ILLUMINATION

Definition – Laws of illumination – Polar curves – Calculation of MHCP and MSCP. Lamps: Incandescent lamp, Sodium Vapour lamp, Fluorescent lamp. Requirement of good lighting scheme – Types, Design and Calculation of illumination. Street lighting and Factory lighting – Numerical Problems

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 output, as well as its low it is playing an increasingly important part in modern everyday life. The science of illumination engineering is, therefore, becoming of major importance.

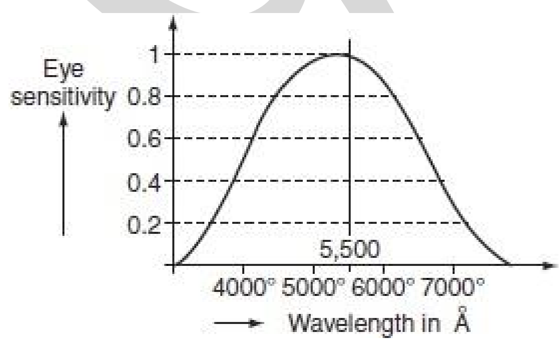
Nature of light:

Light is a form of radiant energy. Various forms of incandescent bodies 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.

A hot body about 500-800°C becomes a red hot and about 2,500-3,000°C the body becomes white hot. While the body is red-hot, the wavelength of the radiated energy will be sufficiently large and the energy available in the form of heat. Further, the temperature increases, the body changes from red-hot to white-hot state, the wavelength of the radiated energy becomes smaller and enters into the range of the wavelength of light. The wavelength of the light waves varying from 0.0004 to 0.00075 mm, i.e. 4,000-7,500 Å (1 Angstrom unit = 10^{-10} mm).

Relative Sensitivity:

The reacting power of the human eye to the light waves of different wavelengths varies from person to person, and also varies with age. The average relative sensitivity is shown in Fig



The sensitivity of eye to yellow-green radiation is taken as unity or 100% and the sensitivity to other wavelengths is expressed as a fraction or percentage of it. The relative sensitivity at awave length $\lambda$is written k $\lambda$and is known as relative luminosity factor.

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 between4,000A and 7,500A as shown in the figure1.1.

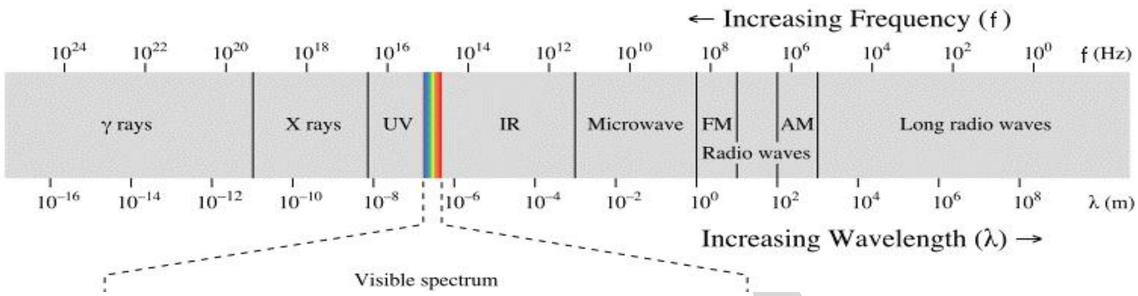
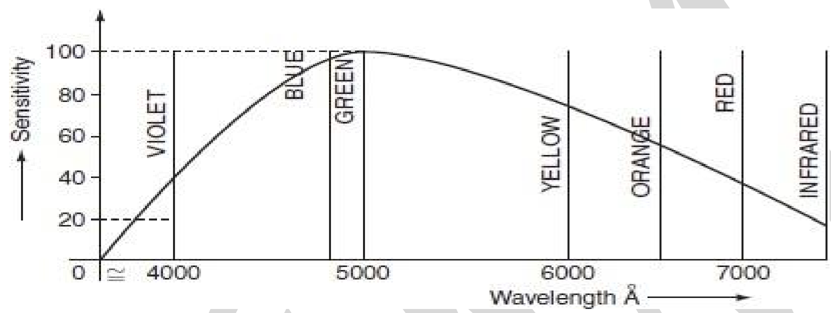


Fig 1.1 wave lengths of the light



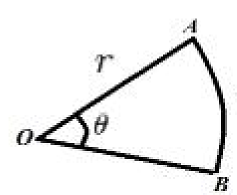
Wavelength of the colour light

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 otherwise. 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:

1. Plane Angle: The angle subtended at a point in a plane by two converging straight lines and its magnitude is shown by $\theta = \frac{Length\ of\ the\ arc}{Radius}$



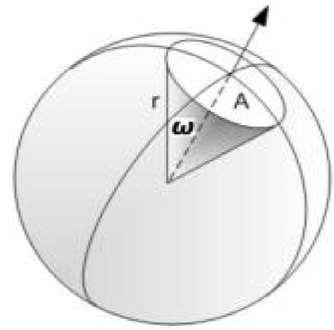
It is measured in Radians.

The largest angle subtended at a point is '2π 'radians.

Radian: The angle subtended at a point by an arc whose length is equal to the radius.

2. Solid angle : A Solid angle is subtended at a point in space by an area and is the angle enclosed in the volume formed by an infinite number of lines lying on the surface of the volume and meeting at the point. It is represented by greek letter **ω**.and is measured in steradian.

$$\text{Solid Angle } \omega = \frac{Area}{(Radius)^2} \text{ steradian}$$



The largest solid angle subtended at certre of a sphere

$$\frac{Area\ of\ sphere}{Radius^2} = \frac{4\pi r^2}{r^2} = 4\,\pi\ steradian$$

3. Light: It is defined as the radiant 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 analogues to watt-hours.

4. Luminous Flux (F): It is defined as total quantity of light energy emitted per second from a luminous body. It is represented by the symbol 'F'and is measured in Lumens.

$$F = \frac{Q}{t}$$

5. Luminous Intensity (I): It is the luminous flux per unit solid angle in a given direction.It is represented by I and is measured in (lumen/steradian or) candela (cd).

$$I = \frac{F}{\omega}$$

6. Lumen: Luminous flux emitted by a source of one candle power in a unit solid angle.

Lumen= candle power of source X solid angle

=c.p X ω

It is the unit of luminous flux.

