Chapter 2

Illumination

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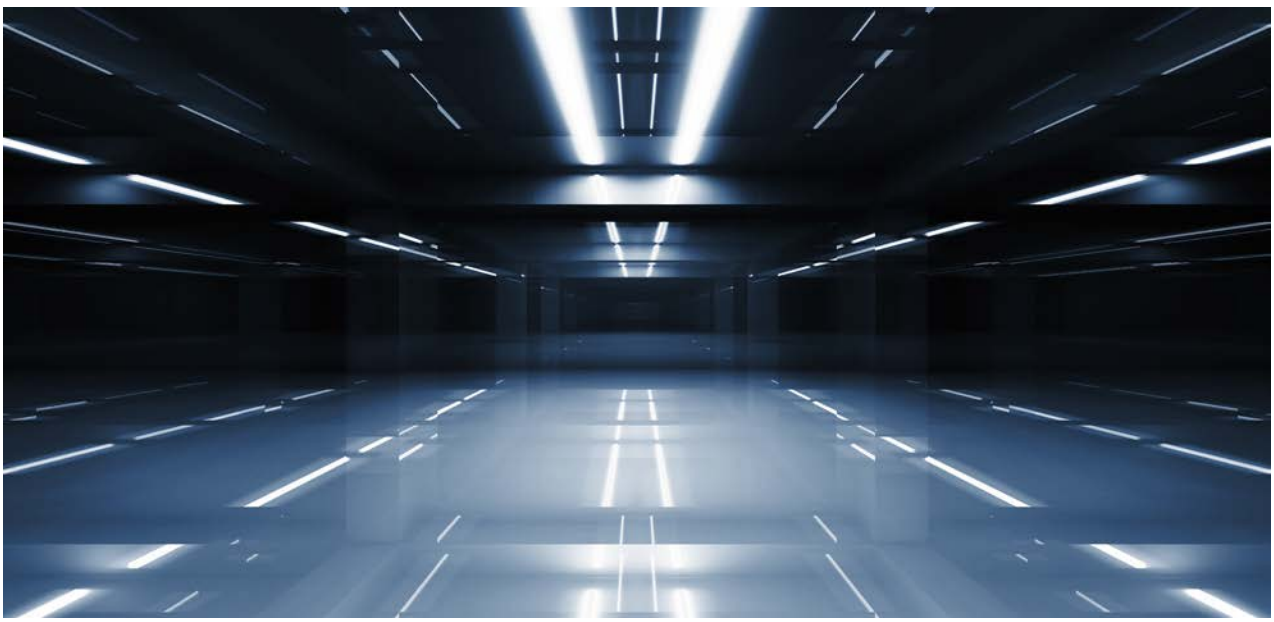

The best way to win is the lack of tension.

A.P.J. Abdul Kalam

Learning Objectives

In this lesson, students will get to know the various terms regarding illumination and can easily understand the concept of light. Various types of lighting systems and their uses are given. One of the main objectives is the study of various types of lamps and their merits and demerits. According to new trend, it is necessary to know the various types of lights used in shops, industries, streets and in homes. Students have to know, what are the factors to be considered, while designing good lighting system. This is the right time to think for saving electrical energy by using low wattage bulbs like CFL, LED by adopting new techniques.

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2.1 Introduction

Almost all human activities are based on light. Natural light is obtained from the sun. Artificial light plays an important role in our everyday life. In places where natural light is not available, artificial light is obtained by electric lamps. Lighting plays an important role because of its belief, consistency, simple control and low price. The electrical lighting is mainly used for domestic purpose, decorative purpose, advertising, traffic- control, medical field and for street lighting also.

When light falls on a surface, it becomes visible and the phenomenon is called as illumination. It is denoted by E and is measured in lumen per square meter.

2.2 Important terms in illumination

2.2.1 Plane angle

The angle subtended at a point by two converging lines lying in the same plane is called plane angle, and is measured in radians. It is shown in figure 2.1. It is equal to the ratio of the length of the arc to its radius.

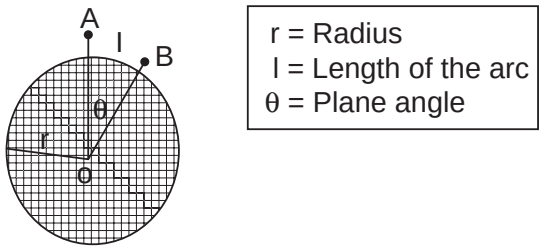


Fig. 2.1 **Plane angle**

$$\theta = \frac{Arc}{\text{radius}} \text{radian}$$

$$\theta = \frac{l}{r} \text{radians}$$

2.2.2 Solid angle

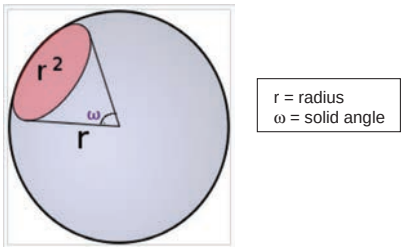


Fig. 2.2 **Solid angle**

Solid angle is measured in steradians. Solid angle is the ratio of area of the surface to the square of radius of sphere. It is shown in figure 2.2.

