1.7 BASIC DESIGN OF ILLUMINATION SCHEMES

Depending upon the requirements and the way of light reaching the surface, Lighting schemes are classified as follows,

(i) Direct lighting

(ii) Semidirect lighting

(iii) Indirect lighting

(iv) Semi – indirect lighting and

(v) General lighting.

Direct lighting:

In the direct lighting system, the luminaries direct the 90 to 100% of the light output of the lamp towards downward (light falls just below the lamp). This scheme is more efficient but it suffers from hard shadows and glare. It is mainly used for industrial and general outdoor lighting.

Semidirect lighting scheme:

In semidirect lighting scheme, about 60 – 90% lamps luminous flux is made to fall downwards 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. This scheme will improve not only the brightness but also the efficiency.

Indirect lighting schemes:

In this lighting scheme, 90% of the light output from the lamp is directed upward to the ceiling and upper side of walls and reflected back to the working plane area. In such scheme, the ceiling acts as the lighting source and glare is reduced to minimum.

Semi – indirect lighting scheme.

In semi – indirect lighting scheme, the luminaries direct the light output of the lamp partially (10 to 30%) downward, but with a major portion of light output (70 to 90 %) upward. Glare will be completely eliminated with such type of lighting scheme. This scheme is widely preferred for indoor lighting decoration purpose.

General lighting scheme:

In this scheme, lamps made of diffusing glass are used which are nearly 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 Figure.

RESIDENTIAL LIGHTING

The light in home can be peaceful, comfortable, romantic and intimate or cheerful and festive. Light can turn strangers away and welcome friends inside. Options for lighting each room are as varied as the colours of paint and features of carpet selected. Rating of lamps for illuminating a lightly coloured drawing room of size 8m long, 3m wide 3.5 m high. Following data may be assumed:

- Required illumination level 100 lumens/m2
- Coefficient of utilisation on horizontal plane 0.5
- Type of lamps - standard fluorescent lamps: 40 W, 1600 W per lamp.

COMMERCIAL LIGHTING

In commercial shopping complex, each shop has a different image to convey and different product to sell. Each aspect of a shop should be carefully designed with its client or customers in mind. Shops also carry their own identity. Lighting supports a shop in its identity, shows off the shop's merchandise to its best advantage, serving as a true magnet, drawing customers into the shop and persuading them to buy. Recommended lamps for commercial buildings

- For general purpose lighting – Fluorescent Lamps
- For display lighting – LV Halogen Lamp
- For boarding & hoarding – Metal Halide Lamp
- For textile shops – Filament/LV Halogen Lamp

STREET LIGHTING

The main objectives of the street lighting are 1. to make the street more attractive, so that obstructions on the road is clearly visible to the drivers of vehicles, 2. to increase the community value of the street, 3. to clear the traffic easily in order to promote safety and convenience. The two basic principles are usually employed for the street lighting design are given below:

Diffusion principle:

In this method, light is directed downwards from the lamp by the suitably designed reflectors. The design of these reflectors is in such a way that they may reflect total light over the road surface uniformly as much as possible. The reflectors are made to have a cut off between 30o and 45o, so that the filament of the lamp is not visible expect just below the source, which results in eliminating glare. Illumination at any point on the road surface is calculated by applying inverse square law (or) point-by-point method.

Specular reflection principle:

The specular reflection principle enables a motorist to see an object about 30 m ahead. In this case, the reflectors are curved upwards, so that the light a thrown on the road at a very large angle of incidence. This can be explained with the help of Figure. An object resides over the road at 'P' in between the lamps S1, S2 and S3 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:

Normally illumination required depends upon the class of street lighting installation. The illumination required for different areas of street lighting are given in table.

S. No.	Area	Illumination (lumens/m^2)
1	Road junction and important shopping centres	30
2	Poorly lighted sub-urban streets	4
3	Average well-lighted street	8-15

Mounting height: Normally spacing for the standard lamps is 50 m with a mounting height of 8m. Lamp posts should be fixed at the junctions of roads.

Types of lamps: Mercury vapor and sodium vapor discharge lamps are preferable for street lighting. Since, the overall cost of the installation of discharge lamps are less than the filament lamps and also the less power consumption for a given amount of power output.

S. No.	Area	Illumination (lumens/m^2)
1	Single side mounting	Not for straight roads Recommended for bends with radius less than 75H, H-height of mounting Mounting outside the bend
2	Opposite mounting	Superior to other three methods More number of lamps Uniform illumination on road surface Used for very wide roads
3	Staggered arrangement	Lamps on alternate columns on the opposite side of central strip Suitable and economical for road width of 15m between two foot oaths at extreme ends
4	Central mounting	A central lamp post has two lamps back to back Used for very wide roads May be supplemented by staggered or opposite arrangement

FACTORY LIGHTING

Industry (or) factory lighting must satisfy the following aspects.

1. The quality of work is to be improved
2. Accidents must be reduced.
3. The productivity of labour should be increased.

The above requirements can be meet by the factory lighting only when the lighting schemes provides: (i) Adequate illumination on the working plane, (ii) Minimum glare, (iii) Clean and effective source fitting, and (iv) Uniform distribution of light over the working plane. The lamps used for factory lighting are fitted with specially designed reflectors and they can be easily cleaned.

- Industrial lighting fittings
- Standard reflectors
- Diffusing fittings
- Concentrating diffusing fittings
- Angle reflectors.

FLOOD LIGHTING

Flood lighting means flooding of large surfaces with light from powerful projectors. A special reflector and housing are employed in flood lighting in order to concentrate the light emitted from the lamp into a relatively marrow beam, which is known as flood lighting projector. It is employed to serve one or more of the following purposes.

1. Aesthetic flood lighting:

For enhancing beauty of building at night such as public places, ancient buildings and monuments, religious buildings on important festive occasions etc.

2. Industrial and commercial flood lighting

For illuminating railway yards, sports stadium, car parks, construction sites, quarries etc.

3. Advertising

They are used for illuminating showcases and advertisement boards and for the decoration of houses etc. The projectors of floodlighting schemes are classified into

(a) Narrow beam projectors

(b) Medium angle projectors

(c) Wide angle projectors.

Flood Lighting Calculation

While calculating the number of projectors required for flood lightings, it is necessary to know the level of illumination required and it is depending on the type of building and the purpose of floodlighting. And also the type of projector and the selection of projector depend upon the beam size as well as the light output. The three steps of lighting calculations are,

Step 1 : Illumination level required

Step 2 : Type of projector

Step 3 : Number of projector

1. Illumination level required:

The Illumination level in lumens/m2 required depends upon the type of building, the purpose of the flood lighting. The amount of conflicting light in the vicinity etc.

2. Type of projector:

Based on beam size, light output, the choice of projector is made. The beam size determines the area covered by the beam and the latter the illumination provided.

3. Number of projectors:

$$N = \frac{A \times E \times DF \times Waste\ light\ factor}{UF \times Wastage\ of\ lamp \times Luminous\ efficiency\ of\ lamp}$$

1.9 ENERGY EFFICIENT LAMPS

Electric lighting burns up to 25% of the average home energy budget. The electricity used over the lifetime of a single incandescent bulb costs 5 to 10 times the original purchase price of the bulb itself. Light Emitting Diode (LED) and Compact Fluorescent Lights (CFL) bulbs have revolutionized energy-efficient lighting. CFLs are simply miniature versions of full-sized fluorescents. They screw into standard lamp socket s, and give off light that looks similar to the common incandescent bulbs - not like the fluorescent lighting we associate with factories and schools. LEDs are small, very efficient solid bulbs. New LED bulbs are grouped in clusters with diffuser lenses which have broadened the applications for LED use in the home. LED technology is advancing rapidly, with many new bulb st yles available. Initially more expensive than CFLs, LEDs bring more value since they last longer. Also, the price of LED bulbs is going down each year as the manufacturing technology continues to improve.

BCFL Lighting: Benefits

Efficient: CFLs are four times more efficient and last up to 10 times longer than incandescents. A 22 watt CFL has about the same light output as a 100 watt incandescent. CFLs use 50 - 80% less energy than incandescents.

Less Expensive: Although initially more expensive, you save money in the long run because CFLs use 1/3 the electricity and last up to 10 times as long as incandescents. A single 18 watt CFL used in place of a 75 watt incandescent will save about 570 kWh over its lifetime. At 8 cents per kWh, that equates to a $45 savings.