7. Candle Power (C P): The candle power of a source is defined as the number of lumens emitted by that source in a unit solid angle in a given direction.

$$C.P = \frac{lumens}{\omega} \text{ lumen/steradian or candela}$$

8. Illumination (E) : Illumination of a surface is defined as the luminous flux received by the surface per unit area. It is represented by the symbol '**E**' and is measured in lux (or lumen/m_2).

$$Illumination\ E = \frac{Flux}{Area} = \frac{F}{A} = \frac{c.p\ X\ \omega}{A}\ \ lux$$

Light is the cause and illumination is the effect.

9. Brightness or Luminance (L): It is defined as luminous intensity per unit projected area of a given surface in a given direction.

$$L = \frac{I}{A}\ cd/n^2$$

I= Luminous Intensity (candela)

A= Projected area (m^2)

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

11. Mean Spherical Candle Power (M.S.C.P): It is defined as the mean of candle power in all directions and in all planes from the source of light.

$$M.S.C.P = \frac{Total\ Flux}{4\pi}$$

12. Mean Hemi-Spherical Candle Power (M.H.S.C.P): It is defined as the mean of candle power in all directions above or below horizontal plane passing through the source of light.

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

$$Reduction\ Factor = \frac{M.S.C.P}{M.H.C.P}$$

14. Lamp Efficiency: It is defined as the ratio of the luminous flux to the power input. It is expressed in Lumens / Watt.

15. Space Height Ratio: it is the ratio of horizontal distance between lamps and the height of their mountings.

16. Utilisation Factor or Co-efficient of utilisation (UF): It is the ratio of total lumens reaching the working plane and the total lumens given out by the lamp.

17. Maintenance Factor (MF): It is the ratio of illumination under normal working conditions to the illumination under clear and clean conditions.

18. Depreciation Factor (DF): It is the ratio of initial illumination to the maintained illumination on the working plane. DF > 1 always.

19. Glare: Brightness within the field of vision such a character as to cause annoyance, discomfort, interference with the vision of eye fatigue. This is found in car head lights.

Relationship between ω and :

$$\text{Solid angle } \omega = \frac{surface\ area\ of\ xyz}{radius^2}$$

$$= \frac{2\pi r\,h}{r^2}$$

$$= \frac{2\pi\,h}{r} \quad \text{\_\_\_\_\_\_\_\_\_\_}(1)$$

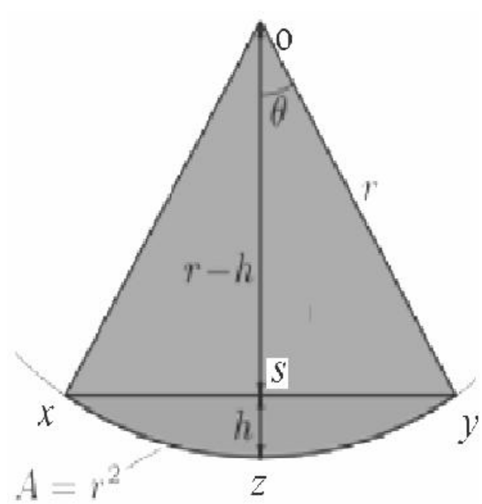
SZ=OZ-OS

h=r − r $\cos\theta$= r (1-cos θ)______ (2)

Substituting h in eq (1) we get

$$\omega = \frac{2\pi r\,(1 - cos\theta)}{r}$$

$$\omega = 2\pi\,(1 - cos\theta)$$



Laws of Illumination: There are two laws of illumination

1. Law of inverse squares
2. lamberts 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'.

Proof:

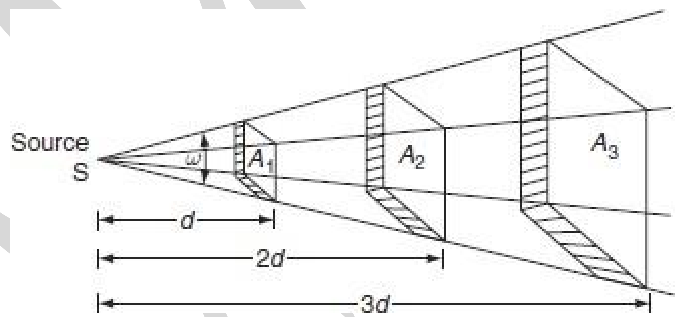
Let, S= a point source of luminous intensity

I= candela, the luminous flux emitting from source

A1 A2, and A3= Three parallel surface area's in square meters,

d, 2d, and 3d =distances of A1 A2, and A3 from the point source respectively as shown in Fig

For area A1 solid angle $\omega = \frac{A_1}{d^2}$



Flux on area A1= luminous Intensity X solid angle

$= I \times \omega = I \times \frac{A_1}{d^2}$

$= \frac{I A_1}{d^2}$ ______ (1)

Illumination E_1 on surface A_1 $= \frac{Flux}{Area}$

$= \frac{I A_1}{d^2} \times \frac{1}{A_1}$

$E_1 = \frac{I}{d^2}$ lux ________(2)

