kitchen** | **200** |
| **Kitchen sink** | **300** |
| **Laundry** | **200** |
| **Bathroom** | **100** |
| **Bathroom mirror** | **300** |
| **sewing** | **700** |
| **workshop** | **200** |
| **stairs** | **100** |
| **Garage** | **70** |

Illumination level required, as per ISI, for various types of traffic routes is given below


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| Classification of lighting Installation | Type of road | Average level of illuminatuion on road surface |
|---|---|---|
| Group A1 | important traffic routes carrying fast traffic | 30 |
| Group A2 | mixed traffic like main city streets, arterial roads, through ways etc. | 15 |
| Group B1 | secondary roads with considerable traffic like princijpal local traffic routes, shopping streets etc. | 8 |
| Group B2 | secondary roads with light traffic | 4 |

**(ii) Uniformity of illumination :** The human eye adjusts itself automatically to the brightness within the field of vision. If there is a lack of uniformity, pupil or iris of the eye has to adjust more frequently and thus fatigue is caused to the eye and productivity is reduced. It has been found that visual performance is best if the range of brightness within reduced. It has been found that visual performance is best if the range of brightness within the field of vision is not greater than 3:1, which can be achieved by employing general lighting in addition to localized lighting. A part from the consideration of causing fatigue, local lighting without using matching general lighting creates psychological feeling of loneliness, gloom and unfriendliness. The modern trend is thus towards 'localized lighting plus general lighting' and towards the adoption of " general lighting oriented towards the working surface ' especially in mass production factories, offices, drawing offices, shops etc.

**(iii) colour of light :** The appearance of the body colour entirely depends upon the colour of the incident light. In general the composition of the light should be such that the colour appears natural i. e . its appeareance by artificial light is not appreciable different from that by day light. Day- light fluorescent tubes now a-days make it possible to illuminate economically even large spaces with artificial day light giving good colour rendering and at sufficiently high level. For certain applications such as street lighting, colout of light does not matter much if different components have not to be distinguished from each other by their colours, highly efficient discharge lamps, which cause colour distortion, can be used.

iv. **Shadows:** In lighting installations, Formation of long and hard shadows causes faigue of eyes and therore is considered to be a short-coming. Complete absence of shadows altogether again does not necessarily mean an ideal condition of lighting installations. contrary, perhaps to popular opinion, a certain amount of shadow is desirable in artificial lighting as it helps to five shape to the solid objects and makes them easily recognized. Objects illuminated by shadow less light appear flat and un-interesting, contours are lost, and it is difficult for the eye to form a correct judgment of the shape of an object. How're, there is one exception to this i.e. in drawing offices, where we are to see flat surfaces, shadow less light is essential otherwise shadows will hinder the work. Hard and long shadows can be avoided by (i) using large no of small luminaries mounted at height not less than 2.5 meters and (ii) by



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using wide surface sources of light using globes over filament lamps or by using indirect lighting system.

v. **Glare :** It may be direct or reflected i.e it may come directly from the light source or it may be reflected brightness such as from a desk top, nickeled machine parts , or calendred paper. Direct glare from a source of light is the more common, and is more often a hindrance to vision. A glance at the sun proves that an extremely bright light source causes acute eye discomfort. Light sources of far less brilliancy than the sun, such as the filament of an incandescent lamp, or the incandescent metal of a gas lamp, also cause discomfort by a direct glare. Reflected glare is which comes to the eyes as glint or reflection of the light source in some polished surface.

vi. **Mounting height:** The mounting height will largely be governed by the type of the building and type of lighting scheme employed. In the case of direct lighting, in rooms of large floor area, the luminaries should be mounted as close to the ceiling as possible. Lowering them not only will make the illumination less uniform, but will also bring them more into the field of vision, thus increasing the flare, without causing an appreciable increase in the coefficient of utilization. In the unusual case of small rooms with high ceilings, there is something to be gained by lowering the luminaires, but even here a better solution might be to use filament lamps with focusing reflectors and to mount them high. In the case of indirect and semi-indirect lighting, it would of course be desirable to suspend the luminaries far enough down from the ceiling in order to give reasonably uniform illumination on the ceiling. In practice this is usually taken to mean that the length of the suspension tubes should be one-quarter to one-third the horizontal spacing b/n ween tows of luminaries.

vii. **Spacing of luminaires:** correct spacing is of great importance to provide uniform illumination over the whole area and thus do away with comparatively dark areas which are so often found when the fittings are badly spaced.