Reduces Air and Water Pollution: Replacing a single incandescent bulb with a CFL will keep a half-ton of CO_2 out of the atmosphere over the life of the bulb. If everyone in the U.S. used energy-efficient lighting, we could retire 90 average size power plants. Saving electricity reduces CO_2 emissions, sulfur oxide and high-level nuclear waste.

High-Quality Light: Newer CFLs give a warm, inviting light instead of the “cool white” light of older fluorescents. They use rare earth phosphors for excellent color and warmth. New electronically ballasted CFLs don’t flicker or hum.

Versatile: CFLs can be applied nearly anywhere that incandescent lights are used. Energy-efficient CFLs can be used in recessed fixtures, table lamps, track lighting, ceiling fixtures and porchlights. 3-way CFLs are also now available for lamps with 3-way settings. Dimmable CFLs are also available for lights using a dimmer switch

Choosing a CFL

CFLs come in many shapes and sizes. When purchasing CFLs, consult the seller for recommendations and consider the following: Choose your preferred light quality CFL bulbs have a Kelvin or 'K' number listed on the packaging. CFLs with K numbers between 2700-3000 give off a soft bright light like incandescent. CFLs with K numbers between 3500-6000 give off a bright light. As you go up the K number scale the light gets bluish and closer to daylight.

For example:

Approx. 2700K = Warm White (looks just like incandescent)

Approx. 5000K = CoolWhite (white/blue, bright light)

Choose the shape. CFLs are available in a variety of shapes to fit a range of lamps and lighting fixtures. See below on this page for the most popular CFL shapes. Match lumens to the incandescent being replaced. Lumens indicate the amount of light being generated. (Watts is a measure of energy use, not light strength.) Lumen output is printed on the bulb package or on the bulb product page if purchasing bulbs online.

CFL Light Bulb Models

CFLs are available in a variety of styles or shapes. Some have two, four, or six tubes. Older models, and specialty models, have separate tubes and ballasts. Some CFLs have the tubes and ballast permanently connected. This allows you to change the tubes without changing the ballast. Others have circular or spiral-shaped tubes. In general, the size or total surface area of the tube determines how much light the bulb produces. The following CFL bulb models come with standard sockets for easy installation in most common household applications.

1. Spiral Lamps

These bulbs are designed as a continuous tube in a spiral shape which has similar outside shape and light casting qualities to a standard incandescent bulb. Spiral CFL bulbs are made in several sizes to fit most common fixtures.

2. Triple Tube Lamps

These CFLs have more tubing in a smaller area, which generates even more light in a shorter bulb. They pack high light output into a very small space and can be used in fixtures designed for incandescent bulbs, such as table lamps, reading lamps, open hanging lamps, and bare bulb applications.

3. Standard Lamps

These are regular CFL spiral lamps which are placed inside a dome cover and fitted with a standard base which fits common lamp sockets. They are designed to give the appearance of the traditional light bulb for consumers looking for the more familiar light bulb appearance. The glass diffuser provides a quality of light similar to the 'soft-white' type of incandescent bulbs.

4. Globe Lamps

This shape is commonly used in bathroom vanity mirrors or open hanging lamps, and bare bulb applications. Bathroom vanities usually require multiple bulbs, which generate radiant heat. The CFL globe will reduce this heat buildup while saving energy. The glass diffuser provides a soft-white light.

5. Flood Lamps

These lamps are designed to be ideal for recessed and track lighting fixtures, indoors and outdoors. They provide diffused, soft, white light, and generate less heat than will an incandescent flood or a halogen bulb. CFL flood lamps are available in varying sizes and wattages.

6. Candelabra

The screw-in torpedo-shape and the small-base of this bulb is designed for smaller light fixtures throughout the house, from chandeliers to sconces. To use a smaller candelabra-based bulb in a regular socket, you can use a socket reducer.

Limitations of CFL lightbulbs

Although CFLs are an excellent source of energy-efficient lighting, they are not always the best choice for all lighting applications. Here are a few limitations to consider:

On/Off cycling: CFLs are sensitive to frequent on/off cycling. Their rated lifetimes of 10,000 hours are reduced in applications where the light is switched on and off very often.

Closets and other places where lights are needed for brief illumination should use incandescent or LED bulbs.

Dimmers: Dimmable CFLs are available for lights using a dimmer switch, but check the package; not all CFLs can be used on dimmer switches. Using a regular CFL with a dimmer can shorten the bulb life span.

Outdoors: CFLs can be used outdoors, but should be covered or shaded from the elements. Low temperatures may reduce light levels - check the package label to see if the bulb is suited for outdoor use.

Retail lighting: CFLs are not spot lights. Retail store display lighting usually requires narrow focus beams for stronger spot lighting. CFLs are better for area lighting.

Mercury content: CFLs contain small amounts of mercury which is a toxic metal. This metal may be released if the bulb is broken, or during disposal. For more information about mercury and CFLs, see below. The principle reason for reduced lifespan of CFLs is heat. CFLs exhibit shorter lifespans in light fixtures and sockets where there is low air-flow and heat build-up such as recessed lighting. For these types of sockets, it is recommended to use specially designed CFLs for recessed lighting or LEDs. Another main reason for reduced lifespan of CFLs is too-frequent on/off cycling. These bulbs should be used where they will be left on for steady periods without being flicked on and off.

Mercury and CFLs

Mercury is a toxic metal associated with contamination of water, fish, and food supplies, and can lead to adverse health effects. A CFL bulb generally contains an average of 5 mg of mercury (about one-fifth of that found in the average watch battery, and less than 1/100th of the mercury found in an amalgam dental filling). A power plant will emit 10mg of mercury to produce the electricity to

run an incandescent bulb compared to only 2.4mg of mercury to run a CFL for the same time. The

net benefit of using the more energy efficient lamp is positive, and this is especially true if the mercury in the fluorescent lamp is kept out of the waste stream when the lamp expires.

Handling and Disposal of CFLs

The mercury in compact fluorescent bulbs poses no threat while in the bulb, but if you break one:

- Open a window and leave the room for 15 minutes or more
- Use a wet rag to clean it up and put all of the pieces, and the rag, into a plastic bag
- Place all materials in a second sealed plastic bag
- Call your local recycling center to see if they accept this material, otherwise put it in your local trash. Wash your hands afterward. Burned out CFLs can be dropped off at Home Depot and Ikea stores. Another solution is to save spent CFLs for a community household hazardous waste collection, which would then send the bulbs to facilities capable of treating, recovering or recycling them. For more information on CFL disposal or recycling, you can contact your local municipality.

1.2 IMPORTANCE OF LIGHTING

Humans depend on Light for all activities. Light is a natural phenomenon, very vital for existence, which is taken for granted. In fact, Life involves day night cycles beginning with sunrise and ending with sunset. Pre-historic man had activities limited only to day time. Artificial light enables extended activity period employing in a planned optimized manner, minimizing the resources. Vision is the most important sense accounting for 80% information acquisition for humans. Information may be acquired through sun/moon light (direct/ reflected) or by using artificial light (closest to natural light). Before we go any further, it is worth looking at Teichmuller's definition for lighting. "We say the lighting is good, when our eyes can clearly and pleasantly perceive the things around us". Therefore, artificial light should be functional and pleasant both physiologically and psychologically. This is often achieved employing multiple sources. It must be borne in mind that the sources should be economic and energy efficient. As all of us are aware, all sources today employ electrical energy. Electrical energy is supplied as AC (alternating current) or DC (direct current). Usually electric power supply is AC in nature, either single phase or three phases. It must be borne that close circuit is a must for current flow. As it is well known losses exist in all electrical circuits or lines.

PROPERTIES OF GOOD LIGHTING SCHEME

1. Incandescence

Thermo luminescence is by definition radiation at high temperature. The sources employing this process are Incandescent Lamp, Gas Lamp, (flames and in oil Lamps and wax candles). They lead to a continuous spectrum of radiation.

2. Luminescence:

Luminescence Electro luminescence by definition Chemical or Electrical Action on gases or vapour radiation. Here color of radiation depends on the material employed. Usually this process leads to Line or Band Spectrum.

3. Fluorescence:

Fluorescence is a process in which the radiation is absorbed at one wavelength and is radiated at another wavelength. This re-radiation makes the light radiated visible.

Example: UV impinging on Uranium-Fluorescent oils.

