9 Illumination

9.1 Introduction

In our everyday life, we perform different activities in presence of sun light. But our activities are required to be continued when day light is insufficient or completely fails. This is possible by use of artificial light. Similarly the number of activities in different industries are also carried out in presence of artificial light. Such artificial light offers number of advantages like cleanliness, ease of control etc. Good lighting schemes improve efficiency of work and reduce chances of accidents. Naturally these things lead to an industrial growth. In some hotels, shops, streets such lighting prove to be a part of decorative aspect. So study of this subject called Illumination Engineering and knowing its basics is important. In this chapter different important terms involved in illumination, laws of illumination and different lighting schemes and their applications are discussed. Let us discuss first the different types of artificial lamps used in practice.

9.2 Types of Lamps

Now a days, variety of artificial lamps are used in practice to achieve good illumination. Few of these commonly used lamps are,

1. Fluorescent lamp or tube light.
2. Sodium vapour lamp.
3. Mercury vapour lamp.

Let us discuss the working of these three types of lamps in detail.

9.3 Fluorescent Lamp or Tube Light

The Fig 9.1 shows the constructional details of fluorescent lamp. It consists of a long glass tube which is internally coated with a suitable amount of fluorescent powder. A small amount of mercury along with a little quantity of argon gas is also filled in the tube.

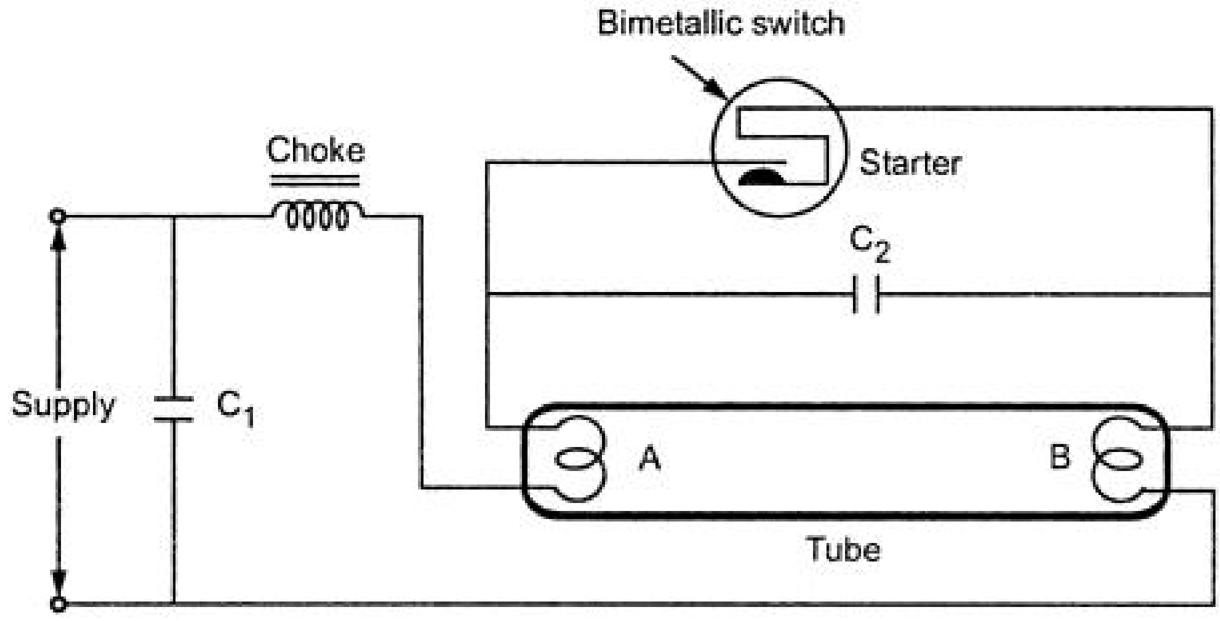


Fig. 9.1 Fluorescent tube

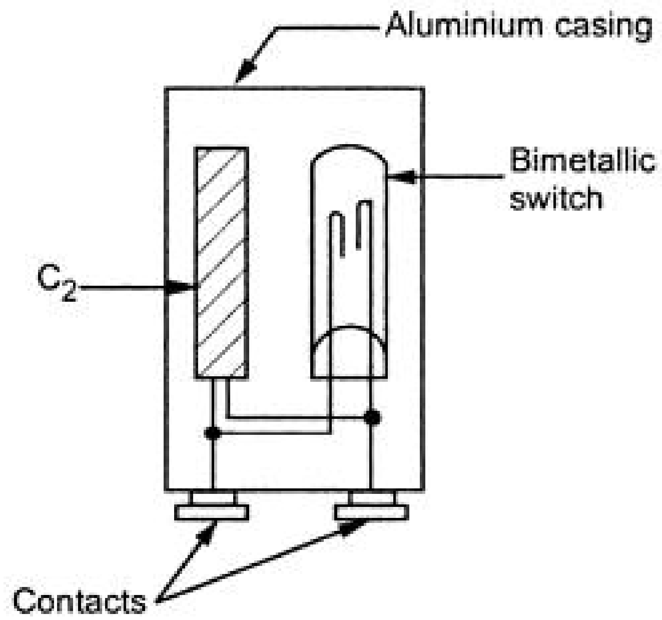


Fig. 9.2 Glow type starter

There are two electrodes A and B made up of coiled tungsten filament coated with an electron emitting material. The control circuit of the tube contains glow type starter, choke L and two capacitors C_1 and C_2.

Fig 9.2 shows a cut section of a glow type starter.

There are two electrodes of which one is fixed while other is U shaped bimetallic strip made of two different metals. These electrodes are sealed in a glass bulb which is filled with a mixture of helium and hydrogen. The contacts are normally open.

9.3.1 Working

When the supply is switched ON, as electric arc is established between the electrodes of the starter due to flow of current through small air gap between the electrodes. Due to this arc, heat is produced which is sufficient to bend the bimetallic strip which makes contact with fixed electrode. This closes the circuit and therefore choke carries large current. Once the electrodes close, arc vanishes and bimetallic strips cools down again.

Now the electrodes A and B become hot and due to cooling the choke circuit opens. The current through the choke coil is suddenly reduced to a small value. This change in current induces an e.m.f. which is very high of the order of 1000 V, in the choke coil.This e.m.f. induced is sufficient for ionizing the gas molecules between electrodes A and B which establishes the discharge between the electrodes A and B through the gas.

The potential difference across the tube falls to about 100-110 V which is sufficient to maintain the discharge but not sufficient to restart the glow in the circuit.

So even if starter is removed from the circuit, discharge continues as the current flows from electrode A and B due to ionization of gas. If the supply voltage is low, there is difficulty in starting the tube as the low voltage is insufficient to establish a glow in the starter.

As choke lowers the power factor, the capacitor C_1 used in the circuit improves the power factor of the circuit.

The capacitor C_2 suppresses the radio interference developed due to arcing. The function of the inductive choke is to supply a large voltage surge for establishing the discharge between the electrodes A and B.

9.3.2 Advantages

1) The light available is much more than the normal incandescent lamp. Fluorescent lamp gives 2200 to 2400 lumens while normal lamp gives 600 lumens.
2) The life of the fluorescent tube is much more than the incandescent lamp.
3) The fluorescent tube gives effect of day light while incandescent lamp gives yellowish light.
4) Low power consumption.
5) High efficiency.
6) Instantaneous switching without any warming period.
7) Using different fluorescent materials various coloured lights can be obtained.