Similarly, illumination 'E2' on the surface area A2 is: $E_2 = \frac{I}{(2d)^2}$ lux

and illumination 'E3' on the surface area A3 is: $E_3 = \frac{I}{(3d)^2}$ lux

$E_1 : E_2 : E_3 :: \frac{I}{d^2} : \frac{I}{(2d)^2} : \frac{I}{(3d)^2}$

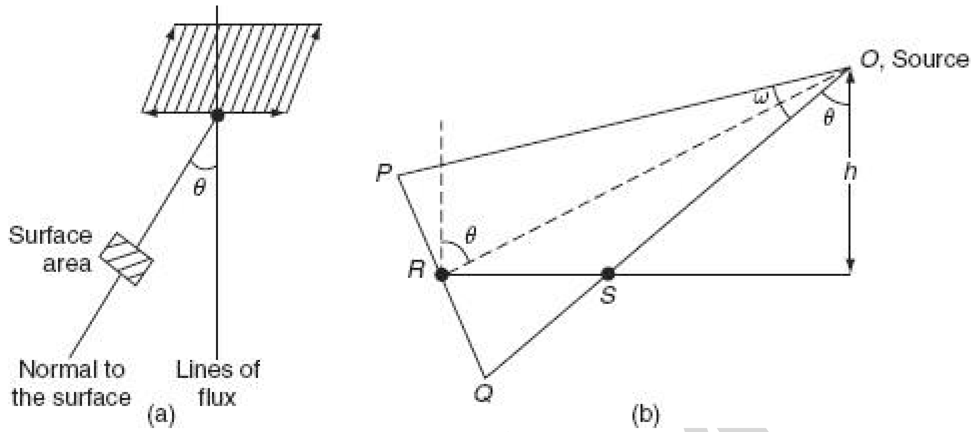
Lambert's cosine law: This law states that 'illumination, E at any point on a surface is directly proportional to the cosine of the angle between the normal at that point and the line of flux'.

Proof:

While discussing, the Lambert's cosine law, let us assume that the surface is inclined at an angle 'θ' to the lines of flux as shown in Fig

Let PQ = The surface area normal to the source and inclined at 'θ' to the vertical axis.

RS = The surface area normal to the vertical axis and inclined at an angle θ to the source 'O'.



From above fig

$$PQ = RS\cos\theta.$$

$$\therefore \text{The illumination of the surface } PQ, E_{PQ} = \frac{\text{flux}}{\text{area of } PQ}$$

$$= \frac{I\times\omega}{\text{area of } PQ} = \frac{I}{\text{area of } PQ}\times\frac{\text{area of } PQ}{d^2} \quad \left[\because \omega = \text{area}/(\text{radius})^2\right]$$

$$= \frac{I}{d^2}.$$

$$\therefore \text{The illumination of the surface } RS, E_{RS} = \frac{\text{flux}}{\text{area of } RS} = \frac{\text{flux}}{\text{area of } PQ/\cos\theta}$$

$$[\because PQ = RS\cos\theta]$$

$$= \frac{I}{d^2}\cos\theta.$$

From fig (b) $\cos\theta = \frac{h}{d}$

or $d = \frac{h}{\cos\theta}.$

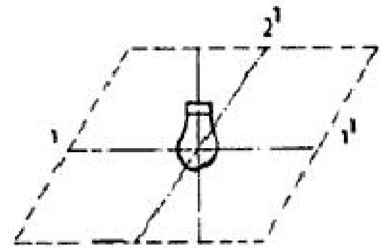
Substituting 'd' from the above equation in Equation $\therefore E_{RS} = \frac{I}{(h/\cos\theta)^2}\times\cos\theta = \frac{I}{h^2}\cos^3\theta$

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

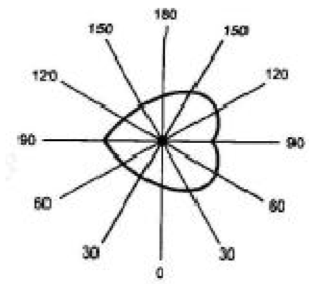
POLAR CURVES:

They are the plot drawn between the Candle Power and Angular Position. The light intensity is not same in all directions in most of the lamps because of their unsymmetrical shape. The luminous intensity in all directions can be represented by polar curves. They help to find the distribution of candle power, i.e. light in different directions.

Horizontal polar curves: it is the curve drawn showing the distribution of candle power on a horizontal plane about a vertical axis passing through the source of light. The dip at 90º is due to coiled coil filament occupying an arc subtending an angle less than 360º.



Vertical polar curves: it is the plot drawn showing the relation between the candle power and the angle of illumination on a vertical plane passing through the lamp. The dip at 180º is due to the position of lamp holder.



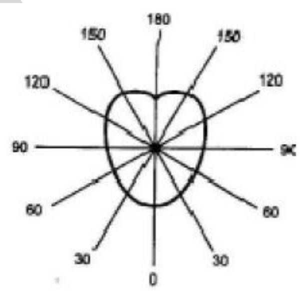
(a) Polar Curve For Horizontal Plane

Polar curves are used to determine:

-MHCP and MSCP.

-Actual illumination of a surface with the help of these curves.

-MHCP can be determined from horizontal polar curves by taking mean of candle powers in horizontal direction. This can be done drawing a planar graph between angular direction and the candle powers and deriving the mean form that graph.



(b) Polar Curve For Vertical Plane

-MSCP can be derived from vertical polar curves by Rousseau's construction diagram.

Rousseau's construction:

When vertical plane is in the form of two lobes, symmetrical about the vertical axis YOY'.

Construction steps:

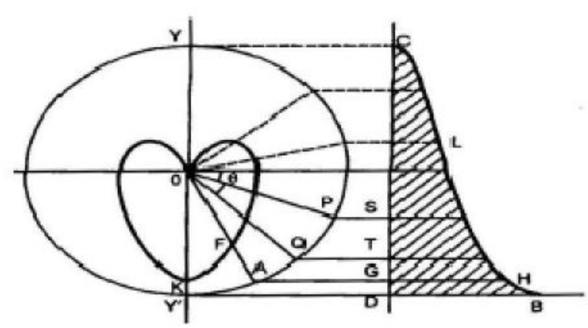
-Draw circle with convenient radius with O as center.

-Draw CD // YOY' and equal to vertical diameter of the circle.

-Draw any line OFA meeting the polar curve in F and circle at A. let the projection be G.

-At G erect an ordinate GH = OF

-By similar construction draw other ordinates.



-The curve CSTGDBHL obtained by joining these ordinates is known as Rousseau's curve. The mean ordinate of the curve gives the MSCP.

-Mean ordinate of the curve = $\frac{Area\ CSTGDBHLC}{Length\ of\ CD}$

-The area can be determined by using a graph or by Simpson rule.