4. Phosphorescence:

Phosphorescence is a process when energy is absorbed at some time and radiated later as glow. Examples of this process are luminous paints that contain calcium sulfide that lead to Phosphorescence. They produce light Radiation after exposure to light. In practice, good efficient lighting is obtained by combining Luminescence and Fluorescence. Fluorescent lamp is Luminescent source of low luminous value activating Fluorescent surfaces which lead to visible radiation. Here intensity depends on gas or vapor involved and phosphor material. However, the temperatures of the material play a role in radiation.

1.1 INTRODUCTION

Illumination differs from light very much, through 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 a certain colour and it is this brightness and colour which the eyes sets and interprets 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 light is due to fluorescence excited by radiation arising from the passage of electric current through mercury vapour. Some bodies reflect light in some measure, and when illuminated from an original source they become secondary sources of light. A good example is the moon, which illuminate the earth by means of the reflected light originating in the sun. Lamp is an equipment, which produces light. Lighting is an essential service of human for the day to day activity. Light is in the form radiant energy. Light is a cause of illumination is the result of light falling on the surface. Illumination makes a surface to be visible. It is different from lights.

DEFINITIONS OF LIGHTING

1) 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, (lumen-hours) and is analogous to W-h.

2) Luminous flux

It is defined as the total quantity of light energy emitted per second from a luminous body. It is represented by symbol ‘F’ or ‘Φ’ and is measured in lumens. The conception of luminous flux helps us to specify the output and efficiency of a given light source.

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

where Q - light energy (or) radiant energy

3) 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 (or) lumens per steradian.

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

Unit is lumens/steradian (or) candela

4) Lumen:

The lumen is the unit of luminous flux. It is defined as the amount of luminous flux emitted by a source of one candle power in a unit solid angle.

Lumens = Candle power × Solid angle

5) Candle Power (CP):

It is defined as the number of limens emitted by that source per unit solid angle in a given directions. It is denoted by CP.

CP = Lumens/Solid angle

6) 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/m^2 (or) lux (or) metre -candle. If a flux of 'F' lumens falls on a surface of area 'A', then the illumination of the surface is given by,

$$E = \frac{F}{A}$$

Unit - lumens/m^2 (or) lux

7) Lux (or) Metre Candle

It is the unit of illumination defined as the luminous flux falling per square metre on the surface, which is perpendicular to the light rays from a source of 1 CP and one metre away from it.

8) 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 perpendicular to the rays of light from a source of 1 CP and one foot away from it.

i.e., 1 Foot-candle = 1 lumen/ft^2. 1 Foot - candle = 10.76 metre - candle or lux.

9) Candela:

It is the unit of luminous intensity. It is defined as 1/60*th* of the luminous intensity per cm^2 of a black body radiator at the temperature of solidification of platinum.

10) Mean Horizontal Candle Power (MHCP)

It is defined as the mean of candle powers in all directions in the horizontal plane containing the source of light.

11) Mean Spherical Candle Power (MSCP)

It is defined as the mean of candle powers in all directions and in all planes from source of light.

12) Mean Hemi - Spherical Candle Power (MHSCP)

It is defined as the mean of candle powers in all directions above or below the horizontal plane passing through the source of light.

13) Reduction Factor:

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

$$Reduction\ factor = \frac{MSCP}{MHCP}$$

14) Lamp efficiency:

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

15) Brightness (or) Luminance

Brightness (or) Luminance 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'. Lambert is also the unit of brightness which is lumens/cm^2. Foot lamberts is lumens/ft^2.

16) Glare:

Glare may be defined as the brightness within the field of vision of such a character as to cause annoyance, discomfort, interference with vision or eye - fatigue.

For example, Motor car head lights.

17) Space Height ratio:

It is defined as the ratio of horizontal distance between adjacent lamps and height of their mountings.

$$Space\ height\ ratio = \frac{Horizontal\ distance\ between\ two\ adjacent\ lamps}{Mounting\ height\ of\ lamps\ above\ working\ plane}$$

18) Utilization Factor (or) Co-efficient of Utilization:

It is defined as the ratio of total lumens reaching working plane to total lumens given out by the lamp.

$$Utilization\ factor = \frac{Total\ lumens\ reaching\ the\ working\ plane}{Total\ lumens\ given\ out\ by\ the\ lamp}$$

19) Maintenance factor:

It is defined as the ratio of illumination under normal working conditions to the illumination when the things are perfectly clean.

$$Maintenance\ factor = \frac{Illumination\ normal\ working\ condition}{Illumination\ when\ everything\ is\ perfectly\ clean}$$

20) Beam factor:

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

21) Plane angle:

A plane angle is subtended at a point and is enclosed by two straight lines lying in the same plane. A plane angle is expressed in terms of degrees or radian. A radian is the angle subtended by an arc of a circle whose length equals the radius of the circle.

22) Solid angle:

A concept which frequently is used for illumination calculation is the solid angle. Consider an area A relative to a point P in the figure 1.1.1. if all the points on the boundary of the area A are joined to P, a cone-like shape is formed at P and the angle subtended by the area A at P is known as the solid angle. Let P represent the centre of a sphere. There will be a boundary of intersection where the solid angle subtended by area A passes through the sphere. This area on the sphere surface and area A are subtending the same solid angle at P.

$$Solid\ angle\ subtended\ by\ area\ A = \frac{Area\ of\ intersection\ at\ sphere\ surface}{(Radius\ of\ sphere)^2}$$

Solid angle is expressed in steradians.

$$Solid\ angle\ subtended\ by\ a\ sphere\ at\ its\ centre = \frac{Area\ of\ sphere}{r^2} = \frac{4\pi r^2}{r^2} = 4\pi$$

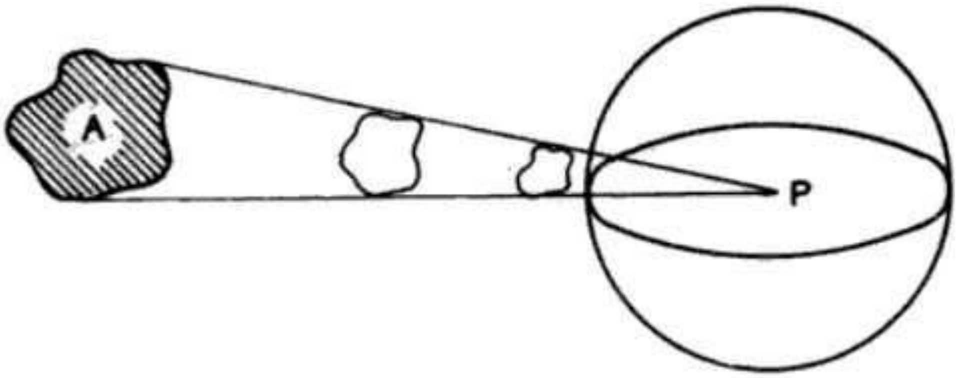


Figure 1.1.1 Concept of Solid Angle

[Source: "Generation, Distribution and Utilization of Electrical Energy" by C. L. Wadhwa, Page: 236]

Relationship between ω and θ. On referring to figure 1.1.2, let the segment ABC subtend a solid angle of ω and the lines OA and OC subtend a plane angle, θ at the centre 'O' of the circle.

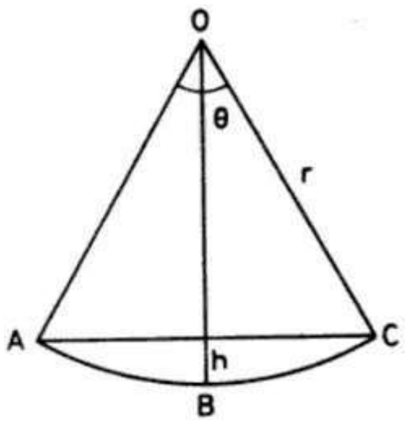


Figure 1.1.2 Relationship between Solid and Plane Angles

[Source: "Generation, Distribution and Utilization of Electrical Energy" by C. L. Wadhwa, Page: 237]

$$\omega = \frac{Surface\ area\ of\ segment\ ABC}{r^2} = \frac{2\pi rh}{r^2} = \frac{2\pi h}{r}$$

Also,

$$\frac{r-h}{r} = \cos\left(\frac{\theta}{2}\right)$$

$$h = r\left(1 - \cos\left(\frac{\theta}{2}\right)\right)$$

Substituting in the relation for ω, we get,

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

1.8 LED LIGHTING

LEDs (Light Emitting Diodes) are solid light bulbs which are extremely energy efficient. When first developed, LEDs were limited to single-bulb use in applications such as instrument panels, electronics, pen lights and, more recently, strings of indoor and outdoor Christmas lights. Manufacturers have expanded the application of LEDs by "clustering" the small bulbs. The first clustered bulbs were used for battery powered items such as flashlights and headlamps. Today, LED bulbs are made using as many as 180 bulbs per cluster, and encased in diffuser lenses which spread the light in wider beams. Now available with standard bases which fit common household light fixtures, LEDs are the next generation in home lighting. A significant feature of LEDs is that the light is directional, as opposed to incandescent bulbs which spread the light more spherically. This is an advantage with recessed lighting or under-cabinet lighting, but it is a disadvantage for table lamps. New LED bulb designs address the directional limitation by using diffuser lenses and reflectors to disperse the light more like an incandescent bulb. The high cost of producing LEDs has been a roadblock to widespread use. However, researchers at Purdue University have developed a process for using inexpensive silicon wafers to replace the expensive sapphire-based technology. This promises to bring LEDs into competitive pricing with CFLs and incandescents. LEDs may soon become the standard for most lighting needs. We are following these developments with interest and will report the latest updates in this research.