9.3.3 Disadvantages

1. Very high initial cost.
2. Produces radio interference.

9.4 Sodium Vapour Lamp

The Fig. 9.3 shows sodium vapour lamp construction.

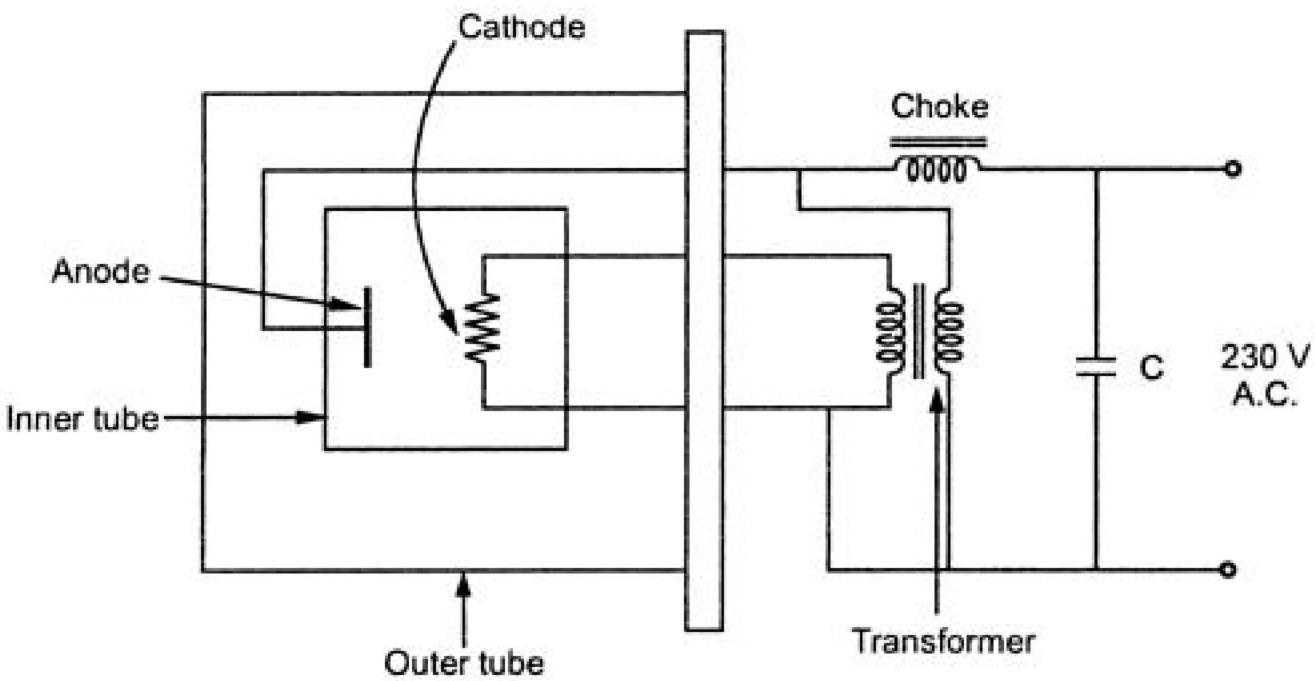


Fig. 9.3 Sodium vapour lamp

9.4.1 Construction

It consist of two glass tube, outer glass tube and inner glass tube. The inner glass tube contains two electrodes. Sodium along with the small quantity of neon or argon gas is filled in inner tube to make discharge self starting. Sodium vapour is chemically very active. The glass of the tube is made up of suitable material to resist this action.

To maintain the correct temperature in the discharge, it is placed in an evacuated outer tube. The outer tube reduces the heat loss. The transformer included in the circuit heats the cathode while the choke stabilises the discharge.

9.4.2 Working

When the lamp is switched on, the discharge is first established through the neon or argon gas, This gives out reddish colour. After some time heat is developed due to this discharge which vaporizes sodium vapour. In this way, lamp starts its normal operation giving yellow colour. Capacitor C is connected to have a better power factor. The operating temperature of this lamp is about 300°C. These lamps are commonly used for illumination of roads, good yards, airports etc.

9.4.3 Advantages

1. Its efficiency is higher than that of the filament lamps.
2. It has a long life.

9.4.4 Disadvantages

1. The bright yellow colour obtained is not suitable for indoor lighting. So it is not useful in houses.
2. For the necessary output, long tubes are required.
3. For giving full output, some time (about 10 minutes) is required.

9.5 Mercury Vapour Lamp

Fig. 9.4 shows mercury vapour lamp.

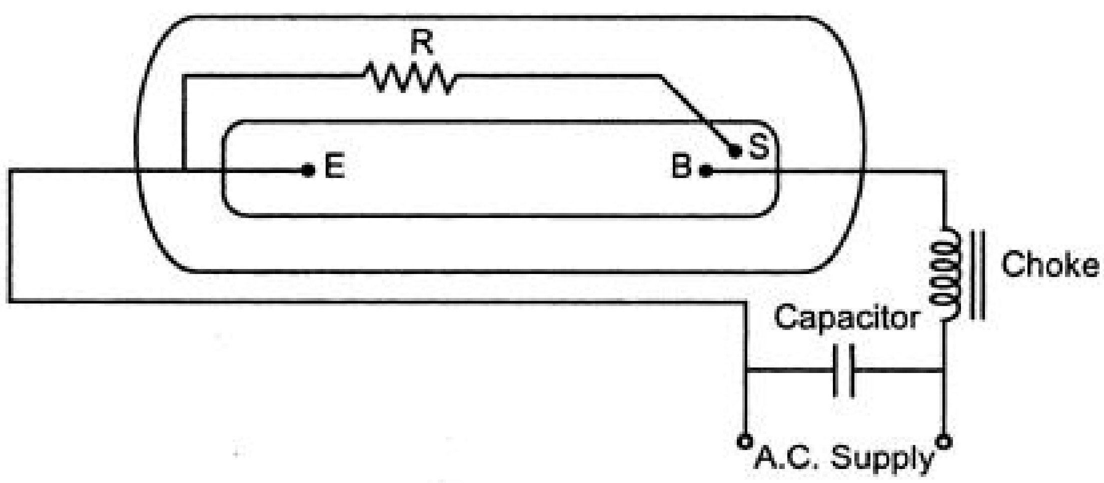


Fig. 9.4 Mercury vapour lamp

Construction : The lamp consists of two bulbs, inner bulb and outer bulb. The electric discharge takes place in the inner bulb. The outer bulb protects the inner bulb and reduces loss of heat. The inner bulb consists of a small amount of mercury and argon gas. The two electrodes E and B are made up of electron emitting material. Three electrodes B, E and S are provided in the inner bulb. The electrode 'E' is connected to electrode 'S' through a high resistance.

Choke (L) and capacitor (C) forms the control circuit of the lamp.

Working of mercury vapour lamp :

When the supply is switched ON, the initial discharge is established between electrodes B and S through the argon gas and then between electrodes B and E. The heat produced due to this discharge is sufficient to vapourise mercury and discharge through the mercury vapour takes place. In this normal operation of the lamp, it emits or radiates its characteristics light.

The electrode 'S' is called as starting electrode or auxilliary electrode. The choke serves to limit the current drawn by the electrodes to a safe limit. The capacitor C improves the power factor of the lamp.

These lamps are widely used for outdoor street lighting where a high illumination is necessary, where the colour of the light is not important.

Advantages :

1) It is high efficiency and gives more output.
2) It has long life.