ARTIFICIAL SOURCES OF LIGHT:

There are several alternative schemes that act as substitute for sunlight. But light be electricity is pollution free and easy control method. Illumination by electricity is mainly classified into three types they are:

1. By temperature incandescence.(incandescent lamps)
2. By producing an arc between electrodes.(arc lamps)
3. By discharge of electrons.(fluorescent lamps and vapour lamps).

INCANDESCENT LAMPS:

Electric current is passed through a filament of thin wire placed in vacuum or an inert gas. The current generates sufficient heat to raise the temperature of the filament to luminosity. Their output depends on the temperature of the filaments so they are termed as "Temperature Radiators". The fine wire is known as filament placed inside it.

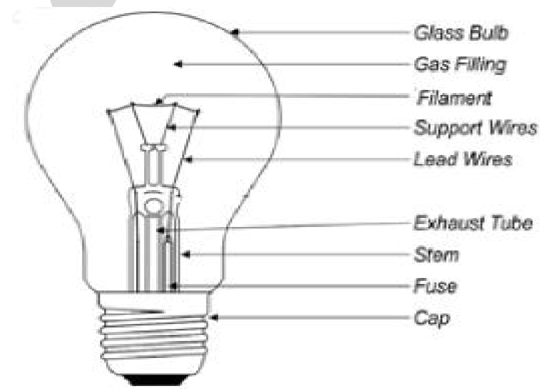
Construction:

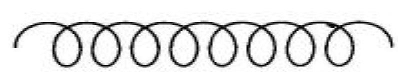
It consists of a evacuated glass globe structure. The evacuation is to:

- To prevent oxidation and

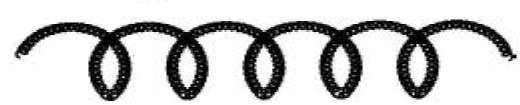
- Convectional currents of filament.

- To prevent decrease of temperature by radiation. Coiled coil is employed to avoid convectional currents. The coiled-coil filament is the heart of the lamp, where the light is created. It is supported at two intermediate points by fine molybdenum wires, slightly springy. The electrical current is carried to the filament by a pair of nickel plated steel lead-in wires. a very special alloy which forms a gas-tight seal between the glass and wire is welded to a copper plated steel wire which makes the electrical connection to the cap. In one or both of these outer leads there is a fuse wire section. The lead wires are held in a glass assembly called the stem, through which a smaller glass tube, the exhaust tube is also sealed. This is kept open at the top of the stem which allows the air to be pumped out of the bulb after sealing. The cap is affixed to the bulb with special heat-curing cement, and the copper lead wires pass through eyelets in the end of the cap where they are fluxed and soldered to the brass contact plates. The terminals are insulated from each other by a special black glass called vitrite, which offers high electrical resistance even at elevated temperatures. a mixture of Argon and Nitrogen in the ratio of 85% Argon





(a) Coiled Filament



(b) Coiled Coil Filament

-15% Nitrogen are employed.

Properties of filament made of ideal material:

-High melting point.

-High resistivity.

-Low temperature coefficient.

-Low vapour pressure.

-Ductility

-Sufficient mechanical strength to withstand vibrations during use.

Materials used for making filaments:

Property	**Carbon**	**Tantalum**	**Tungsten**
Resistivity (ρ)	10 - 70 μ Ω - m	0.056 μ Ω - m	0.124 μ Ω - m
Temperature coefficient (α)	-0.0002 to -0.0008	0.0036	0.0045
Melting point	3500ºC	2996 ºC	3400 ºC
Density	1.7- 3.5 kg/m^3 (maintained at 1800 ºC to avoid blacking)	16.6 kg/m^3	19.3 kg/m^3
Efficiency (η)	4.5 lumen/watt	2 lumen/watt	18 lumen/watt at 2000 ºC in vacuum bulb.

Filament made of tungsten is most preferred instead of carbon filament due to the accumulation of ash on the walls of the bulb as life goes on leading to reduction of life of bulb.

Aging effect:

Decrease in light output of lamp with time is called aging effect. The cause for aging effect is evaporation of filament that results in blackening of bulb and also reduces the diameter of the filament which increases the resistance. The aged filament draws less current and operates at lower temperature that decreases the light output and efficiency.

The total depreciation of light output is roughly 15% over the life range.

Filament manufacturing:

Pure tungsten powder is pressed in steel mould for small bars. The mechanical strength of the bars is improved by heating electrically near to the melting point. Bars are then hammered at red heat and drawn into filaments. To increase the efficiency of the bulb it is filled with inert gas Argon and small percentage of Nitrogen. To decrease the convectional currents due to gas molecules in the bulb, the filament is wound into a close spiral and suspended horizontally in the form f a circular arc.

- Efficiency is 30 lumen/watt for a gas filled coiled coil at working temperature of 2500ºC.

The diameter of tungsten filament depends upon voltage and wattage.

- Size is as small as 10 microns (1/6th of human hair).
- Diameter depends upon current rating.
- In vacuum:

Heat produced = heat lost by radiation.

$$P = I^2 R = I^2 \frac{\rho l}{A} = I^2 \frac{\rho l}{\frac{\pi d^2}{4}} = I^2 \frac{4\rho l}{\pi d^2}$$

Heat lost/ sec **α** surface area x emissivity

$$I^2 \frac{4\rho l}{\pi d^2} \ \alpha \ (l \, x\pi \, d) \ X \ e$$

$$I^2 \ \alpha \ d^3$$

Clear gas filled incandescent lamps: They facilitate light control. It is used where lighting units are to be distributed accurately. They are used in flood lights, projectors, car head lights.

Disadvantage is they produce hard shadows and glare from the filament.

Inside frosted gas filled lamps: their luminous output is 2% less than clear glass lamps of same rating. They produce soft shadows and practically eliminate glare from filaments. Used in industrial open fittings located in line of sight at low mounting heights. These are used in diffuse fittings of opal glass type in order to avoid the presence of filament striations on the surface of glass ware.

Inside silica coated lamps has high diffusion of light output due to fine coating of silica. They are less glaring and produce soft shadows. The brightness of reflection from shiny surfaces is minimized.