Benefits of LED lightbulbs

Long-lasting - LED bulbs last up to 10 times as long as compact fluorescents, and far longer than typical incandescents.

Durable - since LEDs do no t have a filament , t hey ar e not damaged under circumstances when a regular incandescent bulb would be broken. Because they are solid, LED bulbs hold up well to jarring and bumping.

Cool - these bulbs do not cause heat build-up; LEDs produce 3.4 btu's/hour, compared to 85 for incandescent bulbs. Common incandescent bulbs get hot and contribute to heat build-up in a room. LEDs prevent this heat build-up, thereby helping to reduce air conditioning costs in the home.

Mercury-free - no mercury is used in the manufacturing of LEDs.

More efficient - LED light bulbs use only 2-17 watts of electricity (1/3rd to 1/30th of Incandescent or CFL). LED bulbs used in fixtures inside the home save electricity, remain cool and save money on replacement costs since LED bulbs last so long. Small LED flashlight bulbs will extend battery life 10 to 15 times longer than with incandescent bulbs.

Cost-effective - although LEDs are initially expensive, the cost is recouped over time and in battery savings. LED bulb use was first adopted commercially, where maintenance and replacement costs are expensive. But the cost of new LED bulbs has gone down considerably in the last few years. and are continuing to go down. Today, there are many new LED light bulbs for use in the home, and the cost is becoming less of an issue. To see a cost comparison between the different types of energy-saving light bulbs, see our Light Bulb Comparison Charts.

Light for remote areas and portable generators - because of the low power requirement for LEDs, using solar panels becomes more practical and less expensive than running an electric line or using a generator for lighting in remote or off-grid areas. LED light bulbs are also ideal for use with small portable generators which homeowners use for backup power in emergencies.

Choosing an LED lightbulb

Many different models and styles of LED bulbs are emerging in today's marketplace. When choosing a bulb, keep in mind the following:

 Estimate desired brightness - read the package to choose desired brightness level. You can use wattage to compare bulb illumination, for example, a 9W LED is equivalent in output to a 45W incandescent. However, the new method for comparing bulbs is lumens. Lumens is the measure of perceived brightness, and the higher the lumens, the brighter the bulb. The FTC has mandated that all light bulb packages display lumens as the primary measure for comparing bulbs. For more information about lumens, see LED Terminology further down this page.

 Do you need a 3-Way bulb? - new LED bulbs are available as combination 3-Way bulbs. These replace 30, 60 and 75-watt incandescent bulbs, while consuming 80% less power than an incandescent bulb! TheSwitch 3-Way LED is also omnidirectional, so it can be used anywhere you would use an incandescent.

 Choose between warm and cool light - new LED bulbs are available in 'cool' white light, which is ideal for task lighting, and 'warm' light commonly used for accent or small area lighting.

 Standard base or pin base - LEDs are available in several types of 'pin' sockets or the standard "screw' (Edison) bases for recessed or track lighting.

 Choose between standard and dimmable bulbs - some LED bulbs, such as the Switch, LED novation and FEIT LED bulbs, are now available as dimmable bulbs. They will work on your standard dimmer switch.

 Choose high quality bulbs or they will die prematurely - do not buy cheap bulbs from eBay or discounters. They are inexpensive because the bulbs use a low quality chip which fails easily.

 Look for certifications - including FCC, Energy Star and UL.

The common styles of LED bulbs include the following:

1. Diffused bulbs

In this style LED bulb, clusters of LEDs are covered by a dimpled lens which spreads the light out over a wider area. Available in standard Edison bases, these bulbs have many uses, such as area lighting for rooms, porches, reading lamps, accent lamps, hallways and low-light applications where lights remain on for extended periods.

2. Dimmable Globe LED bulbs

Designed for bathroom vanities or anywhere a globe bulb is required, these bulbs produce light equivalent to a 40-watt incandescent bulb, yet only consume 10 watts of power. Dimmable from 100% to 10%, these bulbs have a 200-degree beam angle to cast light in a wide area.

3. Track Lighting, pin base

Available in MR-16 (pin base), LEDs are ideal for track lighting. LEDs do not contribute to heat buildup in a room because no matter how long they remain on, they do not get hot to the touch. Also, because they are 90% more efficient than incandescent, and last 10 times longer than CFLs, the frequency of changing bulbs is greatly reduced.

4. Flood Reflector LEDs for Recessed Cans and Track lights, screw-in base

LEDs are now available for standard recessed lighting pots and housings. They range from 7.5 to 17watts, with beam widths from PAR20 to PAR38. Several models are dimmable. Also, because they are 90% more efficient than incandescent and last 10 times longer than CFLs, the frequency of changing bulbs is greatly reduced.

5. Flame Tip, Candelabra Base LEDs

Designed to replace incandescent candelabra bulbs, these flame tip LEDs deliver the equivalent light of 25 - 35 watt incandescent while only drawing 3.5 watts of electricity. Because of the heat sink in the base, light doesn't disperse downwards as much as a typical incandescent candelabra bulb.

6. LED Tube Lights

Designed to replace fluorescent tube bulbs, these LED tubes are available in 8 and 16 watts, which replace traditional 25-watt and 40-watt T8/T10/T12 fluorescent tubes. Because fluorescent lights are often installed in high ceilings in commercial sites, there are additional savings because the frequency of changing bulbs is greatly reduced.

1.6 LIGHTING CALCULATIONS

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

1. Watts - per square metre method
2. Lumen (or) light flux method
3. Point - to - point method

Watts - per square - metre method:

This method is more adaptive for rough calculation or checking and it is simple "Thumb rule" method of calculation. It consists in making an allowance 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 or where an average value is required.

$$Total\ lumens\ received\ on\ working\ plane = Number\ of\ lamps \times Wattage\ of\ each\ lamp \times Efficiency\ of\ each\ lamp\ in\ terms\ of\ \frac{lumens}{watt} \times Coefficient of\ utilisation \times \frac{1}{Depreciation\ factor}$$

$$Maintenance\ factor = \frac{1}{Depreciation\ factor}$$

(i) Total lumens received:

It is defined as the ratio of lumens reaching the working plane to the total lumens given out by the lamp or lamps. It is known as utilisation factor or co-efficient of utilisation. Its value varies from 0.25 to 0.5 and from 0.1 to 0.25 for direct and indirect lighting schemes respectively.

(ii) Maintenance factor:

It is defined as the ratio of ultimate maintained metre-candles on the working plane to the initial metre-candles. Its value is more if the lamp fittings are cleaned regularly, say 0.8, and less of there is much dust etc, say 0.6.

(iii) Depreciation factor:

This is merely the inverse 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 greater than unity.

Point to point (or) Inverse square law 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 and cumbersome applications); it is employed only in some special problems such as flood lighting, yard lighting etc.,

Calculation of Illumination:

In general, illumination can be calculated by using the empirical formula:

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

where,

N → Number of fittings required

E → Illumination required in lux

A → Area of the working plane in m2

Φ → Luminous flux produced per lamp in lumens

UF → Utilisation factor

MF → Maintenance factor

1.4 PHOTOMETRY

Photometry involves the measurement of candled power or luminous intensity of a given source. The candle power of a given source in a particular direction can be measured by the comparison with a standard or substandard source. Primary Standard is normally defined based on the brightness of a body (i.e. black body) maintained at freezing temperature of platinum. Unit of luminous intensity abbreviated as is candela cd (z). Light Flux hence emanating from a point source in all directions is illuminance - ¼ π lumens and is termed MSLI is the light flux incident on a task surface in lumens per unit area and is called lux.