$$\omega = \frac{Area\ of\ surface}{\text{Square of radius}} \text{steradians}$$

$$\omega = \frac{A}{r^2} \text{steradians}$$

2.2.3 Luminous flux

It is the light energy radiated out per second from the body in the form of luminous light waves. The unit of luminous flux is lumen (lm).

In LED lamps,

15 Watts= 900 Lumens

2.2.4 Lumen

It is the unit of luminous flux. One lumen is defined as the luminous flux emitted per unit solid angle from a point source of one candle power.

2.2.5 Luminous intensity (I)

Luminous intensity or Candle-power of a point source in any particular direction is given by the luminous flux radiated out per unit solid angle in the direction.

2.2.6 Lux

The amount of light that causes a luminous flux over a square meter surface is called lux.

2.2.7 Mean Horizontal Candle Power (MHCP)

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

2.2.8 Glare

Glare is difficulty seeing in the presence of bright light such as direct or reflected sun light or artificial light. It causes annoyance, discomfort or interference with vision or eye fatigue.

2.2.9 Space height ratio

Space height ratio is defined as the ratio of the distance between adjacent luminaries (center to center) to their height above the working plane.

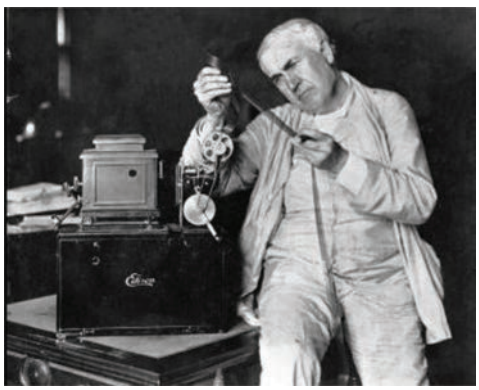
2.2.10 Utilization factor

Utilization factor or coefficient of utilization is defined as the ratio of total lumens reaching the working plane to the total lumens given out by the lamp.

$$\text{Utilization factor} = \frac{\text{Lumens reaching at the working place}}{\text{Total lumens emitted by the source}}$$

It usually varies from 0.5 to 0.8.

Do you Know?



An American inventor, Thomas Alva Edison, discovered 1368 inventions. His most popular invention is electric bulb. He invented many devices in the field such as mass communication, electric power generation, sound recording and motion pictures. Edison designed a system of conductors, meters, lamp fixtures, sockets, fuses and current switches.

2.3 Laws of illumination

The illumination on a surface depends upon the luminous intensity, distance between the source and surface and the direction of rays of light. It is governed by following laws.

1. Inverse square law
2. Lambert's cosine law

2.3.1 Inverse square law

It states that the illumination of a surface is inversely proportional to the square of the distance of the surface from the source.

$$E \alpha \frac{1}{d^2}$$

2.3.2 Lambert's cosine law

This law states that the illumination on any surface is proportional to the cosine of angle between the directions of the incident flux and perpendicular to the area.

$$E = \frac{1}{d^2} \cos \theta$$

2.3.3 Light

The radiant energy from a hot body which produces the visual sensation on human eye is called light.

2.3.4 Electrical method of producing light

Following are the methods of producing light:

1. Developing arc between two electrodes.
2. Passing a current through a filament.
3. Electric discharge through vapours or gases.

2.4 Arc lamp

The principle of an arc lamp is that when two electrodes carrying current are separated through a small distance, an arc is struck between them. The arc lamps were used in the past for street lighting purposes but nowadays these are used when extreme brightness is required. Carbon arc lamp is most commonly used arc lamp.

2.4.1 Carbon arc lamp

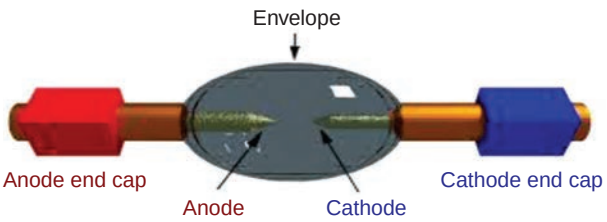


Fig. 2.3 Arc lamp

Arc lamp is shown in figure 2.3. Carbon arc lamp is the oldest type of lamp and is still being implied in cinema projectors and searchlights. It consists of two hard carbon rods (Electrodes). The diameter of positive electrode is double to that of negative electrode. The negative electrode is generally fixed and positive electrode is placed in adjustable holder and the process is manual or automatic. The arc consists of carbon vapours surrounded by orange red zone of burning carbon and pale green flames.