In case of direct and semi-direct luminaires the ration of the horizontal spacing b/n rows to the height of the luminaires aboue the working plane depends to quite an extent on the candle power-distribution curve of the luminaire. In the case of tungsten lamps combined with focusing reflectots, the ratio of spacing to height should be about 0.6. In the case of indirect and semi-indirect luminaries. It is good practice to aim at a horizontal spacing b/n rows approximately equal to a height of the ceiling above the working plane, and in no case should the horizontal spacing exceed $1\,{}^{1}/_{2}$ times this height.

In case of fluorescent luminaries, it is common practice to join two are more summaries end to end so that they can share a common outlet. In fact it often works out well to use continuous tows of luminaries, especially when the specified illuminating is fairly high.

viii. **Cooler of surrounding walls :** The illumination in any room depends upon the light reflected from the walls and ceilings. White walls and ceiling reflect more light as compared to colored ones.

**Factory Lighting :**

Adequate lighting of factories is of very importance, as it provides improved amenities for the employees, increased production and has a definite economic value in reducing accidents with their consequent loss of time and compensation payments.

**General Requirements and Types of installations :** A factory lighting installation, in common with other indoor equipments should provide and adequate illumination on the working plane and give a god distribution of light, employ simple and easily cleaned fittings and avoid glare. It is essential not only to avoid glare from the lamp itself but also reflected glare from any polished surface, which may be within the line of vision.

**General lighting :** The usual scheme in factories and workshops is to mount a number of lamps at a sufficient height so that uniform distribution of light over the working plane is obtained. In large machine shops the height is governed by the necessity of keeping the lamps above the travelling crane. In such cases it is often desirable to supplement the main lighting by side lighting in order to five additional illumination on a vertical plane. Since light coloured walls and ceiling add to the effectiveness of an installation, therefore it is necessary to get white washing or painting done,

**Local Lighting :** On some points fairly intense illumination is required for thus jpurpose local lighting can ve provided by means of adjustable fittings attached to the machine or bench in question or mounted on portable floor standard. Such lamps should be mounted in deep reflectors so that glare Is avoided.

**Emergency lighting :** Some lights, such as for (i) internal pilot lighting required for safe and speedy evacuation of personnel after main lighting circuit is off (ii) cxternal pilot lighting, provided with careful shades leading to shelters required for evacuation of personnel (iii) for control posts, first aid centres etc. (iv) dials and gauges in important plants required to be watched regularly are required during an air raid when all the factory lights are off as a matter of air raid precaution. The circuit supplying the above emergency light should be independently controlled. It is very desirable to provide auxiliary lighting from the source other than the main electric supply preferably from batteries or from small petrol driven generator ser. If however, emergench light circuits are operated from main electric supply, these shoukd be completely separated from main lighting circuit.

**Industrial lighting fittings:** Reflectors for industrial purpose must be sinple in design and easily cleaned. The requirements of most of the installations can be met by one of the following types of fittings.

**Standard Reflectors:** These reflectors are made to accommodate lamps of ratings from 40 to 1,500 watts and designed so that they give adequate and uniform illumination when they are mounted at a spacing equal to about 1.5 times their mounting height above the working plane.

**Diffusing Fittings:** When more diffused light is required than that given by the standard reflector a diffusing glass screen may be fixed across a standard type of reflector. Such fittings are used where highly polished articles are dealt with.

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**Concentrating Reflectors:** A refliector with a concentrated beam is employed in large machine shops and foundaries, where the fittings are to be mounted on a considerable height above the working plane. In such places and ordinary reflector would have too wide angle of divergence and would waste a great deal of light on the walls

**Enclosed Diffyusing fittings:** An opal globe completely enclosing the lamp giving a very enen and well diffused light is used when light coloured walls and ceiling are there.

**Angle Reflectors:** Angle reflectors are used to provide illumination in a vertical plane when concentrating type reflectors are used. These can be mounted on suitable stanchions or the walls.