Comparison with standard

Normally primary standards are kept in standards laboratories. Usually incandent lamp is compared with a primary standard is used as a laboratory standard. The test source / lamp is compared with the laboratory standard. However, incandent lamp is not suitable beyond the range of 50-100 hours. Standardization of lamp is by voltage rating, current rating and wattage. These measurements comprise the photometry. They employ a photometric bench with a photometric head which is an opaque screen. These measurements involve comparing the test lamp with standard lamp.

a. By varying the position of comparison lamp (standard lamp), I_s

b. By varying the position of the test lamp, I_T

c. By varying the position of the screen

Measurement is complete when the bench is balanced. It is balanced when two sides of the screen are equally bright [in a Dark Room] as shown in figure 1.4.1.

Principle of simple photometer

The photometer bench essentially consists of two steel rods with (2-3)m long. This bench carries stands or saddles for holding two sources (test and standard lamps), the carriage for the photometer head and any other apparatus employed in making measurements. The photometer bench should be rigid so that the source being compared may be free from vibration. The photometer head should be capable of moving smoothly and the photometer head acts as screen for the comparison of the illumination of the standard lamp and the test lamp.

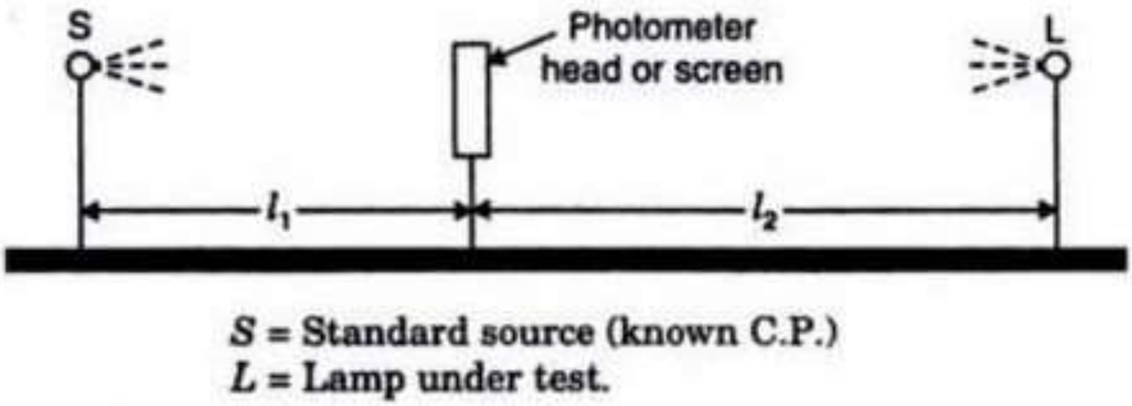


Figure 1.4.1 Photometric bench

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 20]

Measurements may be made on illumination meter or Lux meter. Also, in this method, instead of the screen adjustment, the meter can be adjusted to get the same reading on photometric bench. A method where distance is varied to get the same reading on the meter. Alternatively, the distance on the bench may be kept constant and readings on the meter are noted. Normally, the photometer comprises of a standard point source of light at the centre of an opaque sphere. It has an opening where a photo cell is placed that receives diffused light from the source. The window is shielded by diffusing screen from direct light. Reading on the micrometer is first taken with a standard Lamp and later with the test lamp. In a photocell sensitive element 'S' is selenium coated in the form of a thin layer on a steel plate P. This is in turn covered with a thin layer of metal 'M' on which is a collection ring R.

$$Candle\ power\ of\ standard\ source \propto {L^2}_1$$

$$Candle\ power\ of\ test\ source \propto {L^2}_2$$

$$\frac{Candle\ power\ of\ test\ source}{Candle\ power\ of\ standard\ source} \propto \frac{L_2^2}{L_1^2} = S\frac{L_2^2}{L_1^2}$$

In order to obtain the accurate candle power of test source, the distance of the sources from the photometer head should be measured accurately.

PHOTOMETER HEADS

The photometer heads that are most common in use are:

(i) Bunsen grease spot photometer

(ii) Lumer-Brodhun photometer

Bunsen grease photometer

Bunsen photometer consists of a tissue paper, with a spot of grease or wax at its centre. It held vertically in a carrier between the two light sources to be compared. The central spot will appear dark on the side, having illumination in excess when seen from the other side. Then, the observer will adjust the position of photometer head in such a way that until the semitransparent spot and the opaque parts of the paper are equally bright then the grease spot is invisible, i.e., same contrast in brightness is got between the spot and the disc when seen from each sides as shown in figure 1.4.2. The distance of photometer from the two sources is measured. Hence, candle power of test source is then determined by using relation,

$$\text{Candle power of test source} = \text{Candle power of standard source} \times \frac{L_2^2}{L_1^2}$$

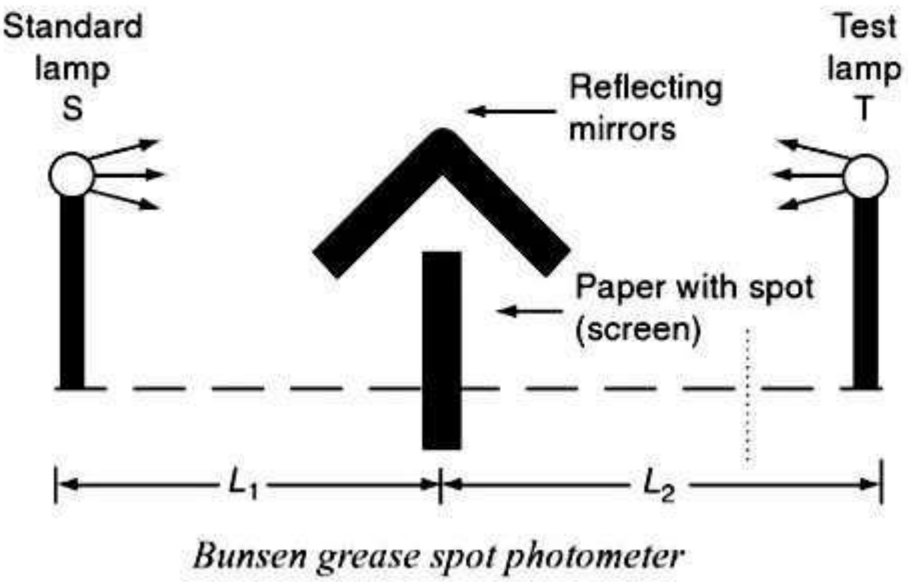


Figure 1.4.2 Bunsen grease spot photometer

[Source: "Generation and Utilization of Electrical Energy" by Sivanagaraju, Balasubba Reddy, Srilatha, Page: 255]

Lumer-Brodhun photometer

The photometer head essentially consists of screen made of plaster of Paris, two mirrors, M_1 and M_2, glass cube or compound prism and telescope. The compound prism is made up of two right angled glass prisms held together, one of which has sand blasted pattern on its face, i.e., principal surface as spherical with small flat portion at the center and the other is perfectly plain. A typical Lumer-Brodhun photometer head is shown in figure 1.4.3.