When the lamp is switched OFF, the two electrodes touch each other due to spring pressure on positive electrode. When the supply is ON a large current flows through electrodes. The temperature of carbon electrode is increased and thus

the positive electrode is pulled away against its spring pressure through a small distance by coil and thus an arc is struck between electrodes. This arc is maintained by transfer of carbon particles from one electrode to other electrode. These particles travel from positive electrode to negative electrode, thus after sometime of operation positive electrode becomes hollow and negative becomes pointed. That's why positive electrode is made double than negative electrode. In carbon arc lamp 85 % of light is given by positive electrode which produces high intensity light and only 10% by negative electrode and 5% by air. The temperature of the positive electrode is 4000°C and that of the negative electrode is about 2500°C. The luminous efficiency of such lamps is approximately 9 lumen / watt.

2.5 Incandescent lamp

The filament of this lamp is heated up to the incandescent stage of heat. So these types of lamps are called as incandescent lamps. There are two types.

1. Vacuum type lamp and
2. Gas filled type lamp

In this type of lamp, the sphere shaped glass cover is used. The glass stem is fixed in the centre of the lamp. This stem supports wires in holding the filament. The top of the lamp is sealed. Pins are used for holding the lamp in the holder.

2.5.1 Vacuum lamp

In this lamp, the air is evacuated to protect the filament from burning by oxygen mixed in the air. Vacuum lamp is shown in figure 2.4 and 2.4(a).

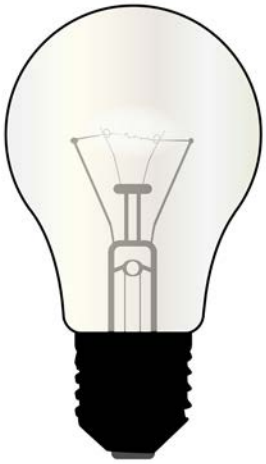


Fig. 2.4 Vacuum lamp

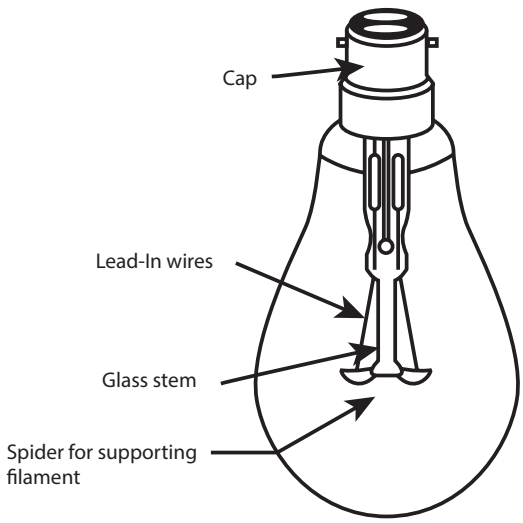


Fig. 2.4(a) Line diagram of vacuum lamp

When the filament is heated, due to the current that passes through the high resistance filament, the moving electron creates friction. So the heat is generated in the filament. When the heat raises up to the incandescent stage, the light is emitted from the filament. The emitted light is reflected by a sphere-shaped glass cover.

2.5.2 Gas filled lamp

It is shown in figure 2.5. In the evacuated lamp, the filament evaporates and deposits inside of the glass cover after long use and makes black shade on the glass

cover. To rectify this disadvantage, inert gases are filled in this lamp. Presence of inert gas causes heat loss. To compensate the heat loss, the filament is made as coiled wire. Increase in length of the filament leads to an increase in power.

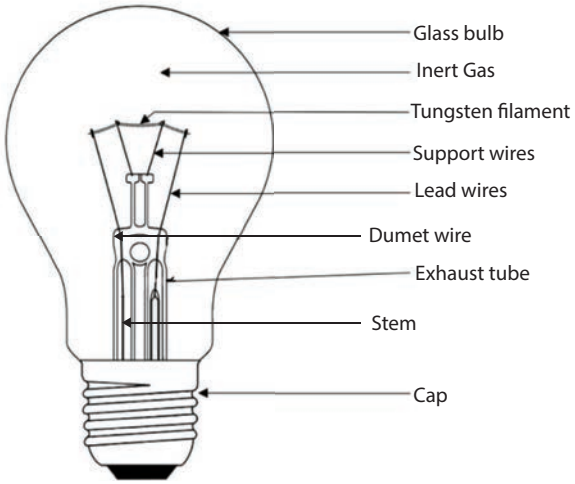


Fig. 2.5 **Gas filled lamp**

a. Working principle of a filament or an incandescent lamp

As we know, when a room heater is switched on, it gives out red light with heat at the working temperature of 750°C. At this temperature, the radiations are produced by infra red rays.