Halogen filled incandescent lamps: as the life of incandescent lamp falls with time due to

- Slow evaporation of filament
- Black deposit formed on the inside of bulb.

When the bulb is filled with halogen vapour is filled along with filling gas it restores a part of evaporated filament due to chemical reaction i.e. by “Regenerative Cycle Process”.

Advantages: - life time is about 2000 hrs

- Very high operating temperature.
- increased luminous efficiency from 22 to 33 lumen/watt
- Reduced blacking effect.
- No depreciation of lumens.

DISCHARGE LAMPS:

An electric current is passed through a gas or vapour which renders its luminous. The light is produced by the process of gaseous conduction. The commonly used elements are Neon, Mercury, Sodium vapours. The color depends on the nature of gas or vapour.

Neon: Orange Red Light.

Mercury: Bluish.

Sodium: Orange Yellow.

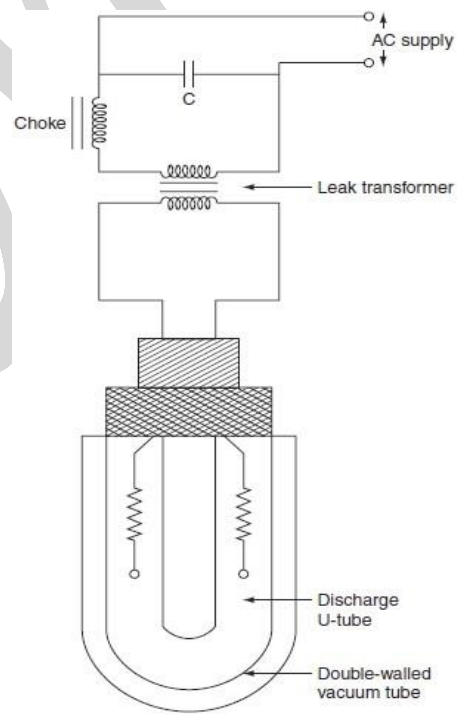
Discharge lamps are categorized into two types they are:

i) Vapour discharge lamps. ii) Fluorescent lamps.

SODIUM VAPOUR LAMP:

This type of the lamp has low luminosity, so length of lamp is large. To get required length it is made in form of U tube. Two oxide coated electrodes are sealed with the ends. The tube contains Neon and Sodium gas. The U tube is enclosed in a double walled vacuum flask to keep the temperature within the working range. It employs high leakage reactance transformer to provide sufficient voltages to increase the temperature of the oxide coated electrodes that emits the electrons to liberate light. Due to this transformer the regulation will be poor and the power factor will be low about 0.3. Capacitor at the input terminals is provided to improve power factor to 0.8.

Working:



Before stating the Sodium in the solid form is deposited on the walls of the tube. When the supply is fed by closing the switch, the bulb operates as low pressure Neon lamp with pink color. The lamp gets warm and the Sodium is vaporized and radiates yellow light. After 10-15 minutes it illuminates full light.

For a 40 W lamp, 380 V is required to start the discharge. For 100W lamp 450V is required. These voltage levels are obtained from the high reluctance transformer or auto transformer.

The no-load voltage is high, which decreases gradually when the lamp starts glowing on account of production of electron current between the electrodes, which results in poor regulation of transformer.

Specifications:

- Efficiency of lamp is about 40-50%.
- Available in 45W, 60W, 85W, 140W ratings.
- Average life is 3000 hrs.
- It is not affected by voltage variations.
- At the end of life output is reduced by 15% due to aging.

Causes for failure of lamp:

- Burn out or breaking of filament.
- Cathode stops to emit electrons.
- Sodium particles may concentrate on one side of the tube.

- The blackening of lamp due to sodium vapour action on the glass.

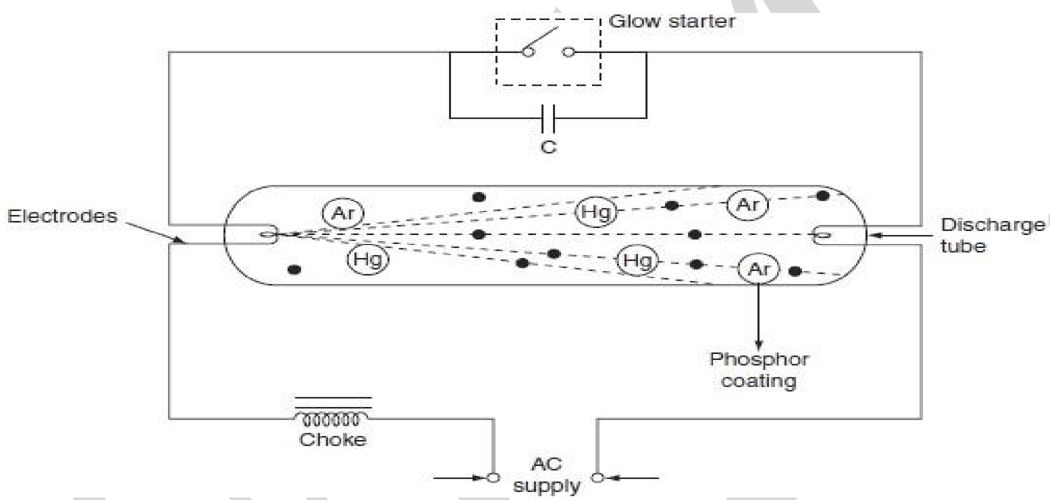
Applications:

These lamps are employed where color discrimination is not required.

- Highway lighting.
- Outdoor lighting.

FLUORESCENT LAMPS:

It is a low pressure mercury vapor lamp. It consists of a glass tube 25 mm in diameter and 0.6 m, 1.2 m and 1.5 m in length. The tube contains argon gas at low pressure about 2.5 mm of mercury. At the two ends, two electrodes coated with some electron emissive material are placed.



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

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 ballast in running condition and provides a voltage impulse for starting. A capacitor is connected across the circuit to improve the power factor at the supply side. The filament is connected to a starter switch which is small with bimetal strip connecting the two electrodes.