Disadvantage :

1) The initial time required for warming up is more about 5 minutes.
2) If lamp goes out while in service, cooling is required for restarting. This cooling reduces the vapour pressure.

9.6 Important Definitions Related to Illumination

Before discussing about the various lighting schemes, it is necessary to be familiar with various terms used in illumination engineering.

Light is in the form of radiant energy. Similar to the sound waves, light waves are produced. Natural source of light is sun which emits both light waves and heat waves. In case of artificial light source, when temperature of incandescent material is increased it starts emitting light. It is convenient to measure the wavelength of light in much smaller unit than centimeter or meter. Such unit is called angstrom unit denoted as AU.

$$\boxed{1 \text{ AU} = 10^{-10} \text{ m}}$$

Key Point: *A visible light has wavelength of 4000 AU upto 7000 AU.*

9.6.1 Light

It is defined as that part of energy which is radiated from a body in the form of waves and sensed by human eyes.

9.6.2 Radiant Efficiency

A body radiates energy when its temperature is increased. The entire energy is not in the form of light but some may be in the form of other type of energy such as heat. So radiant efficiency is defined as the ratio of energy radiated as light by a body when its temperature is increased to the total energy radiated by the body.

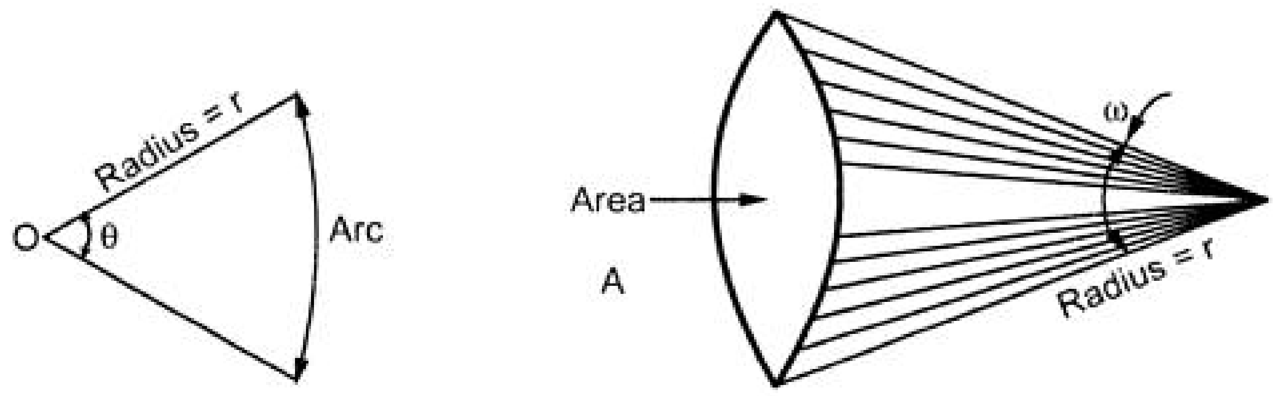
$$\text{Radiant efficiency} = \frac{\text{Energy radiated as a light energy}}{\text{Total energy radiated by the body}}$$

9.6.3 Plane Angle

The angle made by two straight lines meeting at a point lying in the same plane is called plane angle. It is measured in radians.

$$\text{Plane angle } \theta = \frac{\text{Arc}}{\text{Radius}} = \frac{S}{r} \text{ radians}$$

This is shown in the Fig. 9.5 (a).



(a) Plane angle (b) Solid angle

Fig. 9.5

9.6.4 Solid Angle

The angle subtended at a point in space by an area is called solid angle ω.

It is the angle generated by the lines passing through the point in space and periphery of the area. It is measured in **steradians**.

$$\text{Solid angle } \omega = \frac{\text{Area}}{(\text{radius})^2} = \frac{A}{r^2} \text{ steradians}$$

This is shown in the Fig. 9.5 (b).

9.6.5 Luminous Flux

It is the energy in the form of light waves radiated per second from a luminous body (such as lamp). It is denoted by ϕ and measured in lumens.

The whole of the electrical energy input is not converted into luminous flux. Some energy gets lost in conduction, convention and radiation. Out of the remaining radiant flux, only a fraction of flux is available in the form of luminous flux. The value of luminous flux specifies the output and efficiency of a given light source.

9.6.6 Luminous Intensity

It is a measure of the brightness for the source of light in comparison with the standard lamp.

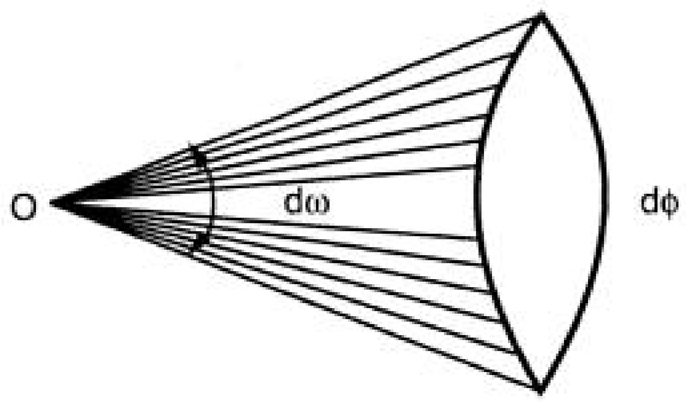


Fig. 9.6 Luminous intensity

The luminous intensity of a point source is defined as the luminous flux radiated out per unit solid angle, in that direction.

Consider a point source 'O' as shown in the Fig. 9.6.

Let $d\,\phi$ = the luminous flux passing through the solid angle $d\,\omega$ then the luminous intensity denoted as I is defined as

$$I = \frac{d\phi}{d\omega}$$

It is measured in **candela**.

Lumens emitted by one candela source of light is one lumen per steradian.

9.6.7 Illuminance or Illumination

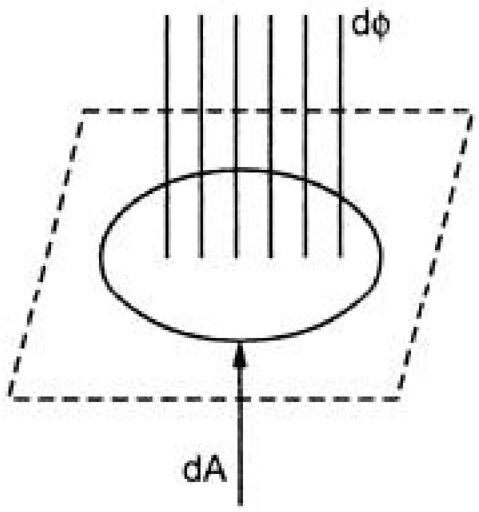


Fig. 9.7 Illumination

When a light or luminous flux falls on a surface gets illuminated. The illuminance is defined as the total luminous flux received by the surface received per unit area.

Consider the surface of area dA and receiving the total luminous flux of $d\,\phi$ lumens, as shown in the Fig. 9.7. Then the illumination denoted as E is defined as,

$$E = \frac{d\phi}{dA} \text{ lumens/m}^2$$

The unit lumens per square meter is also called **lux**.

The visibility becomes zero by rod cells at about 6000 AU, this effect is known as **purking effect**.