When an electric current is passed through a fine metallic wire, it raise the temperature of the wire. At low temperature, only heat is produced but at a higher temperature light radiation goes on increasing. The filament lamp consists of fine wire of high resistive material placed in an evacuated glass bulb. This type of lamp is operated at the temperature of 2500°C. A tungsten filament is covered in an evacuated glass bulb. But to improve the life of the filament, some chemicals like argon or nitrogen or neon gases are filled.

b. Properties of metal for filament

1. It can be operated at a high temperature, since it has a high melting point.
2. It produces more heat because it has a high specific resistance.
3. Filament resistance may not change at the operating temperature because it has a low temperature co-efficient.
4. Because of low vapour pressure, it may not get vapour.
5. Because of high ductility, it may withstand mechanical vibrations.

2.6 Sodium vapour lamp and mercury vapour lamp

2.6.1 Sodium vapour lamp

Sodium vapour lamps are some of the most efficient lamps in the world. They have an efficiency of up to 190 lumens per watt compared to an incandescent street lamp which has between 15 and 19 lumens per watt.

This sodium vapour lamps comes in two major groups:

1. High pressure sodium vapour lamps (HPS)
2. Low pressure sodium vapour lamps (LPS)

This lamp consists of discharge tube made from special heat resistance glass, containing a small amount of metallic sodium, neon gas and two electrodes. Neon gas is added to start the discharge and to develop enough heat to vapour sodium. A long tube is required to get more light from this lamp. To reduce overall dimensions of the lamp, the tube is generally bent into U-shape.

a. Working principle

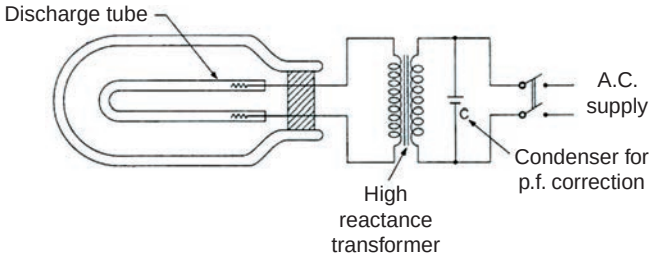


Fig. 2.6 Sodium vapour lamp

The construction of sodium vapour lamp is shown in figure 2.6. Electric discharge lamps require a high voltage at start and a low voltage during operation. The tungsten-coated electrodes are connected across auto-transformer, having high leakage reactance. The open-circuit voltage of this transformer is about 450 V which is sufficient to initiate a discharge through the neon gas.

After 10 to 15 minutes, the voltage falls to 150 V, due to low power factor. A capacitor is connected across the supply to improve the power factor. The colour of light produced is yellowish.

b. Applications

1. LPS lamps are rarely used for indoor lighting and are best suited for outdoor lighting.
2. LPS lamps are used in security lighting as their high efficiency.
3. LPS lamps are also often used in long tunnels.

2.6.2 Mercury vapour lamp

On the basis of pressure inside the discharge tube, the mercury vapour lamps are classified as High pressure mercury vapour lamp and Low pressure mercury vapour lamp. High pressure mercury vapour lamps are classified as:

1. MA type (Mercury vapour lamp with auxiliary electrode)

These are operated at 220 - 250 volt, AC supply and manufactured in 250 to 400 watts.

2. MAT type (Mercury vapour lamp with tungsten filament)

These are manufactured between 300 to 500 watts and works at 200 to 250V (Both AC and DC)

3. MB type (Mercury vapour lamp with auxiliary electrode and bayonet cap)

This type is operated at 200 – 250 volt, (AC and made in 80 watts and 125 watts)

a. Construction

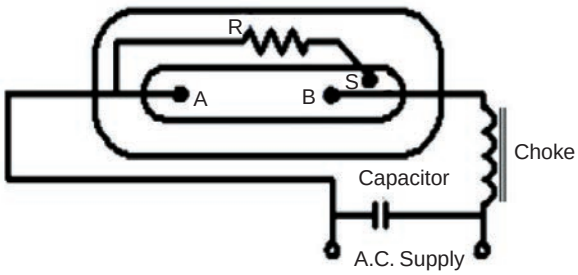


Fig. 2.7 Mercury vapour lamp

The construction of mercury vapour lamp is shown in figure 2.7. It consists of hard glass tube enclosed in outer bulb of ordinary glass. The space between two bulb is completely evacuated to prevent heat loss by convection from the inner bulb. The outer bulb absorbs harmful ultraviolet rays. The inner bulb contains argon gas with a certain quantity of mercury. In addition to two electrodes, starting electrode having high resistance, connected in series is also provided. The main electrodes are made of tungsten wire in a helical shape. The lamp has a screwed cap and is connected to supply with a choke. A capacitor is connected across supply to improve power factor.