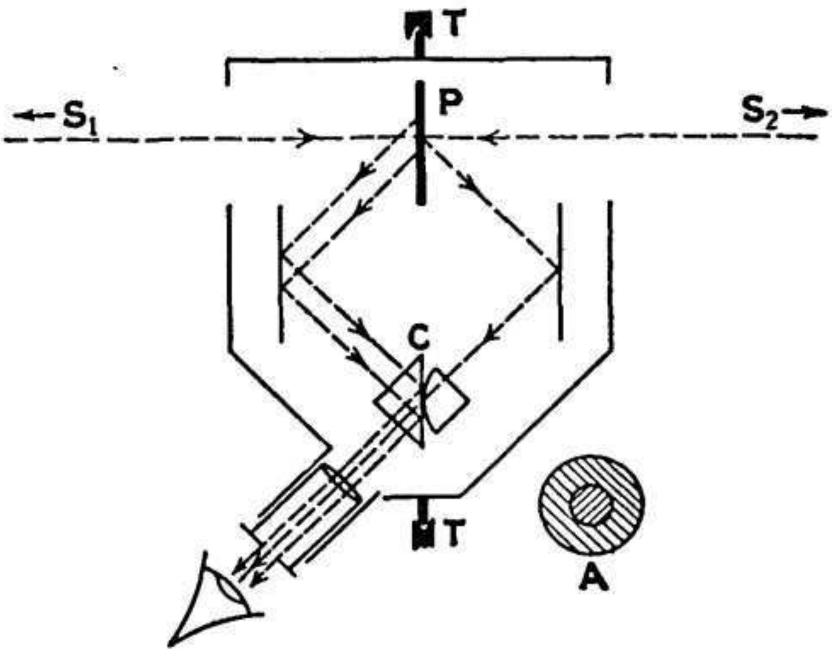


Figure 1.4.3 Lumen-Brodhun photometer

[Source: "Generation and Utilization of Electrical Energy" by Sivanagaraju, Balasubba Reddy, Srilatha, Page: 255]

The two sides of the screen are illuminated by two sources such as the standard and test lamps. The luminous flux lines emitting from the two sources are falling on the screen directly and reflected by it onto the mirrors M_1 and M_2, which in turn reflects the same onto the compound prism. The light ray reflected from M_2 is passing through the plain prism and the light ray reflected by M_1 is falling on the spherical surface of the other prism and is reflected again which pass through the telescope. Thus, the observer views the center portion of the circular area illuminated by the test lamp, S_2 and the outer ring is illuminated by the standard lamp, S_1. The positioning of the photometer head is adjusted in such a way that the dividing line between the center portion and the surrounding disappears. The disappearance of dividing line indicates the same type of colour of the test lamp and the standard lamp. Now, the distance of photometer head from the two sources are measured and the candle power or luminous intensity of test lamp can be calculated by using inverse square law.

PHOTOVOLTAIC CELL

In photometry, the current output of a photocell should be proportional to the illumination which is achieved by keeping the external resistance at a low value. Sensitive element is a semi-conductor that releases electrons upon exposure to light. Selenium and Cuprous oxide are most suitable semi-conductor materials. Steel Plate 'P' coated with thin layer of Selenium at 200°c and annealed at 80°c producing crystalline form. It is in turn coated by a thin transparent film of metal 'M' with a collection ring 'R' of metal. B is the barrier layer upon exposure to light – light enters through 'M' releases electrons from metallic Selenium. They cross barrier 'B' to 'M' and are collected through 'R' and P.

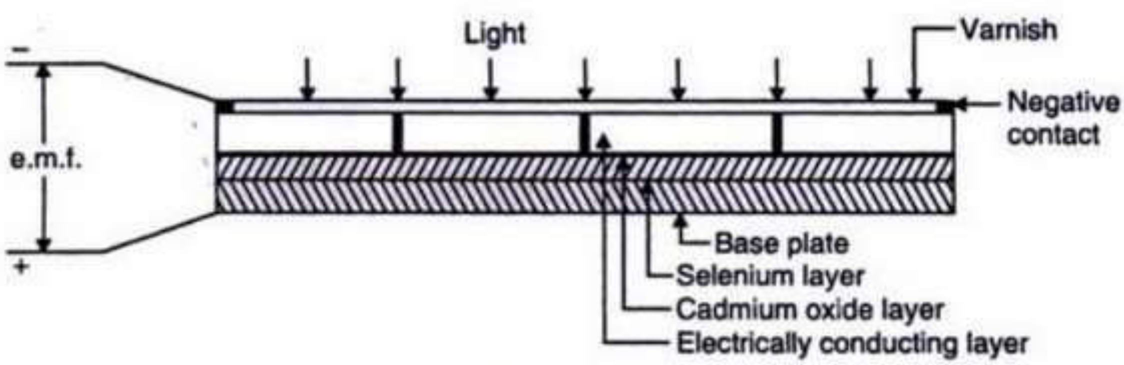


Figure 1.4.4 Photometric bench

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 22]

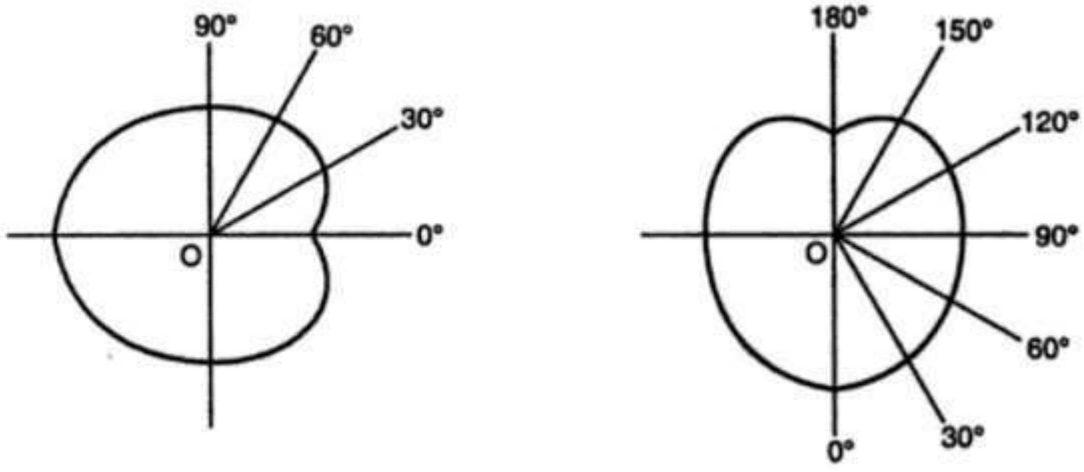
Current indicated by (A) is proportional to Illuminance. Often (A) is a micro ammeter calibrated in lm.

POLAR CURVES

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

a) A curve is plotted between the candle power and the angular position, if the luminous intensity, i.e., candle power is measured in the horizontal plane about the vertical axis, called '*horizontal polar curve.*'

b) A curve is plotted between the candle power, if it is measured in the vertical plane and the angular position is known as '*vertical polar curve.*'



(*a*) For horizontal plane. (*b*) For vertical plane.

Figure 1.4.5 Polar curves

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 19]

Figure 1.4.5 shows the typical polar curves for an ordinary lamp. Depression at 180° in the vertical polar curve is due to the lamp holder. Slight depression at 0° in horizontal polar curve is because of coiled coil filament. Polar curves are 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. These are also used to determine mean horizontal candle power (MHCP) and mean spherical candle power (MSCP).

MHCP of a lamp can be determined from the horizontal polar curve by considering the mean value of al the candle powers in the horizontal direction.

MSCP of a symmetrical source of a light can be found out from the polar curve by means of a Rousseau's construction.

Rousseau's Construction

Suppose the vertical polar curve is in the form of two lobes symmetrical about YOY's axis. The Rousseau's construction for this polar curve is illustrated in figure 1.4.6.

- Draw a circle with any convenient radius with point O as the centre.
- Draw PQ parallel to YOY' and equal to the vertical diameter of the circle.
- Draw any line OEA meeting the polar curve in E and the circle in A. Let the projection be S.
- At S erect an ordinate ST = OE.
- By similar construction draw other ordinates. The curve PSQUTVP obtained by joining these ordinates is known as Rousseau's curve. The mean ordinate of this curve gives the mean spherical candle power.

$$\textit{The mean ordinate of the curve} = \frac{\textit{Area PSQUTVP}}{\textit{Length of PQ}}$$

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

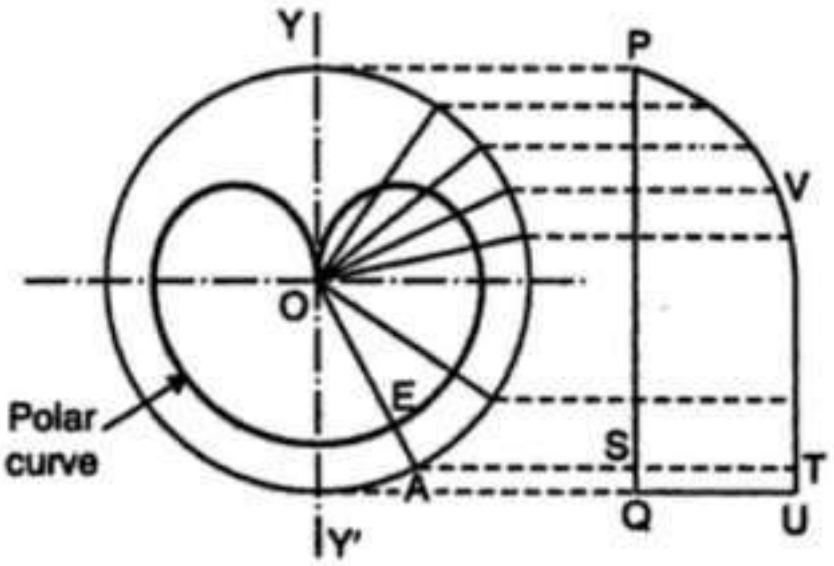


Figure 1.4.6 Rousseau's construction

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 19]

1.5 TYPES OF LAMPS

According to principle of operation the light sources may be grouped as follows.