9.6.12 Mean Spherical Candle Power (M.S.C.P.)

It is the mean of candle powers in all the directions in all places.

$$\text{M.S.C.P} = \frac{\text{Total flux in all directions in all planes in lumen}}{4\pi}$$

9.6.13 Mean Half Spherical Candle Power (M.H.S.C.P.)

It is the mean of the candle powers in all the directions below a horizontal plane passing through the light source.

$$\text{M.H.S.C.P.} = \frac{\text{Total flux emitted in the hemispjhere}}{2\pi}$$

9.6.14 Different Units

i) Candela (cd) : It is seen that luminous intensity is measured in candela. One candel gives out luminous flux of 4π lumens in space. So one lumen per steradian is called light source of one candela.

It is also defined as the luminous intensity, in the perpendicular direction, of a surface of 1/600000 square meters of a black body at the temperature of freezing platinum under standard atmospheric pressure.

ii) Lumen (lm) : It is the unit of luminous flux. It is defined as the flux contained per unit solid angle of a source of one candela.

Hence for a uniform point source having a luminous intensity of I candelas, the total flux radiated is solid angle ω is,

$$\phi = I \times \omega \quad \text{lumens}$$

$$1 \text{ lumen} = 0.0016 \text{ watts}$$

iii) Lux : It is the unit of illumination. It is defined as lumens per square metres, (lm/m^2)

9.7 Laws of Illumination

9.7.1 Inverse Square Law of Illumination

The law states that the illumination at a point on any surface is inversely proportional to the square of the distance between the surface and the light source provided that the distance is sufficiently large so that source can be considered as a point source.

Proof : Let us consider surface of area A_1 and surface of area A_2 at a distance of r_1 and r_2 respectively from the point source 'O'. The luminous intensity of point source is I and all the rays of light are reaching the surface, normally. Let the solid angle subtended by both the surfaces at 'O' is ω steradians as shown in the Fig. 9.9.

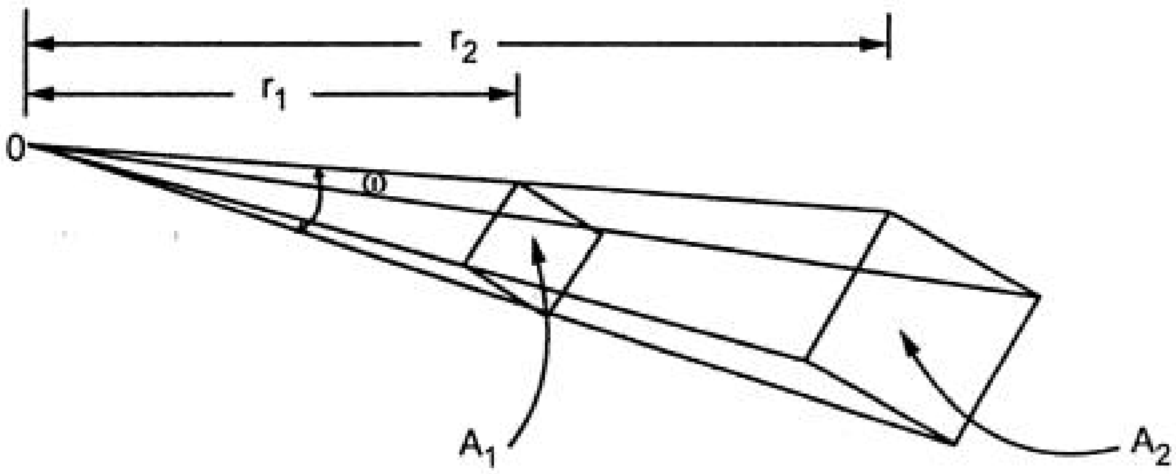


Fig. 9.9 Inverse square law

Luminous flux radiated in ω steradians

$$= I \times \omega \text{ lm}$$

Now $\omega = \frac{A}{r^2}$ where A = area

$\therefore$ $A_1 = \omega \times r_1^2$

$\therefore$ $A_2 = \omega \times r_2^2$

$\therefore$ Illumination on surface of area $A_1 = \frac{\text{flux}}{\text{area}}$

$$= \frac{I\omega}{A_1} \text{ lm/m}^2$$

$\therefore$ $E_1 = \frac{I}{r_1^2}$

and illumination on surface of area $A_2 = \frac{\text{flux}}{\text{area}}$

$$= \frac{I\omega}{A_2} \text{ lm/m}^2 = \frac{I\omega}{r_2^2 \omega}$$

$$E_2 = \frac{I}{r_2^2}$$

$\therefore$ $$\boxed{\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}}$$

The above equation proves that illumination at a point on surface is inversely proportional to the square of its distance from the point source.

9.7.2 Lambert's Cosine Law

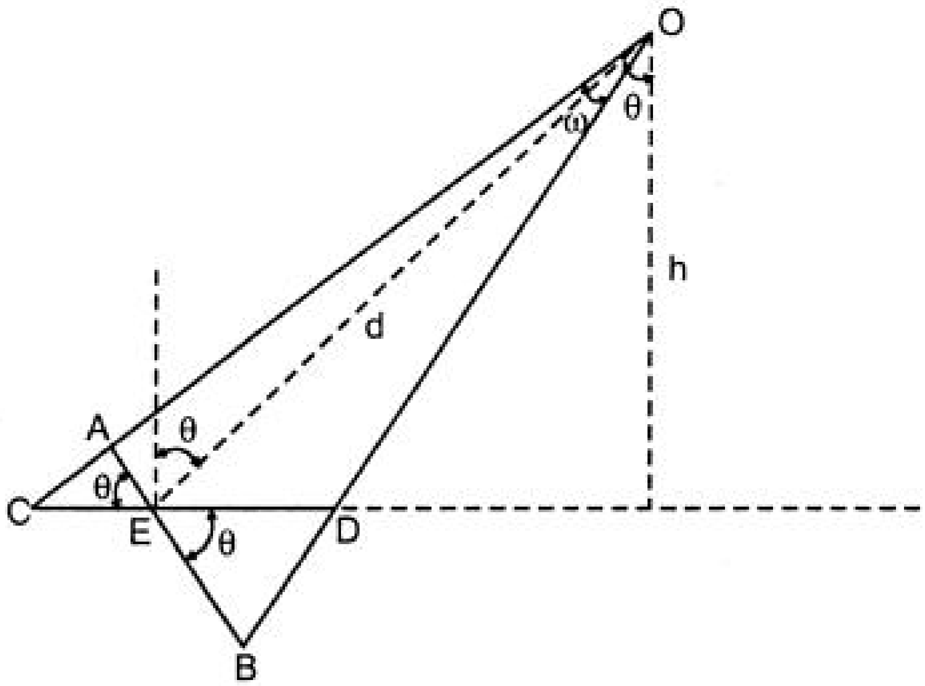


Fig. 9.10 Lambert's cosine law

If rays falling on the surface are normal to the surface, illumination is maximum. But if surface is inclined to the light falling on it, illumination is less. Related to this Lambert's cosine law states that the illumination at a point on any surface is proportional to the cosine of angle which the incident luminous flux makes with the normal to the surface at that point.

Proof : Let 'O' be the point source at height 'h' from the plain containing the surface CD. Let 'E' be the centre point of the surface CD. Let 'E' be the centre point of the surface CD which subtends solid angle ω at the source of light as shown in the Fig. 9.10.

Let AB be the surface perpendicular to EO.

$$\therefore \qquad AB = CD \cos\theta$$

Illumination of AB,
$$E_{AB} = \frac{\text{Flux}}{\text{Area}} = \frac{I\times\omega}{\text{Area AB}}$$

Illumination of CD,
$$E_{CD} = \frac{I\times\omega}{\text{Area CD}} = \frac{I\times\omega}{\left(\dfrac{\text{Area AB}}{\cos\theta}\right)} = \frac{I\times\omega}{\text{Area AB}}\times\cos\theta$$

$$= E_{AB}\times\cos\theta$$

$$\therefore \qquad \boxed{E_{CD} = E_{AB}\times\cos\theta}$$

The above equation states that the illumination at a point on a surface is proportional to cosine of the angle which ray makes with the normal to the surface at that point.