b. Working principle

When the supply is switched on, full voltage is applied across main and starting electrodes. This voltage fills the gap between the electrodes and discharge through argon gas. As the lamp warms up, mercury is vaporized, which increases the vapour pressure. After 5 minutes, the lamp gives full light. It gives a greenish blue colour light. This lamp is always kept in vertical. Otherwise the inner glass tube may break due to excess heat.

c. Advantages

1. Mercury vapour lamps are more energy efficient than incandescent lamps.
2. It has high luminous efficacies of 35 to 65 lumens / watt.
3. It is durable. (in the range of 24,000 hours)
4. It has a high intensity.
5. It gives clear white light output which has made them ideal for outdoor use

d. Applications

1. Mercury vapour lamps are used in lighting applications.
2. It is used in streets and parking places.
3. It is used for landscape lighting.
4. It is used in factories.
5. It is used in gymnasiums.

2.7 Fluorescent lamp and compact fluorescent lamp

2.7.1 Fluorescent lamp

It is a low pressure mercury vapour lamp. It consists of a glass tube 25 mm in diameter and 0.6 m, 1.2 m and 1.5 m in length. The inner portion of the tube is coated with phosphorous. The tube contains argon gas at low pressure and a drop of mercury is added. The choke, two filaments and the starter are connected in series as shown in the figure 2.8.

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a. Working principle

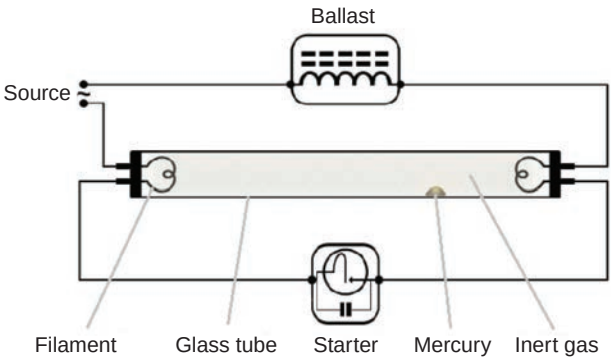

Fig. 2.8 Connection diagram a fluorescent lamp

Fluorescent lamp function based on the principle of current passing through air medium. In the air medium the resistance falls down heavily. When the current passes to the lamp, circuit is closed through choke, filament and starter. So the 230V supply voltage is applied between the starter terminals. Due to this voltage, current starts flowing through the inert gas in the starter. Now the bimetallic strips raised touch each other as the temperature of inert gas has increased. Once the circuit is completed through the bimetallic strips and filaments in the tube light, the bulb will start glowing.

The inert gas in the starter cools down and the bimetallic strip opens again. Therefore the current through the choke decreases and hence the magnetic flux decreases. The decreasing (or alternating) flux is cut by the choke winding which causes self induced EMF in the choke coil.

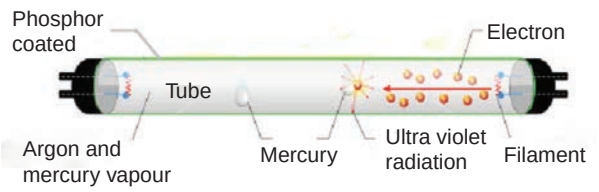

Fig. 2.9 Fluorescent tube

The induced EMF is nearly about 1200V. This voltage is applied between the filaments of the tube light, causing electron flow between the filament and the inert gas of the tube light. The electron collision in to the inert gas produces the ultra violet rays. These rays impinge on the phosphorous coating. Light is emitted by the coating. After light started at 110V is enough for the light to retain the supply voltage 120 volt, which is dropped across the choke. The luminous efficiency of a fluorescent lamp is 60 lumens / watt.

b. Advantages

1. Voltage fluctuation has very small effect on light output.
2. The luminous efficiency is more as length of rod is more.
3. It gives light close to natural light.
4. Heat radiations are negligible.

c. Disadvantages

1. Its brightness is less.
2. Initial cost is more
3. Overall maintenance cost is high.

d. Applications

1. Fluorescent lamp is available in required designs and sizes. Hence it is used largely in residential areas.
2. It is used for good lighting.
3. Special fluorescent lights are used in stage lighting for films and in video camera lighting.

2.7.2 Compact Fluorescent Lamp (CFL)

The compact fluorescent lamps are becoming very useful nowadays, because of consumption of power, cost, longer life, attractive look, smooth light and low maintenance. These lamps are available in different sizes and designs. They have single rod, double rod, triple rod or spiral rod. These lamps are available in different power ratings like 5, 7, 9, 11, 18 and 24 watts in 220 V. It is shown in figure 2.10.