- Arc Lamps
- High Temperature Lamps
- Gaseous discharge Lamps
- Fluorescent type Lamps.

1. Arc lamps

Electric discharge through air provides intense light. This principle is utilized in arc lamps.

2. High temperature lamps

Oil and gas and incandescent filament type lamps, which emit 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 radiations. Sodium and mercury vapours lamps operate on this principle.

4. Fluorescent type lamps:

Certain materials, when exposed to ultra violet rays, transform the absorbed energy into radiations of longer wavelength lying within the visible. This principle is employed in fluorescent lamps.

ARC LAMPS

a) Carbon arc lamp

b) Flame arc lamp

c) Magnetic arc lamp

FILAMENT LAMPS OR INCANDESCENT LAMPS

a) Halogen lamp

b) Cold lamp

FILAMENT DISCHARGE LAMPS

a) Sodium vapour discharge lamp

b) High pressure mercury vapour discharge lamp

c) Neon lamp and Neon tube lamp

FLUORESCENT LAMPS

a) Mercury Iodide lamp

b) Neon lamp

c) Neon tube

d) Fluorescent tube

INCANDESCENT LAMP

The electrical light source which works on the principle of incandescent phenomenon is called **Incandescent Lamp**. In other words, the lamp works due to glowing of the filament caused by electric current through it, is called **incandescent lamp**.

How do Incandescent Lamps Work?

When an object is made hot, the atoms inside the object become thermally excited. If the object is not melting the outer orbit electrons of the atoms jump to higher energy level due to the supplied energy. The electrons on these higher energy levels are not stable they again fall back to lower energy levels. During falling from higher to lower energy levels, the electrons release their extra energy in a form of photons. These photons then emitted from the surface of the object in the form of electromagnetic radiation. This radiation will have different wavelengths. A portion of the wavelengths is in the visible range of wavelengths, and a significant portion of wavelengths are in inferred range. The electromagnetic wave with wavelengths within the range of inferred is heat energy and the electromagnetic wave with wavelengths within visible range is light energy. Incandescent means producing visible light by heating an object. An incandescent lamp works in the same principle. The simplest form of the artificial source of light using electricity is an incandescent lamp. Here we use electric current to flow through a thin and fine filament to produce visible light. The current rises the temperature of the filament to such extent that it becomes luminous.

Working Principle and Construction of Incandescent Lamp

The filament is attached across two lead wires. One lead wire is connected to the foot contact and other is terminated on the metalic base of the bulb. Both of the lead wires pass through glass support mounted at the lower middle of the bulb. Two support wires also attached to glass support, are used to support filament at its middle portion. The foot contact is isolated frommetalic base by insulationmaterials. The entire system is encapsulated by a colored or phasphare coated or transparent glass bulb. The glass bulb may be filled with insert gases or it is kept vacuum depending upon rating of the incandescent lamp. The filament of **incandescent lamps** is air-tightly evacuated with a glass bulb of suitable shape and size. This glass bulb is used to isolate the filament from surrounding air to prevent oxidation of filament and to minimize convention current surround the filament hence to keep the temperature of the filament high. The glass bulb is either kept vacuum or filled with inert gases like argon with a small percentage of nitrogen at low pressure. Inert gases are used to minimize the evaporation of filament during service of the lamps. But due to convection flow of inert gas inside the bulb, there will be greater chances of losing the heat of filament during operation. Again, vacuum is a great insulation of heat, but it accelerates the evaporation of filament during operation. In the case of gas-filled incandescent lamps, 85 % of argon mixed with 15 % of nitrogen is used. Occasionally krypton can be used to reduce filament evaporation because the molecular weight of krypton gas is quite higher. But it costs greater. At about 80 % of atmospheric pressure, the gasses are filled into the bulb. Gas is filled in the bulb with the rating more than 40 W. But for less than 40 W bulb; there is no gas used. The various parts of an incandescent lamp are shown below.

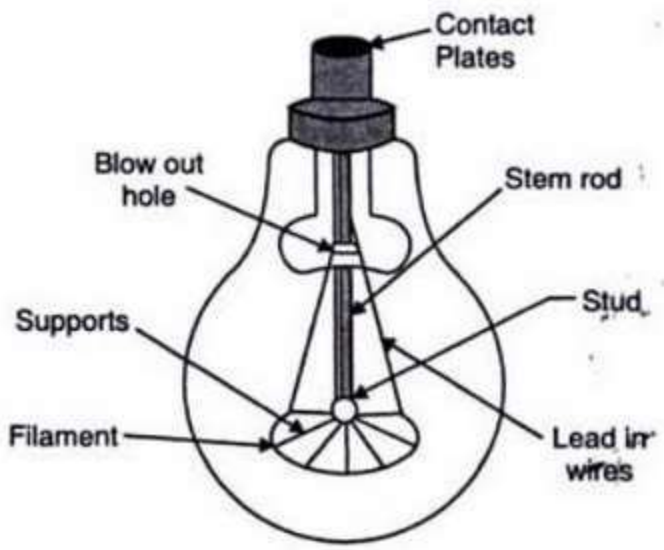


Figure 1.5.1 Incandescent lamp

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 26]

HIGH PRESSURE SODIUM LAMPS or (HPS LAMPS)

It is very difficult to get any material which is free from corrosion in presence of sodium vapour in high temperature and pressure. This was the main difficulty of producing high pressure sodium lamp shown in figure 1.5.2. In 1959, the development of polycrystalline alumina (PCA) opened a new path to introduce the high pressure sodium vapor Lamp. As this material is very rarely affected by high pressure and temperature sodium vapour. The first lamp with 400 W, 42000 initial lumens and 6000 hour life first came in the market in 1965. But afterward some improvements made this lamp with 50000 initial lumens with 24000 hours at 10 hours per start. We can get a lamp that has 2.4 times lumens output of its mercury counterpart with same rated life span.

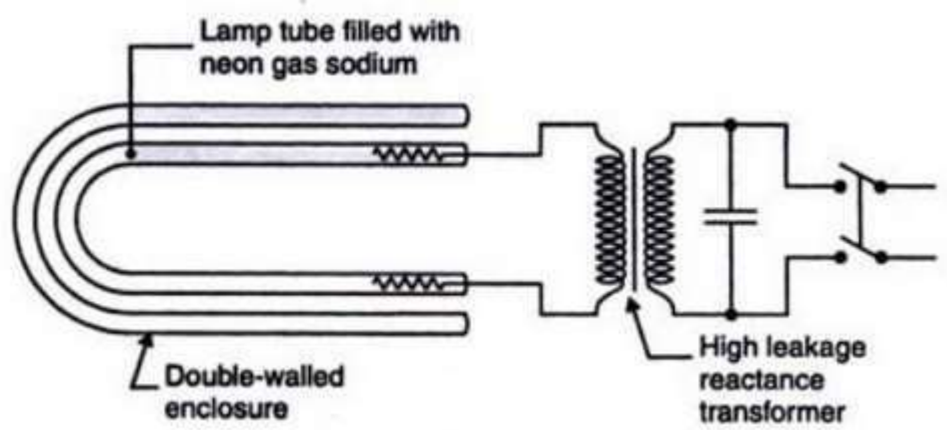


Figure 1.5.2 Sodium vapour lamp

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 32]

It has an inner PCA arc tube that is filled with xenon gas. This xenon gas is used for starting purpose of the lamp as ionization potential of xenon gas is lowest among all other inert gases used for this purpose. In addition to xenon gas sodium mercury amalgam is present in this arc tube, too. In each end, back wound and coated tungsten electrodes are mounted. To seal the tube monolithic seal is used instead of niobium end cap. The arc tube is inserted into a heat resistant outer bulb. It is supported by an end clamp that is floating. This end clamp permits the entire structure to expand contract without distorting. The space between the tube and the bulb is a vacuum space. This vacuum space is needed to insulate heat from the arc tube. Because it is necessary to keep the arc tube at required temperature to sustain arc during normal operation. High pressure sodium lamp has very small diameter (3/8 inch). So, there is no enough space to provide any starting electrode in the arc tube. So higher voltage is required to initiate arc. A ballast with ignitor is used for this purpose. High voltage is fed to the lamp from the ballast by using the phenomenon of superimposing a low energy high voltage pulse. Generally, a typical pulse has a peak voltage of 2500 V and it has durability for only 1 microsecond only. This high voltage pulse makes the xenon gas ionized sufficiently. Then it initiates and maintains the xenon arc. The initial arc has sky blue color. Amalgam used in the reservoir formed inside the arc tube. It is in the back of one of the electrodes. It is normally vaporized during lamp operation. As the xenon arc has started temperature of arc tube is increased which first vaporizes mercury and the lamp start glowing with bluish white color. This color represents the effect of the xenon and mercury mixture at excitation. Gradually the temperature again rises, and sodium becomes vaporized lastly and becomes excited, a low pressure monochromatic yellow sodium spectrum result. During the period of sodium spectral line becomes at 589 nm.