9.7.3 Cosine Cube Law

From the Fig. 9.10 it can be seen that the vertical height of the source 'O' from the horizontal surface,

$$h = d\cos\theta$$

Now Illumination of CD $= \frac{I \times \omega}{\text{Area AB}} \times \cos\theta = \frac{I}{\left(\frac{\text{Area AB}}{\omega}\right)} \times \cos\theta$

$$= \frac{I}{d^2}\cos\theta \quad \text{... by using inverse square law}$$

$$= \frac{I}{h^2 / \cos^2\theta} \times \cos\theta \text{ ... by using } d = \frac{h}{\cos\theta}$$

$$\boxed{E_{CD} = \frac{I}{h^2} \times \cos^3\theta}$$

This expression is called **cosine cube law**.

9.8 Requirements of a Good Lighting Scheme

Following are the various requirements which are to be considered for a good lighting scheme.

9.8.1 Illumination Level

The level of illumination depends on the nature of the work to be carried out. The degree of level of illumination also depends on following factors :

1. The size of the object and its distance from the observer. For smaller objects higher illumination is necessary. Similarly for greater distance of objects from an observer higher illumination level is must.
2. If the object is moving greater level of illumination is necessary than the stationary object.
3. If the contrast between the colour of the object and its background is greater, the illumination level required to distinguish the details of the object is less. However better illumination sharpens the contrast.
4. If the objects are required to be seen for long duration of time, greater level of illumination is necessary. So corridors, staircases require less level of illumination.

9.8.2 Glare

It is mentioned earlier that glare causes unnecessary eye fatigue so it must be avoided. It can be prevented by using diffusing glass screens, suitable reflectors and proper mounting heights. Reflected glare from the polished surfaces within the line of vision should also be avoided.

9.8.3 Shadows

The formation of long and hard shadows must be avoided. The hard and long shadows often cause accidents. Such long shadows can be avoided by :

1. Using proper mounting heights of lamp

2. Using more number of lamps and providing indirect lighting.
3. Employing wide surface sources of light.

Complete absence of shadows is again not recommendable as soft shadows do help us in recognizing the shapes of three dimensional objects.

9.8.4 Colour Rendering

Light given out by incandescent lamp contains all the wave lengths in visible spectrum. Due to such mixture of the radiations, it causes colour distortion. This type of colour distortion by artificial light makes it sometimes difficult to identify true colour of the object. Lighting arrangements required for buying of food stuffs, preparation of paints, colour matching of fabrics in textile industries must be so as to avoid the colour distortion. Sodium and mercury vapour lamps cause the colour distortion and hence are in used for street lighting where such type of colour distortion would not matter much.

9.8.5 Lamp Fittings

Lamp fittings serve the following functions in good lighting schems :

1. To diffuse the light
2. To cut off the light at certain angles to avoid the glare.
3. To give mechanical protection to the light source against mechanical damage.
4. To increase the aesthetical requirements of the premises.
5. To control the colour of the lights.

Hence lamp fitting should be selected as per the requirements of the application which will serve all or few of the above mentioned functions.

9.8.6 Maintenance

Regular cleaning of lights and light fittings is necessary to maintain their efficiency. The maintenance is necessary against dust, water leakage, dangerous gases which may cause the corrosion of the fittings etc. Hence lamp fittings should therefore be simple and easy from maintenance point of view.

9.9 Factors Affecting Design Procedure of Good Lighting Scheme

The design procedure of a good lighting scheme involves the calculation of the light requirements. For doing such calculations it is important to know the following factors :

9.9.1 Space to Height Ratio

It is defined as the ratio of horizontal distance between lamps and the mounting height of the lamps.

$$\text{Space to height ratio} = \frac{\text{The horizontal distance between lamps}}{\text{Mounting height of lamps}}$$

This ratio depends upon the polar curves of the source of light. This ratio is generally choosen for reflectors as 1 to 2.

9.9.2 Coefficient of Utilization i.e. Utilization Factor

All the light emitted by the source cannot reach on the working plane.

Utilization factor is defined as the ratio of the light actually received on the working place to the total light emitted by the light source.

$$\text{U.F.} = \frac{\text{Total lumens utilised on working planes}}{\text{Total lumens radiated by lamp}}$$

Its value depends on the following factors :

1. The height at which the lamps are fitted.
2. The type of the lighting scheme employed.
3. The shape and size of the room.
4. The colour of the walls.
5. The area of the illuminated.

Its value may vary between 0.1 to 0.9. For direct lighting schemes it lies between 0.4 to 0.8 while for indirect lighting schemes it is between 0.1 to 0.35.

9.9.3 Depreciation Factor

This factor takes into account the effect of ageing of the lamps, accumulation of dirt, dust, smoke on the surface of the lamps etc. Due to these factors the effectiveness of the lamps reduces.

The factor is defined as the ratio of the illumination under normal working conditions to the illumination under the conditions when the lamps are new and everything is perfectly clean.

$$\text{D.F.} = \frac{\text{Illumination under normal working conditions}}{\text{Illumination under new and clean lamp conditions}}$$

The value of the factor is generally between 0.7 to 0.85.

9.9.4 Waste Light Factor

When more lamps are provided than the actual requirements so that the light from various lamps get overlapped. So there is wastage of light. Hence while calculating total lumens required it is necessary to multiply the lumens by this factor called as waste light factor. Value of this is 1.2 for rectangular areas and 1.5 for irregular surfaces.

9.10.1 Direct Lighting

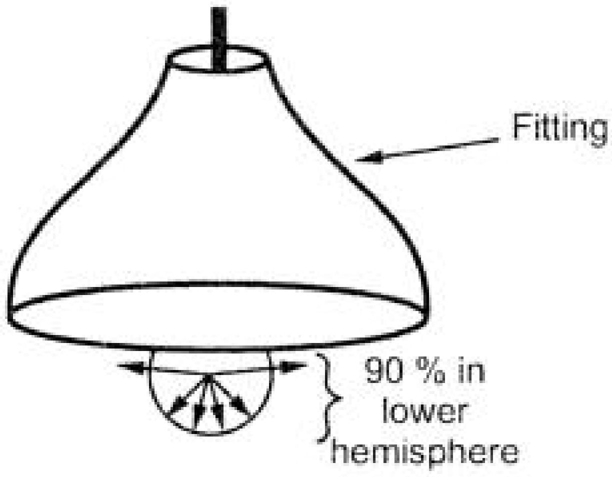


Fig. 9.11 Direct lighting

In this type of lighting, the most of the light from the lamps is directed towards the object using various light fitting. The fitting used in such scheme are as shown in the Fig. 9.11.

Here 90 % to 100 % light of lamp is in lower hemisphere as shown. These fittings are efficient, cheap and give hard light. These fittings create tunneling effect i.e. ceiling remains dark. Commonly used in industries, residential and commercial buildings.