Fig. 2.10 Compact Fluorescent Lamp (CFL)

It is basically a low pressure mercury vapour lamp having two electrodes coated with an electron-emitting material placed in a glass tube. The tube is coated internally with some fluorescent material in the form of powder. In the tube one drop of mercury and argon gas is filled at low pressure. Compact fluorescent lamps are now available in the same popular sizes as incandescent and are used as an energy-saving alternative in homes

a. Advantages

1. Low energy consumption.
2. Low maintenance cost
3. It starts instantly
4. It does not heat the surroundings
5. Excellent colour properties

6. Low operating cost
7. More life

b. Applications

1. The compact size, longer life, low running and maintenance cost, instant glow makes these lamps suitable for all places where uniform illumination is required.
2. It is used in offices, shops, hotels, hospitals, cinema halls, residential buildings etc.

2.8 Neon and Halogen lamp

2.8.1 Neon lamp

Fig. 2.11 **Neon lamp**

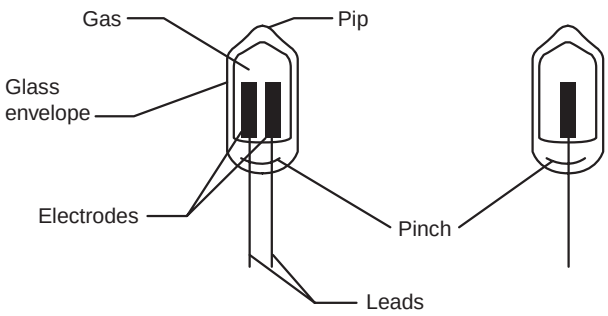

Fig. 2.12 **Line diagram of neon lamp**

a. Construction

The construction of neon lamp is shown in figure 2.11. A neon lamp is a small gas discharge lamp. The lamp commonly consists of a small glass capsule that contains a mixture of neon and different gases at a low pressure, and two terminals (an anode and a cathode). When adequate voltage is applied and sufficient current is supplied between the electrodes, the lamp produces an orange glow discharge. The glowing portion in the lamp is a thin region which is near to the cathode.

b. Applications

1. Neon lamps are generally used for advertising.
2. It is used as an indicator lamps
3. It is used for night lamps

2.8.2 Halogen lamp

Halogen lamp is a special type of tungsten filament lamp which was developed in 1959. In this, a small amount of halogen vapour is added to the inert gas of the bulb. The bulb is made of glass small in size. It operates at a temperature of 3000°C

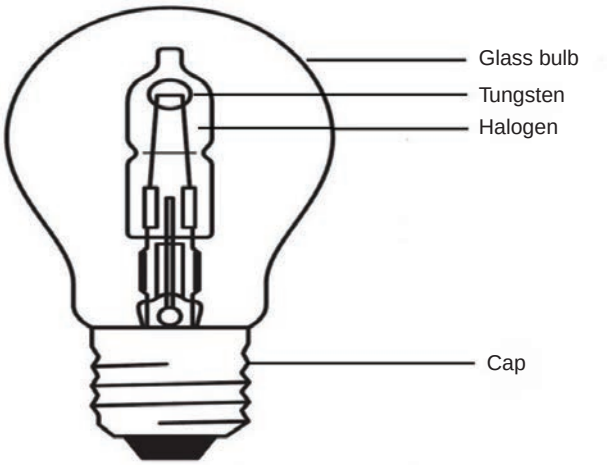

Fig. 2.13 **Halogen lamp**

Working principle

Halogen lamp is shown in figure 2.13. When the supply is given to the lamp, a filament glows, producing light. The halogen, an inert gas, causes the evaporated tungsten to settle back on the filament during cooling. That's why lamps

can be operated at a high temperature. It provides a high intensity light.

a. Advantages

1. It is smaller in size.
2. It does not need any ballast.
3. Good colours can be obtained.
4. Excellent optical control.
5. It gives same output throughout life
6. It has long life

b. Disadvantages

1. During maintenance the handling of lamp is very difficult.
2. Radiation is more which heats the surroundings also.
3. Operating temperature is high which affects its life.

2.9 LED lamp

Fig. 2.14 **LED Lamp**

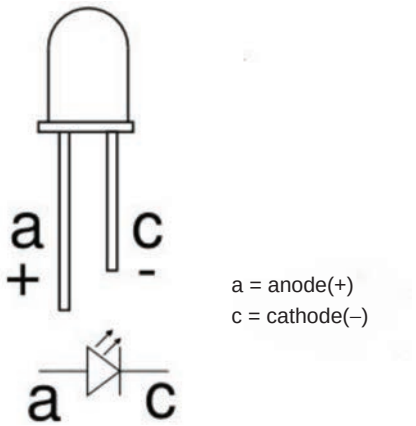

Fig. 2.15 **Line diagram of LED lamp**

The construction of LED Lamp is shown in figure 2.14. An LED lamp is a light-emitting diode (LED) product that is assembled into a lamp (light or bulb) for use in lighting fixtures. The line diagram of a LED lamp is shown in figure 2.15.