Working:

When the starter is cold the electrodes are open.When supply is given the current traces the closed path through the mains - choke – electrode 1 - starter – electrode 2 - mains. At this time the bimetallic strip of the starter operates depending on the type of starter used . when the electrodes are raised to a certain temperature and liberate electrons that bombard on the phosphor coating on the walls of the tube to emit light. Thus the electrons close the path between the electrodes reducing the voltage across the starter which cools down gradually, where the choke provides the necessary voltage transient across the electrodes. The radio interference effect may be reduced to minimum by connecting a small capacitor (0.05ÅF) across starter.

Advantages of Fluorescent Tube:

1. Voltage fluctuation has very small effect on light output.
2. The luminous efficiency is more as length of rod is more.
3. It gives light close to natural light.
4. Heat radiations are negligible.
5. High efficiency.
6. The life of the lamp is three times of the ordinary filament lamp.
7. Less chances of glare.

Although the fluorescent lamp has the above advantages, it sufferers form the following disadvantages

1. The initial cost is high because of choke and starter.
2. The starting time as well as the light output of the lamp will increases because of low ambient temperature.
3. Because of the presence of choke, these lamps suffer from magnetic humming and may cause disturbance.
4. The stroboscopic effect of this lamp is objectionable.

Stroboscopic effect:

We all know that because of 'the alternating nature of supply, it crosses zero two times in a cycle'. 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'.

This effect can be avoided by employing any of the two techniques listed below.

1.If we have three-phase supply, then the fluorescent lamps that are adjacent should be fed from different phases. Then, no two lamps will not be in same phase at zero instant of AC supply, so light is present at any instant.

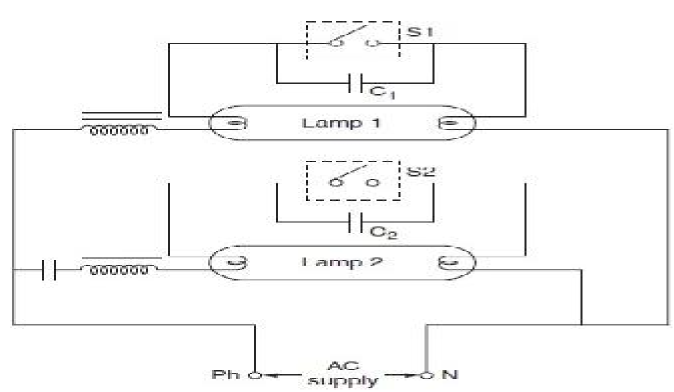


Fig. Lead-lag circuit

2.If the available supply is single phase, then twin tube circuitry as shown in above Fig. we can eliminate stroboscopic effect.

In this lead-lag arrangement, one of the lamps is operating at 0.5 lagging, the other, provided with capacitor, is operating at 0.5 leading.

In general, the life of a fluorescent lamp is about 7,500 hr. Based on the operating conditions, the lamp's actual life can be varied from 5,000 to 10,000 hr. It is recommended to replace a lamp after 4,000-5,000 of its working hours.

BASIC PRINCIPLES OF LIGHT CONTROL:

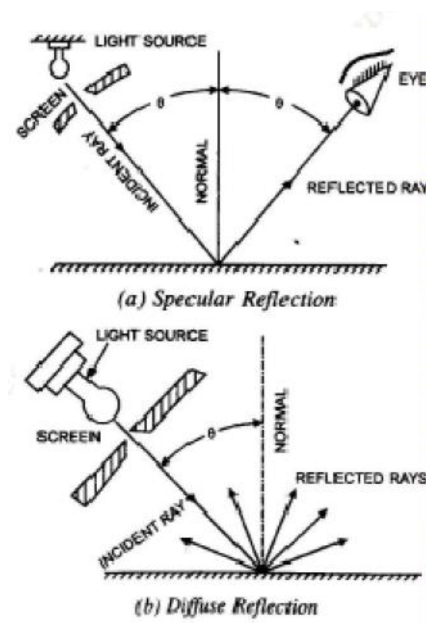
When light falls on a surface, depending up on the nature of the surface of the light, some portion of light energy is reflected, some portion is transmitted through the medium of the surface and the rest is absorbed. The ratio of reflected light energy to the incident light energy is known as reflection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

There are two basic types of reflections:

(i) Mirror or specular reflections

(ii) Diffuse reflection

In case of specular reflection a beam of light is reflected but in the path of the reflected beam, the eye is placed in the path of the existence of the light. Moreover, if the eye is placed in the path of the reflected beam, he sees, not the illuminated surface, but the light source. Surfaces causing specular reflection or silvered mirrors, highly polished metals etc. with diffused reflection the reflected light is scattered in all directions, and the viewer sees the illuminated surface, not the light source. Surface causing diffused 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 when viewed from all possible angles, the reflection is said to be perfectly diffused. Perfect mirror surfaces and perfect diffusing materials are ideals that do not exist in nature. The reflection from do not exists in nature. The reflection from any actual surface is partly specular and partly diffused the promotional varying widely. A surface that is almost free from mirror deflection is called "Mat Surface".

TYPES OF LIGHTING SCHEMES:

The distribution of 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 can be classified as

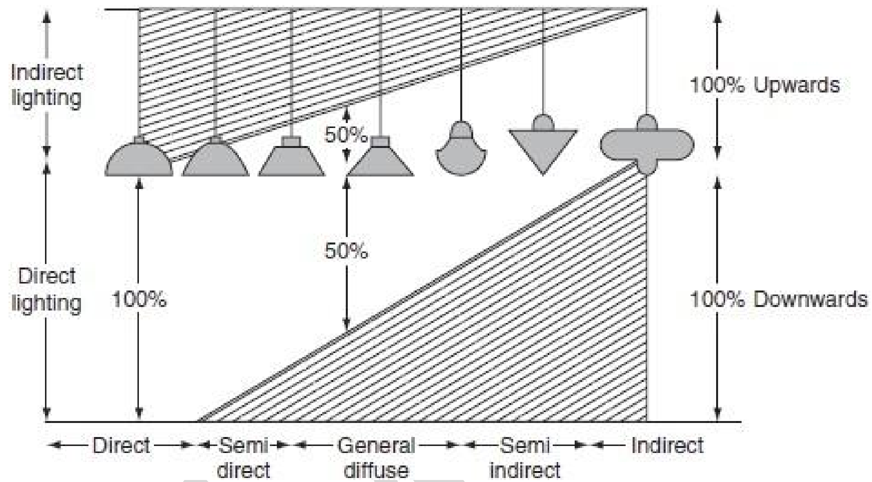
(i) Direct lighting

(ii) Semi- Direct lighting

(iii) Semi- in direct lighting

(iv) Indirect lighting

(v) General lighting



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.