9.10.2 Semi-Direct Lighting

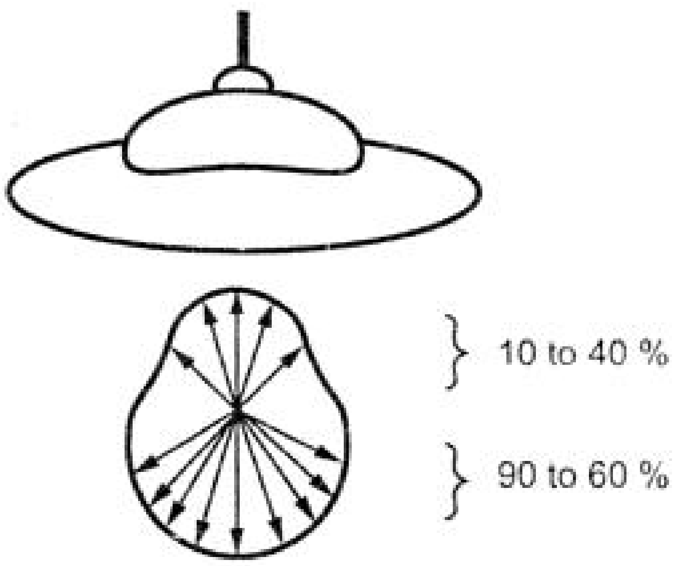


Fig. 9.12 Semi-direct lighting

In such scheme entire light is not directed towards the object or working plane. By using translucent reflectors as shown in the Fig. 9.12, 60 to 90 % of light is directed towards the object. So 60 to 90 % light is in lower hemisphere while 10 to 40 % light is in upper hemisphere as shown in the Fig. 9.12.

These fittings reduce the tunneling effect. This provides more uniform distribution of light. These are less efficient than direct and are more suitable for commercial use.

9.10.3 Indirect Lighting

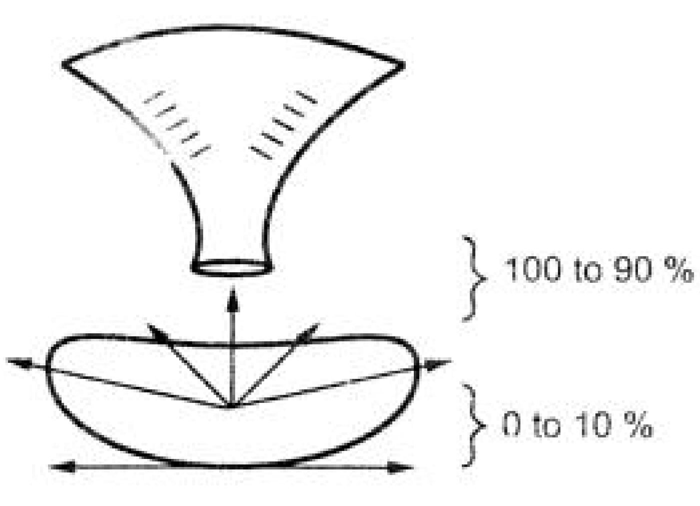


Fig. 9.13 Indirect lighting

In this method, the light does not reach the working plane directly from the lamps. It is all reflected on the walls and ceiling from where it is indirectly reached to the working plane. This is called as diffused reflection.

In this 0 to 10 % of light is in the lower hemisphere and 90 to 100 % is in upper hemisphere as shown in the Fig. 9.13. The advantage of this method is it gives no shadows and no glare. It is used in shops, hotels, drawing offices and workshops.

9.10.4 Semi-Indirect Lighting

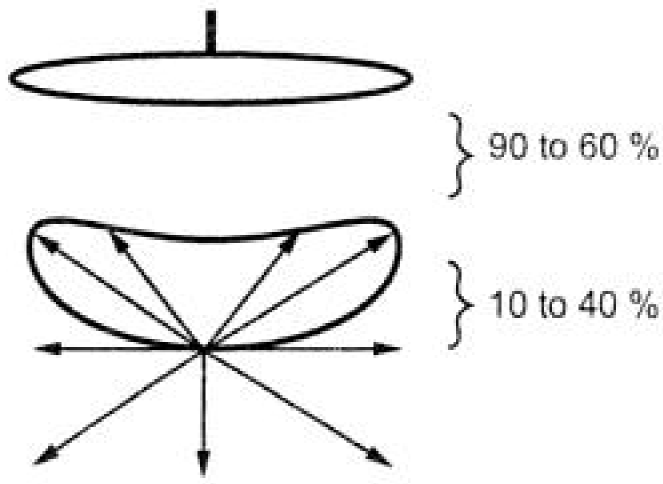


Fig. 9.14 Semi-indirect lighting

In this method, 10 to 40% light is directed towards the working plane and 60 to 90% light is reflected towards the walls and ceiling for diffused reflection.

The inverted type of reflectors are used for this purpose as shown in the Fig. 9.14. This method gives soft shadows and is more efficient than indirect lighting.

9.10.5 General Lighting

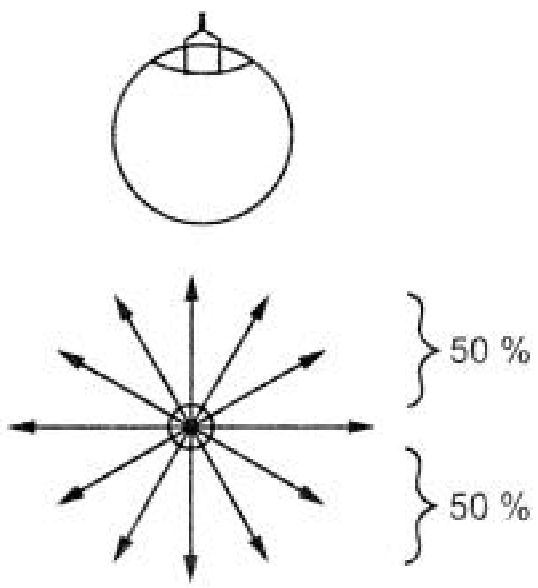
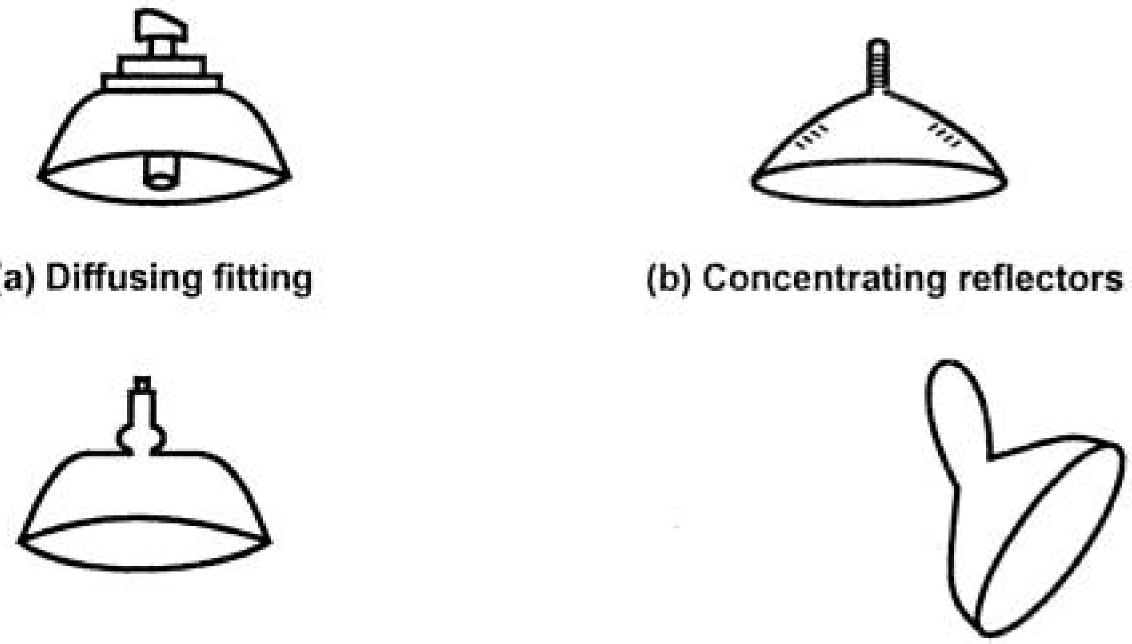


Fig. 9.15 General lighting

This method gives equal distribution of light in all the directions, upward and downwards. The reflectors used are in such a way that 50% of light is in either of hemisphere. This is shown in the Fig. 9.15. This helps in reducing the brightness contrast. This method gives soft light with little shadows. With this method room decoration should be in light colours. Also mounting height of the lamps should be so as to avoid glare. These are used in offices, schools and commercial buildings.