MERCURY VAPOUR LAMP

In case of fluorescent lamp, mercury vapour pressure is maintained at lower level such that 60% of total input energy gets converted into 253.7 nm single line as shown in figure 1.5.3.

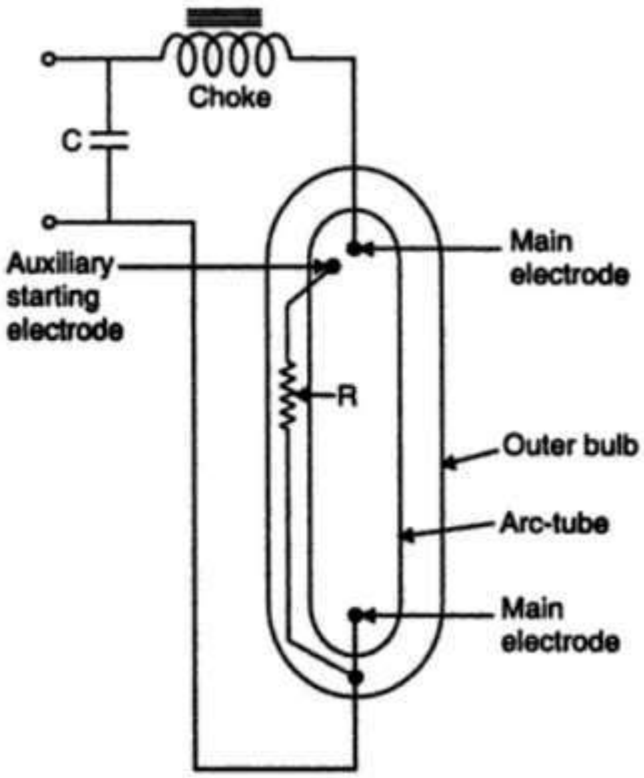


Figure 1.5.3 Mercury vapour lamp

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 33]

Again, transition of the electrons requires least amount of input energy from a colliding electron. As pressure increases the chance of multiple collisions gets increased. A schematic diagram of mercury lamp is shown below. This lamp is containing an inner quartz arc tube and outer borosilicate glass envelope. The quartz tube is able to withstand arc temperature 1300°K, whereas the outer tube withstands only 700°K. Between two tubes nitrogen gas is used to be filled to provide thermal insulation. This insulation is for to protect the metal parts from oxidation due to higher arc temperature. The arc tube contains the mercury and argon gas. Its operational function is same as the fluorescent lamp. Two main electrodes and a starting electrode are inside the arc tube. Each main electrode holds a tungsten rod and upon which a double layer of coiled tungsten wire is wound. Basically, the electrodes are dipped into a mixture of thorium, calcium and barium carbonates. They are heated to convert these compounds into oxides after dipping. Thus, they get thermally and chemically stable to produce electrons. The electrodes are connected through a quartz tube by molybdenum foil leads. Just when the main supply voltage is applied to the mercury lamp, this voltage comes across the starting electrode and the adjacent main electrode (bottom electrode) as well as across two main electrodes (bottom and top electrodes). As the gap between starting electrode and bottom main electrode is small the voltage gradient is high in this gap. Because of this high voltage gradient across the stating electrode and the adjacent main electrode (bottom) a local argon arc is created, but the current gets limited by using a starting resistor. This initial arc heats up the mercury and vaporizes it and this mercury vapor helps to strike the main arc soon. But the resistance for the main arc current control resistor is somewhat less than the resistance of the resistor used in the initial arc current control purpose. For this reason, initial arc stops and main arc continues to operate. It takes 5 to 7 minutes to make all of the mercury to be vaporized completely. The lamp gets its state of its operational stability. The mercury vapor arc gives visible spectra of green, yellow and violet. But there may be still some invisible ultraviolet radiation during discharging process of **mercury vapour** so phosphor coating may be provided on outer glass cover to improve efficiency of the mercury lamp. There are five lamps with phosphor coating to provide improved color performance. As the wattage increases the initial lumen ratings for the phosphor coated lamps get available with 4200, 8600, 12100, 22500 and 63000. The average life of mercury lamp is 24000 hours i.e. 2 years 8 months.

FLUORESCENT LAMP

Tube shaped florescent lamp is termed as tube light. **Tube light** is a lamp that works on low pressure mercury vapor discharge phenomenon and converts ultra violet ray into visible ray with the help of phosphor coated inside glass tube.

Material Used Inside the Fluorescent Lamp

The materials used to build a tube light are given below.

1. Filament coils as electrodes
2. Phosphor coated glass bulb
3. Mercury drop
4. Inert gases (argon)
5. Electrode shield
6. End cap
7. Glass stem

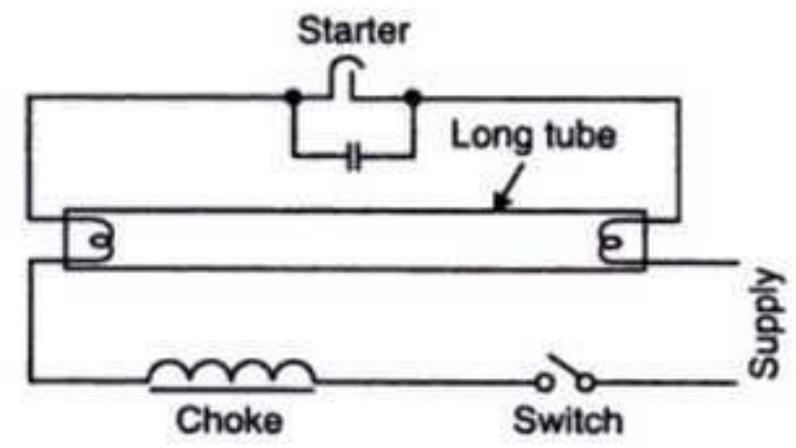


Figure 1.5.4 Fluorescent lamp

[Source: "Utilisation of Electrical Power" by R. K. Rajput, Page: 34]

Auxiliary Electrical Components along with Fluorescent Lamp

The tube light does not work directly on power supply. It needs some auxiliary components to work. They are-

Ballast: It may be electromagnetic ballast or electronic ballast.

Starter: The starter is a small neon glow up lamp that contains a fixed contact, a bimetallic strip and a small capacitor.

Working Principle of Fluorescent Lamp

When the switch is ON, full voltage will come across the tube light through ballast and fluorescent lamp starter. No discharge happens initially i.e. no lumen output from the lamp.

 At that full voltage first the glow discharge is established in the starter. This is because the electrodes gap in the neon bulb of starter is much lesser than that of inside the fluorescent lamp.

 Then gas inside the starter gets ionized due to this full voltage and heats the bimetallic strip that is caused to be bent to connect to the fixed contact. Current starts flowing through the starter. Although the ionization potential of the neon is little bit more than that of the argon but still due to small electrode gap high voltage gradient is appeared in the neon bulb and hence glow discharge is started first in starter.

 As voltage gets reduced due to the current causes a voltage drop across the inductor, the strip cools and breaks away from the fixed contact. At that moment a large L di/dt voltage surge comes across the inductor at the time of breaking.

 This high valued surge comes across the tube light electrodes and strike penning mixture (mixture argon gas and mercury vapor).

 Gas discharge process continues and current gets path to flow through the tube light gas only due to low resistance as compared to resistance of starter.

 The discharge of mercury atoms produces ultra violet radiation which in turn excites the phosphor powder coating to radiate visible light.

 Starter gets inactive during operation of tube light.