Semi direct lighting schemes:

In semi direct 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.

Indirect lighting schemes :

In this lighting scheme more than 90% of total 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 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 workshops where large machines and the other obstructions would cause trouble shadows if direct lighting is employed.

Semi-Indirect Lighting:

In this lighting scheme 60 to 90%of total light flux is thrown upwards to the ceiling for diffuse 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.

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. Lamp fittings of various lighting schemes are shown in above Fig.

DESIGN OF LIGHTING SCHEMES:

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.

1. Illumination Level:

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.

2. 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. Local lighting without using matching general lighting creates psychological feelings of loneliness, gloom and unfriendliness.

3. Color of the Light: The appearance of the body color entirely depends up on the color of the incident light. In general composition of the light should be such that the color appears natural. Day light fluorescent tubes now a day make it possible to illuminate economically even large spaces with artificial day light giving good color rending and at sufficiently high level. For certain applications such as street lighting, color of light does not matter much if different components have not be distinguished from each other by their colors, highly efficiency discharge lamps, which cause color distortion, can be used.

4. Shadows: In lighting installations, formation of long and hard shadows causes to give eyes and therefore is considered to be a short-coming. Perhaps to popular opinion a certain amount of shadows is desirable in artificial lighting as it helps to give shape to the solid objects and makes them easily recognized. Objects illuminated by shadow less light appear flat and uninteresting, contours are lost and it is difficult for the eye to form a correct judgment of the shape of an object.

5. Glare: It may be direct (or) reflected. 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.

6. Mounting Height: In the case of direct lighting in the rooms of large floor area, the luminaries should be mounted as close to the ceiling as possible. In the case of indirect lighting it would of course be desirable to suspend luminaries far enough down from the ceiling in order to give reasonably uniform on the ceiling.

7. Spacing of Luminaries: Correct spacing is one of great importance to provide uniform illumination over the whole area and thus do away with comparatively dark areas which are so often when the fittings are badly spaced.

8. Color of Surrounding Walls: The illumination in any room depends upon the light reflected from the walls and ceilings. White walls and ceilings reflect more light as compared to colored ones.

FACTORY LIGHTING:

Adequate lighting of factories is of vital 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 Illumination: A factory lighting installation in common with other in order equipments should provide an adequate illumination on the working plane and give a good 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 workshops is to mount a no. of lamps at a sufficient height so that uniform distribution of light over the working plane is obtained. Since light colored 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 this purpose local lighting can be provided means of adjustable fittings attached to the machine or bench in question or mounted on portable floor standards. Such lamps should be mounted in deep reflectors. So that glare is avoided. Low voltage lamps of not more than 50 volts are recommended for use as portable hand lamps because such lamps have thicker filament, more robust is also avoided in these few volt lamps. Local lighting should never be employed alone, good general lighting is essential so that the dark places between the local lighting units are avoided dark places between the local lighting units cause fatigue to the eyes on account of its continually to adjust itself to new conditions.

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) external 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.

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.

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 cannot be avoided.

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

(i) diffusion principle (ii) specular reflection principle

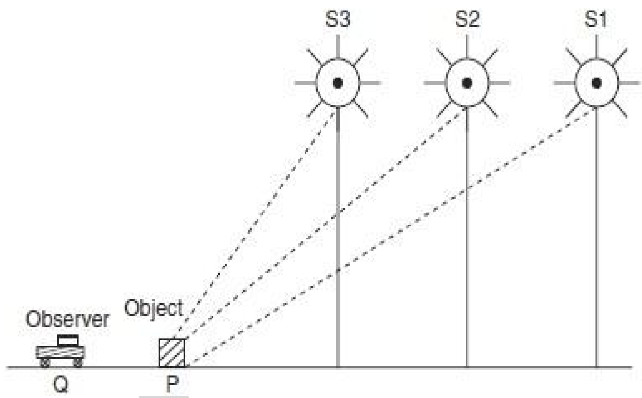
Two general principles are usually employed in the design of street lighting installations ,namely Diffusion and specular reflection principle.

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 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:

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 below 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'.

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.



Illumination Level For Street Lighting And Mounting Height Of Lamps:

The illumination required depends up on the class of street lighting installations. In class A installations i.e. in important shopping centers and road junctions, illumination level of 30 lumens/m^2 is required where as a in poorly lighted suburban streets, illumination level of 4 lumens/m^2 is sufficient. An average well lighted street will require illumination level between 8 to 15 lumens/m^2. Excellent illumination is considered when the distance apart is not more than the roads and as far as possible lamps near large trees should be avoided.

Types of Lamps for Street Lighting: Mercury vapour and sodium discharge lamps have been found to have certain particular advantage for street lighting purpose: lower power consumption for a given amount of light,the overall cost of an installation with discharge lamps less than that employing filament lamps. The color and mono- chromatic nature of the light produced by discharge lamps do not matter much in street lighting installations.

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

Watts-per-square-meter method:

This method is very handy for rough calculations.It consists in making an allowance of watt per square meter of area to be illuminated according to the illumination desired on the assumption of an average figure of overall efficiency of the system.

Lumen or light flux method:

This method is applicable to those cases where the sources of light are such as to produce an approximate uniform illumination over the working plane.