9.11 Factory Lighting

Sufficient lighting of factories is of very much important. Not only it provides improved amenities for the employee but it also provides pleasent working conditions for the workers. The factor lighting should be uniform and glare free. The sufficient lighting increases the production, improves the quality of the work and also reduces the accidents. The proper space to height ratio must be considered which ensures the uniform distribution of the light over the working area. Suitable colour rendering property must be considered i.e. the walls and ceilings must be light coloured preferably white to have maximum reflection of light. If factory has a crane, lamps over the crane may not provide sufficient light. In such cases hanging lamps and side lamps must be provided. Depending upon the nature of factory, the factory environment is likely to be dusty, smoky hence regular maintenance including cleaning of light fittings and lamp surfaces is must. For



(a) Diffusing fitting (b) Concentrating reflectors

(c) Dispersive reflector (d) Angle reflectors

Fig. 9.16 Industrial light fittings

9.12.2 Concentrating Reflectors

These have a shape of deep parabola. The space to height ratio required is one to get uniform distribution of light. Waste light factor is more in such cases. It is suitable for high mounting height as required in workshops and industries having electric overhead cranes. Fig. 9.16 (b).

9.12.3 Dispersive Reflectors

This is most commonly used in industries. The space to height ratio is one and half, which gives uniform illumination. These are preferred for moderate ceiling height. The lamps rated 40 to 1500 W are fixed inside the reflectors. Fig. 9.16 (c)

9.12.4 Angle Reflectors

The vertical surfaces can not be illuminated by normal overhead lamps, in such cases angle reflectors are used. These are available in various shapes like parabolic, elliptical etc. The choice depends on the requirement of illumination. Fig. 9.16 (d).

9.13 Flood Lighting

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

i) Aesthetic flood lighting : It is used for enhancing beauty of buildings at night, ancient buildings and monuments, churches, gardens etc.

ii) Industrial and commercial flood lighting : It is used for illuminating railway yards, art stadiums, car parking areas etc.

iii) Advertising : It is used for illuminating advertisements and show cases at night

The main element of the flood lighting is the projector.

9.13.1 The Projector

The projector called flood light projector concentrates the light form the lamp into a relatively narrow beam. It is usually installed out of doors and in inaccessible positions.

The most important part of the projector is its reflecting surface. This may be of silvered glass, stainless steel or chromium plates. The polished metal is more robust and preferred for reflecting surfaces.

Beam spread : Beam spread indicates amount of divergence of the beam and is defined as the angle within which the minimum illumination on a surface normal to the axis of the beam is $1/10^{th}$ of the maximum.

The casing and mounting must be arranged so that the illumination of the beam can be varied in both horizontal and vertical directions. For permanent installations cast metal cases are used. For temporary installations sheet metal casings are used. Large wattage lamps produce tremendous heat hence for the projectors using lamps of 100 to 1000 W must be provided the proper ventilating accessories.

9.13.2 Types of Projectors

Projectors are classified according to the beam spread as follows :

i) Narrow beam projectors : These are having beam spread of 12° to 25° and are used for distance above 70 m.

ii) Medium angle projectors : These are having beam spread of 25° to 40°. They are used for distances between 30 to 70 m.

iii) Wide angle projectors : These are having beam spread of 40° to 90° and are used for distances between 3 to 30 m.

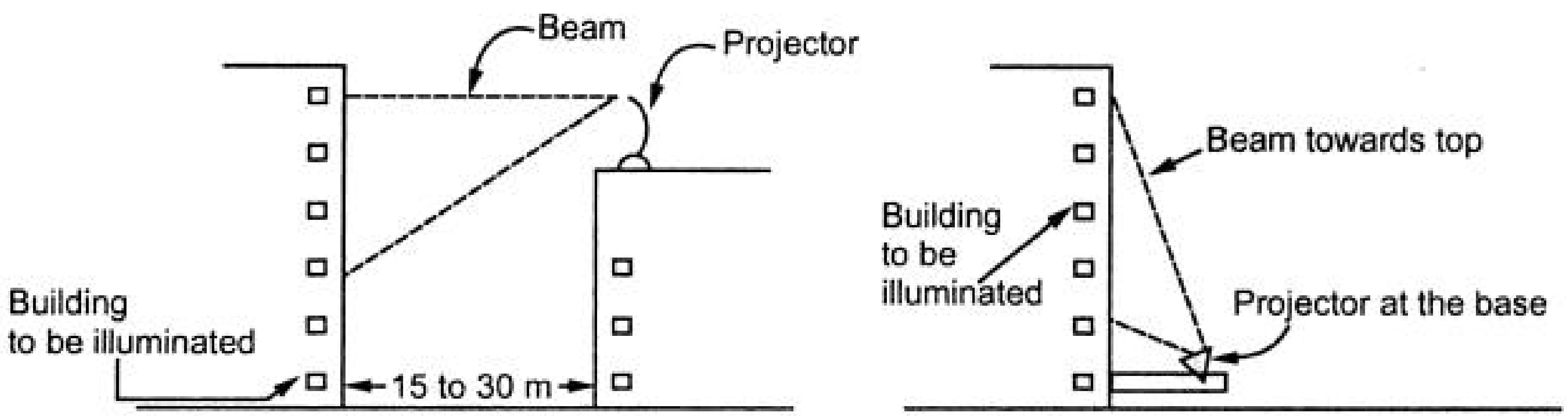
For economic reasons use of wide angle projectors with high wattage lamp is encouraged over narrow beam projectors. High wattage lamp is more efficient than low wattage lamp, used is narrow beam projectors.

9.13.3 Location and Mounting of Projectors

Success of flood lighting depends on choice of suitable sites for the projectors. The source of light must be invisible to the observer and projector must be invisible during the day time. Care must be taken about the shadow cast by projections on the illuminated building.

In long range installation, the projectors are mounted on the adjacent building or at ground level about 15 to 30 m away from the building to be illuminated. The parallel beam is generally used in such situations. This is shown in the Fig. 9.17 (a) . The parabolic reflector is used.

In short range installation, the projector has to be located near the base of the building to be illuminated. An asymmetric reflector is used, which directs more intense light towards the top of the building. This is shown in the Fig. 9.17 (b).