LED lamps have a lifespan and electrical efficiency which are several times greater than incandescent lamps, and are significantly more efficient than most fluorescent lamps. General purpose lighting needs white light. LEDs emit light in a very narrow band of wavelengths. To emit white light from LEDs require either mixing light from LEDs of various colours, or using phosphorous to convert some of the light to other colours.

Basic components for LED lighting are:

1. LED
2. Driver (power conversion device)
3. Control devices (dimming controls, colour mixing controls)
4. Fixture

a. LED driver

Required by the LED system to convert a system voltage into power. The driver also regulates power delivered to LEDs to counter any fluctuations in system conditions. Drivers also isolate the LED system from the high voltage system to reduce shock hazards and make the lighting system safer.

b. Advantages

1. It has a long life.
2. It reduces energy costs.
3. It reduces maintenance costs
4. LEDs produce very little heat.

c. Applications

1. It is used in homes
2. It is used in hotels and restaurants
3. It is used in shops
4. It is used in offices
5. It is used in roads, streets and parks
6. It is used in hospitals
7. It is used in commercial premises

2.10 Lighting schemes

Lighting schemes are classified according into their locations requirement and purposes etc., as stated under:

i. Direct lighting
ii. Indirect lighting
iii. Semi direct lighting
iv. Semi indirect lighting
v. General lighting

i. Direct lighting

In this system almost 90 to 95% of light falls directly on the object or the surface. The light is made to fall upon the surface with the help of deep reflectors. Such a type of lighting scheme is mostly used in industries and commercial lighting. Although this scheme is most efficient, it is liable to cause glare and shadows.

ii. Indirect lighting

In this system, the light does not fall directly on the surface but more than 90% of light is directed upwards by using diffusing reflectors. Here the ceiling acts as a source of light and this light is uniformly distributed over the surface and glare is reduced to minimum. It provides shadow-less illumination which is useful for drawing offices and composing rooms. It is also used for decoration purposes in cinema halls, hotels, etc.

iii. Semi direct lighting

This is also an efficient system of lighting and chances of glare are also reduced. Here transparent type shades are used through which about 60% of light is directed downward and 40% is directed upward. This also provides a uniform distribution of light and is best suited for room with high ceilings.

iv. Semi indirect lighting

In this system about 60 to 90% of total light is thrown upward to the ceiling for diffused reflection and the rest reaches the working plane directly. A very small amount of light is absorbed by the bowl. It is mainly used for interior decoration.

v. General lighting

This system employs such type of luminaries, shades and reflectors which give equal illumination in all the directions.

2.10.1 Design of indoor light scheme

While designing a good lighting scheme, the following points must be kept in mind:

i. It should provide adequate illumination.
ii. It should provide uniformly distributed light all over working plane.
iii. It should avoid glare and shadows as far as possible.
iv. It should provide light of suitable colours.

a. Factors required for good lighting scheme

The following factors are required to be considered while designing a lighting scheme

i. Illumination level
ii. Quality of light
iii. Coefficient of utilization
iv. Depreciation factor
v. Space height ratio

b. Advantages of electrical lighting

i. Cleanliness
ii. Easy to control
iii. Economical
iv. Easy to handle
v. Steady output
vi. Better reliability
vii. Suitable for almost all purposes etc.

C. Type of work recommended and illumination level

Places	Illumination Level
Offices	100-400 lumens/ meter square
Schools	250-400 lumens/ meter square
Industry	1000 lumens/ meter square
Shops	250-500 lumens/ meter square
Hotels	80-100 lumens/ meter square
Hospitals	250-3500 lumens/ meter square

Points to remember

- The unit of solid angle is steradians
- The unit of plane angle is radians
- The unit of luminous flux is lumen
- In LED lamps, 15 watts = 900 lumens
- Glare causes annoyance, discomfort or interference with vision or eye fatigue.
- Law of illumination
  i. Inverse square law
  ii. Lambert's cosine law
- Carbon arc lamp is most commonly used arc lamp.
- Types of incandescent lamp
  i. Vacuum lamp
  ii. Gas filled lamp

- Types of sodium vapour lamps are
  i. High pressure sodium vapour lamps (HPS)
  ii. Low pressure sodium vapour lamps (LPS)
- Neon lamps are operated at a very low temperature of about 200^{0}C.
- LED lamps are used in homes, hotels, restaurants, shops, offices, hospitals, roads, streets and parks.
- Types of lighting schemes
  i. Direct lighting
  ii. Indirect lighting
  iii. Semi direct lighting
  iv. Semi indirect lighting
  v. General lighting