**Maintenance:** In order to maintain the fittings in a condition of reasonable efficiency it is necessary to clean the light fittings periodically. The frequency of cleaning depends on the conditions in the particular factory under consideration and varies from once or twice a week for very dirty surroundings to every four or six weeks under the best conditions.

**Types of Lamps :** The discharge lamps have been used in where colour rendring is not important, The fluorescent lamps are widely employed on account of its natural day light colour, its even illumination and absence of glare and in some cases, the fact that it gives rise to considerably less than filament lamps of the same light output.

## STREET LIGHTING:

The main objectives of street lighting are

(i) To make the traffic and obstructions on the road clearly visible in order to promote safety and convenience.
(ii) To make the street more attractive.
(iii) To increase the community value of the street.

The principle employed for street lighting is different from that of interior lighting. There are no walls and ceiling which reflect or diffuse light, hence only direct lighting scheme can be employed and hard shadows and high contrast can not be avoided.

Two general principles are employed in the design of street lighting installations, namely (i) diffusion principle (ii) specular reflection principle

Two general principles are usually employed in the design of street lighting installations ,namely

Diffusion and specular reflection principle

**Diffusion principle**: In this case the lamps fitted with suitable reflectors are used. The reflectors are so designed that they may direct the light downwards and spread as uniformly as possible over the road surface. in order to avoid glare the reflectors are made to have a cut-off between $30^0$ to $45^0$ so that the filament is not visible except from underneath it. The diffusion nature of the road surface causes the reflection of a


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certain proportion of the incident light in the direction of the observer. The illumination at any point on the road surface is calculated by applying point to point or inverse-square law method. Over certain properties of the road the surface is illuminated from two lamps and the resultant illumination is the sum of the illuminations due to each lamp.

**Specular Reflection principle**: in this case the reflectors are curved upwards so that the light is thrown on the road at a very large of incidence. It is observed that a motorist requires to see objects about 30 meters away. Thus in figure the observer is shown about 30 meters from the object. Much of the light from the lamps $L_3$ is not reflected towards the observer, whereas most of the light from the lamps $L_1$ and $L_2$ is reflected towards him. Thus the object will appear silhouetted against the bright road surface due to lamps at along distance. the requirements of a pedestarian, who requires to see objects in his immediate neighbourhood, is also fulfilled in this method as some light from the lamps falls directly downwards. The method of street lighting is only suitable for straight sections of load. This method is more economical also as compared to the diffusion method of lighting but it suffers from the dis advantages that it produces glare for the motorists.

**Illumination level for street lighting and Mounting-height of lamps**:

The illumination depends upon the class street light installation in class A installation ,i.e in important shopping centres and road junctions, illumination level of 30 lumens/$m^2$ is required in poorly lighted suburban streets, illumination level of 4 lumens/$m^2$ is sufficient. When the distance apart is not more than 8 times than the height of illuminate. they should be spaced not more than 64 meters.

**Types of lamps for street lighting:**

Mercury vapour and sodium discharge lamps have been found to have certain particular advantages for street lighting purposes. The most important of these low power consumption for a given amount of light. The colour and monochromatic nature of the light produced by the discharge lamps does not matter much in street lighting installation.

## FLOOD LIGHTING:

Flood light means flooding of large surfaces with light from powerful projectors. It is employed to serve one or more of the following purposes.

(A) Aesthetic Flood-lighting: For enhancing beauty of building at night such as public places, ancient buildings and monuments, religious buildings on important festive occasions.
(B) Industrial and commercial flood-lighting: for illuminating railway yards, sports stadiums, car parks, constructions sites, quarries etc.
(C) Advertising: For illumination advertisement boards and show-cases. For flood lighting it is necessary to concentrate the light from the light source into a narrow beam. The particular type of reflector and its housing used for concentrating the light into narrow beam is known as flood light projection. The


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reflecting surface is the most important part in a projector. This may b made of the silvered glass or chromium plate or stainless steel, the efficiency of silver glass is about 90% while that of polished metal is only about 70%. Metal reflectors being more robustare usually preferred. The casing and its mounting are arranged so that the inclination of the beam can be varied in both a vertical and horizontal direction on site. For permanent installations use of cast metal cases is made to achieve robustness and protection against weather for temporary installations or those in sheltered situations, use of sheet-metal casing is made. The front of the projector is usually of clear glass, often bowed outwards to protect it from the heat of the lamp, use of diffusing glass is made when a diffuse beam is required. As far as possible the projectors should not be visible to the passers by. In some cases the projectors may be housed in ornamental stand standards.