(a) Long range installation (b) Short range installation

Fig. 9.17

9.13.4 Flood Lighting Calculations

i) Illumination level required : The illumination level in lux (lm/m^2) required depends on the type of building, the purpose of flood lighting, the amount of reflecting light in the vicinity etc.

ii) Type of projector : Beam spread, long range or short range installation and light output necessary decides the type of projector to be used.

iii) Number of projectors : For any desired intensity over a definite surface area, the number of projectors can be obtained by using following relation,

$$N = \frac{A \times E \times \text{Depreciation factor} \times \text{Waste light factor}}{\text{Beam factor} \times \text{Utilization factor} \times \text{Wattage of lamp} \times \text{Luminous efficiency of lamps}}$$

where N = Number of projectors

A = Area of surface to be illuminated in m^2

E = Illumination level required in lm/m^2

Depreciation factor must be used in denominator if its value is less than one or in numerator if greater than one.

9.14 Street Lighting

The street lighting is basically essential for the pedestrians and the vehicle drivers to see the obstructions clearly. The features of the street lighting are, Colour and decoration of walls and ceiling is deciding factor for the portion of light to be reflected. Mounting height of lamp also plays an important role. To avoid glare and long shadows, the lamp should be mounted 8 feet above floor. The cleaning and relamping becomes more dificult as ordinary step ladder can not be used above 12 feet height. Hence mounting height of lamps should be between 8 to 12 feet to avoid special arrangements for its access. In certain cases, the positions of beams and trusses is fixed which decides to some extent the spacing of lamps so that mounting height lamps can be decided.

4) Colour of light

Appearance of body colour depends on incident light composition which should be such that colour appears natural. For certain applications colour of light is not important. But if components are to be distinguished from each other by their colours then colour of light is important consideration. In such cases highly efficient discharge lamps may be used.

5) Financial aspects

Economy plays an important role while designing indoor lighting scheme. Installation cost depends on type and fitting used for lamp. Discharge lamps are more efficient but more costly than filament lamps. For lower rate of electricity and for few working hours in a year, better way is to use filament lamp than discharge lamps which may be used for higher rate and more working hours. The cleaning and maintenance cost along with reclamping cost must be taken into account. For more mounting height this cost may be more. Overall cost of lighting scheme should be economical with high energy efficiency, good life span and having good appearance.

By considering all the above factors final choice about the installation and design of lighting scheme must be made after careful study of each installation independently and taking into consideration the previous experience.

Examples with Solutions

Example 9.1 : *An illumination on the working plane of 70 lux is required in a room 72 m × 15 m in size. The lamps are required to hung 4 m above working plane. Assuming suitable space to height ratio, utilisation factor of 0.5, efficiency of lamp as 14 lumens per watt and depreciation of 20 %, estimate the number, rating and position of lamps.*

Solution : Area of room = $72 \times 15 = 1080 \text{ m}^2$

Illumination required, E = 70 lux

$$\text{Lumens required} = A \times E = 1080 \times 70$$

$$\text{Utilisation factor} = 0.5$$

$$\text{Depreciation factor} = 1 - \text{depreciation} = 1 - 0.2 = 0.8$$

$$\text{Gross lumens} = \frac{A \times E}{\text{Utilisation factor} \times \text{Depreciation factor}}$$

$$= \frac{1080 \times 70}{0.5 \times 0.8}$$

$$= 189000$$

$$\text{Total wattage required} = \frac{189000}{14} = 13{,}500 \text{ watts}$$

Assuming space to height ratio as 1. As mounting height is 4 m spacing should be also 4 m to get ratio 1. Let us assume number of lamps to be 72 with spacing in between the lamps as 4 m. The spacing is shown in the Fig. 9.19.

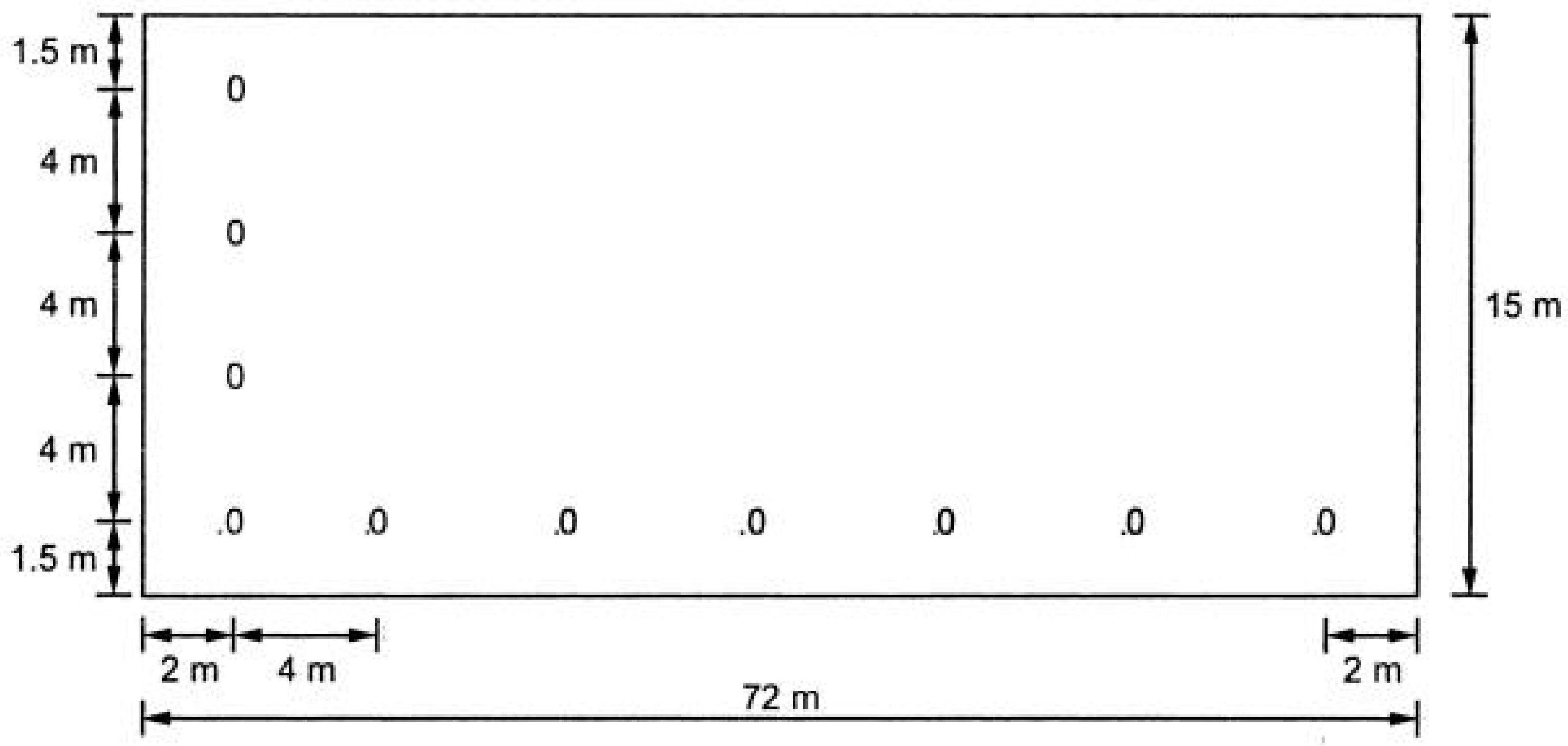


Fig. 9.19

There are 4 rows of lamps. In each row there are 18 lamps situated at a distance of 4 m from each other.

$$\text{Rating of lamp} = \frac{\text{Total wattage required}}{\text{Total no. of lamps}}$$

$$= \frac{13{,}500}{72}$$

$$= 187.5 \text{ watt}$$

Hence the lamps with rating of **200 W** should be selected.