Activities

1. To know about how the electric lamp is controlled by a remote.
2. To know about how the electric lamp is controlled by Passive infra red sensor. (PIR Sensor)

Glossary

Plane angle	-	தளக் கோணம்
Solid angle	-	திண்மக் கோணம்
Luminous flux	-	ஒளிர்வுப் பாயம்
Luminous intensity	-	ஒளி விளக்கச் செறிவு
Luminous efficacy	-	ஒளிர்வுத்திறன் விகிதம்
Lux	-	ஒளித்திறன்
Glare	-	கூசொளி
Depreciation factor	-	தேய்மானக் காரணி
Space height ratio	-	இடைவெளி – உயர விகிதம்
Utilization factor	-	பயன்பாட்டுக் காரணி

Evaluation

13UA5

PART-A

Choose the correct answer **(1 Marks)**

1. Luminous efficacy of a fluorescent lamp is
   a) 10 lumens / watt
   b) 20 lumens / watt
   c) 40 lumens / watt
   d) 60 lumens / watt.

2. In LED lamps, how many watt is equal to 900 Lumens?
   a) 15 watts
   b) 0.16 watts
   c) 0.016 watts
   d) 0.0016 watts

3. Standard wattage of 4 ft. fluorescent lamp is
   a) 10 W
   b) 40 W
   c) 65 W
   d) 100 W

4. A solid angle is expressed in terms of
   a) radians
   b) radians/meter
   c) steredian
   d) steredian/meter

5. Which of the following lamp has a low initial cost?
   a) Incandescent lamp
   b) Fluorescent lamp
   c) Mercury vapour lamp
   d) Sodium vapour lamp

6. An incandescent lamp can be used in
   a) AC supply
   b) DC supply
   c) Both AC and DC supply
   d) No supply

7. Filament lamps operate normally at a power factor of
   a) 0.5 leading
   b) 0.8 leading
   c) 0.8 lagging
   d) Unity

8. The filament of incandescent lamp is
   a) Tungsten
   b) Copper
   c) Aluminum
   d) Carbon

9. The average working life of a fluorescent lamp is about
   a) 1000 hours
   b) 3000 hours
   c) 4000 hours
   d) 5000 hours

10. The luminous efficacy of a sodium vapour lamp is about
    a) 190 lumen/watt
    b) 30 lumen/watt
    c) 50 lumen/watt
    d) 70 lumen/watt

11. Colour of light is depend upon
    a) Frequency
    b) Wave length
    c) Speed of light
    d) Both a) and b)

12. In houses the illumination is in the range of
    a) 2-5 lumens/watt
    b) 10-20 lumens/watt
    c) 35-45 lumens/watt
    d) 60-65 lumens/watt

13. The colour of sodium vapour discharge lamp is
    a) Red
    b) Green
    c) Bluish green
    d) Yellow

14. Which of the following will need the highest level of illumination?
    a) Proof reading
    b) Living rooms
    c) Hospital wards
    d) Railway platforms.

15. The illumination level in houses is in the range
    a) 10-20 lumen/m
    b) 30-50 lumen/m^2
    c) 40-75 lumen/m^2
    d) 100-140 lumen/m^2.

PART-B

Answer the questions in brief **(3 Marks)**

1. Define solid angle.
2. What is meant by luminous flux?
3. What is glare?
4. Define space height ratio.
5. State the two laws of illumination.
6. What are the various electrical method of producing light?
7. Where sodium vapour lamps are used?
8. What are the advantages of mercury vapour lamp?
9. What are the disadvantages of a fluorescent lamp?
10. What are the advantages of a CFL lamp?
11. Briefly describe the working principle of a neon lamp.
12. List out the types of lighting schemes.
13. What are the applications of LED lamps?

PART-C

Answer the questions in one page **(5 Marks)**

1. Write a short note on a carbon arc lamp.
2. Explain the construction of an incandescent lamp.
3. Write down the advantages and applications of a mercury vapour lamp.
4. Explain about neon lamp.
5. Explain the advantages and disadvantages of a halogen lamp.
6. Write short notes on compact fluorescent lamp.
7. Write down the advantages and applications of CFL lamp.
8. What are the factors required for a good lighting scheme?
9. Write short notes on LED.

PART-D

Answer the questions in two page **(10 Marks)**

1. With a neat sketch explain the construction and working principle of sodium vapour lamp.
2. With a neat sketch explain the construction and working principle of mercury vapour lamp.
3. With a neat diagram explain the construction and working principle fluorescent lamp.

Reference Book

1. A text book of 'Electrical Technology' Volume-III B.L.Theraja and A.K.Theraja, S.Chand & Company Ltd.

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2. https://www.electrical4u.com