Projects are classified according to the beam standards.

(i) Narrow beam projectors with beam spread between $12^0$-$25^0$. These are used for distance beyond 70 meters.

(ii) Medium angle projectors-projectors with spread between 25-$40^0$. These are used for distance between 30-70 meters.

(iii) Wide angle projectors- projectors with beam spread between 40-$90^0$ these are used for distance below 30 meters.

For economic reasons use of wide angle projector with high wattage lamp is encouraged over narrow beam projector with low wattage lamp is more efficient than low power used in narrow projectors. Standard gas-filled tungsten filament lamps of 250,500,1000 watts are used in medium and wide angle projectors which require accurate control of light, special lamps having bunched filaments and known as projector lamps are required.

Location and mounting of projectors: one of the most important factor which affects the choice of projector is the location of the projector. There are two possible locations of projectors in practice. here figure indicates symmetric projector kept 20 to 35 meters away from the surface to be flooded and providing approximating parallel beam having beam spread of 25 to $30^0$.

And the next figure indicates when the projector cannot be located away from the building. In such a case, an unsymmetrical reflector mounted in a basement area or on a bracket attached to the building is used which directs more intense light towards the top of the building.

**Flood lighting calculations:** The problem of flood-lighting calculations may be roughly separated into three

**First step:** Illumination level required: the illumination level required depends upon the type of building, the purpose of the flood lighting the amount of conflicting light in the vicinity.

**Second step:** Type of projector : two considerations enter into the choice of a projector .,viz, beam size and light output. The former determines the area covered by the beam and latter the illuminations provided. Beam angle of the projector is decided keeping in view the of projector from the surface


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**Third step:** Number of projectors: For any desired intensity over a definite surface the number of projectors required is obtained from the following relation

N=(A *E* depreciation factor*waste light factor)/(utilisation factor*wattage of lamp*luminous efficiency of lamp)

Here N= number of projectors

A= area of surface to be illuminated in square meters

E=illuminates level required in lumens/$m^2$.

**COMPARISON BETWEEN TUNGSTEN FILAMENT LAMPS AND FLUORESCENT TUBES:**

| Tungsten Filament Lamp | Fluorescent Tubes |
|---|---|
| 1. Voltage fluctuation has comparatively more effect on the light output. | 1. Voltage fluctuation has comparatively low effect on light output as the variations in voltage are absorbed in the choke. |
| 2. Luminous efficiency increases with the increase in the voltage of the lamp. | 2. Luminous efficiency increases with the increase in wattage and increase in length of tube. |
| 3. It gives light close to natural light. Therefore objects are properly seen. | 3. It does not give light close to natural light, therefore, colour rendering is defective. |
| 4. Luminous efficiency of coloured filament lamps is poor because coloured glass is used for this purpose. | 4. Different colour light can be obtained by using different composition of fluorescent powder. Hence efficiency is high and better colours are obtained. |
| 5. Due to comparatively high working temperature heat radiations are also present. | 5. Due to low working temperature heat radiation is low. |
| 6. Its brightness is more. | 6. Its brightness is less. |
| 7. With the time light output is reduced. | 7. With the time light output is gradually reduced. |
| 8. Though the life of the lamps varies with the working voltage, however, its normal life is 1000 working hours. | 8. Life of fluorescent tubes is not effected so much by variations in voltage but it depends on the frequncy |

| | |
|---|---|
| | of starting. The life of the tube is about 7500 working hours. |
| 9. The initial cost per lamp is quite low. | 9. The initial cost per tube is more. |
| 10. For same lumens output more lamps are required and working cost is more. Life of the lamp is also low. Hence overall cost of maintenance is more. | 10. For same lumens output lesser number of tubes are required and wiring cost is more. Life of the tube is comparatively more, therefore replacement cost is low. Hence overall cost of maintenance is low. |