Total lumens required = No.of lamps X wattage of each lamp X efficiency of each lamp (in terms of lumen/watt) X coefficient of utilization X maintenance factor

Point-to-point method:

This method is applicable where the illumination at a point due to one or more sources of light is required,the candle power of the sources in the particular direction under consideration being known. This method is not much used (because of its complicated applications);it is employed only in some special problems, such as flood lighting,yard lighting etc.

$$N = \frac{E\ X\ A}{O\ X\ UF\ X\ MF}$$

Where N=No.of lamp fitting needed,

E=Required Illumination (lux)

A= working area (square meter)

O= Luminous flux produced per lamp (lumens)

UF= Utilisation factor or co-efficient of utilization

MF=Maintaince factor

Example 1: A room 20 × 10 m is illuminated by 60 W incandescent lamps of lumen output of 1,600 lumens. The average illumination required at the workplace is 300 lux. Calculate the number of lamps required to be fitted in the room. Assume utilization and depreciation factors as 0.5 and 1, respectively.

Solution:

The area of the room (A) = 20 × 10 m = 200 m^2.

Total illumination required (E) = 300 lux. T

he wattage of each lamp = 60 W

The luminous output of the lamp (ij) = 1,600 lumens

UF = 0.5, DF = 1.

∴ Maintenance factor, $\text{MF} = \frac{1}{DF} = \frac{1}{1} = 1.$

∴ The number of lamps required:

$$N = \frac{E \times A}{\phi \times \text{UF} \times \text{MF}}$$

$$= \frac{300 \times 200}{1{,}600 \times 1 \times 0.5} = 7.5 \text{ lamps.}$$

Example 2 : A drawing, with an area of 18 × 12 m, is to be illuminated with an average illumination of about 150 lux. The lamps are to be fitted at 6 m height. Find out the number and size of incandescent lamps required for an efficiency of 20 lumens/W. UF = 0.6, MF = 0.75.

Solution:

Given data:

η= 120 lumens/W

E= 150 lux A= 18 × 12 = 216 m^2 UF = 0.6 MF= o.75

$$\text{The total gross lumens required } \phi = \frac{E \times A}{\text{UF} \times \text{MF}}.$$

$$= \frac{150 \times 216}{0.6 \times 0.75} = 72,000 \text{ lumens.}$$

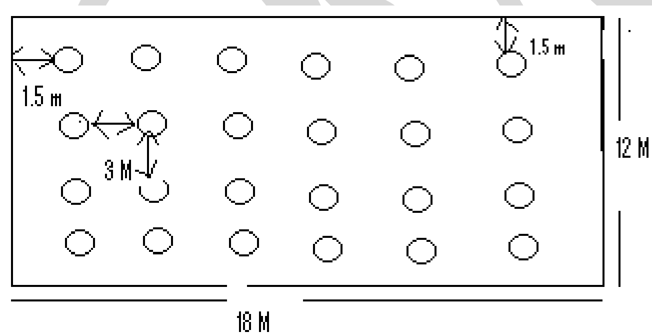
$$\text{The total wattage required } = \frac{72,000}{\eta}$$

$$= \frac{72,000}{20} = 3,600 \text{ W.}$$

Let, if 24 lamps are arranged to illuminate the desired area. For space to height ratio unity, i.e., 6 lamps are taken along the length with a space of 18/6 = 3m, and 4 lamps are along the width giving a space of 12/4 = 3 m.

$$\therefore \text{The wattage of each lamp } = \frac{3,600}{24} = 150 \text{ W.}$$

The arrangement of 24 lamps in a hall of 18 × 12 m is shown in Fig



Example: Four lamps 15 m apart are arranged to illuminate a corridor. Each lamp is suspended at a height of 8 m above the floor level. Each lamp gives 450 CP in all directions below the horizontal; find the illumination at the second and the third lamp.

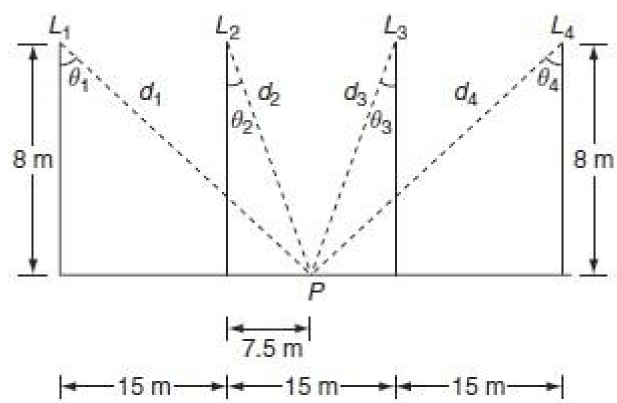
Solution:

Given data:

Luminous intensity = 450 CP

Mounting height = 8 m.

Distance between the adjacent lamps = 15 m



The illumination at 'P' = the illumination due to L1 + the illumination due to L2 + the illumination due to L3 + the illumination due to L4.

The Illumination at 'P' due to L_1, $E_1 = \frac{I}{d_1^2} cos\theta_1$

$$\text{But } d_1 = \sqrt{8^2 + (22.5)^2} = 23.88\ m$$

$$Cos\theta_1 = \frac{h}{d_1} = \frac{8}{23.88} = 0.34$$

$$\therefore\ E1 = \frac{I}{d_1^2} cos\theta_1 = \frac{450}{23.88^2}\ 0.34 = 0.26\ lux$$

The Illumination at 'P' due to L_2, $E_2 = \frac{I}{d_2^2} cos\theta_2$

$$\text{But } d_2 = \sqrt{8^2 + (7.5)^2} = 10.96\ m$$

$$Cos\theta_2 = \frac{h}{d_2} = \frac{8}{10.96} = 0.73$$

$$\therefore\ E2 = \frac{I}{d_2^2} cos\theta_1 = \frac{450}{10.96^2}\ 0.73 = 2.73\ lux$$

Similarly, the illumination at 'P' due to the lamp L3 'E3' = the illumination at 'P' due to the lamp 'L2', 'E2', and the illumination at 'P' due to the lamp L4, 'E4' = illumination at 'P' due to the lamp 'L1', 'E1.'

∴ The total illumination at 'P = E1+ E2 + E3+ E4

= $2E_1 + 2E_2$

= $2(E_1 + E_2)$

= 2 (0.26 + 2.73) = 5.98 lux.