Illumination terms - Laws

Objectives: At the end of this lesson you shall be able to
- **state and explain different terms used in illumination**
- **state properties and advantages of good illumination**
- **state and explain laws of illumination.**

Definitions

A few principle terms in connection with illumination are defined below.

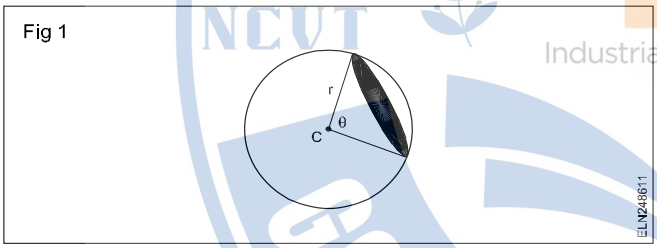
Luminous flux (F or F)**:** The flux of light emitted from a luminous body is the energy radiated per second in the form of light waves. The unit of luminous flux is `lumen'(lm).

Luminous intensity(I): The luminous intensity of a light source in a given direction is the luminous flux given out by the light source per unit solid angle. The angle subtended by an area r^2 on the surface of sphere of radius r, at the centre of sphere is unit solid angle. In SI, the unit of luminous intensity is the candela.

Candela: This is the amount of light emitted in a given direction by a source of one candle power. SI base unit is candela (cd). 1 candela = 0.982 international candles.

Lumen (lm)**:** It is the unit of luminous flux. This is defined as the amount of light contained in one steradian from a source of one candela at its focus. (Fig 1)

Fig 1



If the shaded area = r^2 and a source of one candela is at the centre C, the light contained within the solid angle is one lumen.

The light output of electric lamp is measured in lumens and their luminous efficiency is expressed in lumens per watt (lm/w).

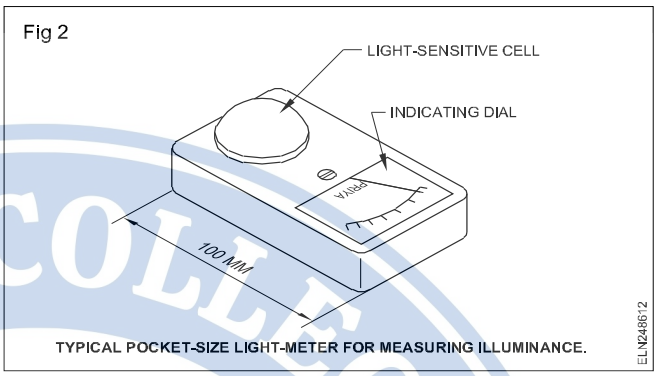
Illuminance or Illumination (E): Illuminance of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The metric unit is the lumen / m^2 or lux (lx).

Lux: This is the total output of light. Lumen per square meter (1m/m^2) or lux is the intensity of illumination produced in the inner surface of a hollow sphere of radius one meter by a standard candle at the centre. Sometimes this is also known as metre-candle.

Lighting engineers use a pocket-size instrument called a `lightmeter' to measure illuminance; and the reading in lux is read off the scale (Fig 2).

Factors to be viewed for correct illumination: The following are the important factors which should be considered while planning correct and a good illumination:

Fig 2



TYPICAL POCKET-SIZE LIGHT-METER FOR MEASURING ILLUMINANCE.

Nature of work : Considering the nature of work , sufficient and suitable lighting sould be maintained. For example, a delicate work like radio and TV assembling, etc. requires good illumination to increase the production of work where as for rough work like storage, garages, etc needs very small illumination.

Design of Apartment : The design of apartment must be kept in view while planning scheme for illumination. It means that the light emitted by the illumination source should not strike the eyes of the occupants or workers.

Cost : It is an important factor which should be considered while designing an illumination scheme for particular purpose.

Maintenance Factor : While planning illumination, it should also be kept in view the amount of reduction of light due to accumulation of dust or smoke on the source of light and after how much period cleanliness is required. Where there is a possibility of heavy loss of light due to the adherence of smoke, arrangement for the extra light is to be made from the very beginning.

Properties of good illumination

An illumination source should, have the following properties.

i It should have sufficient light.

ii It should not strike the eyes.

iii It should not produce glareness in the eyes.

iv It should be installed at such a place that it gives uniform light.

v It should be of correct type as needed.

vi It should have suitable shades and refelectors.

Advantages of good illumination

i It increases production in the workshop.

ii It reduces the chances of accidents.

iii It does not strain the eyes.

iv It reduces the wastage or loss of material.

v It increases the interior decoration of the building.

vi It gives smoothing effect to mind.

Laws of illumination

Inverse square law: If the internal radius of a sphere is increased from 1 metre to r metres, the surface area of it is increased from 4π to $4\pi r^2$ square metres. With a uniform point source of light of one candela at the centre, the number of lumen per square metre on the sphere of radius r metres.

$$= \frac{4\pi}{4\pi r^2} = \frac{1}{r^2}$$

Hence the illumination of a surface is inversely proportional to the square of its distance from the source. This is called the **Inverse Square Law of Illumination.**

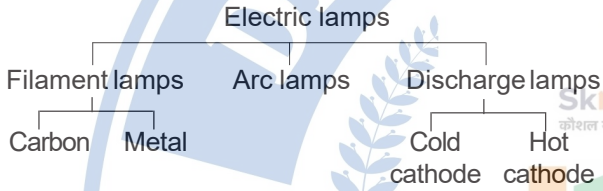
Types of lamps

Objectives : At the end of this lesson you shall be able to
- **list out the types of lamps**
- **explain the different types of lamps**
- **explain the construction and working of tungsten filament lamp.**

Types of lamps

There are many types of electric lamps now available. They differ in construction and in the principle of operation.

They give light as a result of heating the filament to a very high temperature. The lamps can be grouped as follows.



Filament lamp: A lamp in which a metal, carbon or other filament is rendered incandescent by the passage of electric current.

Vacuum lamp: A filament lamp in which the filament operates in a vacuum.

Gas-filled lamp: A filament lamp in which the filament operates in an inert gas.

Halogen lamp: A tungsten filament lamp in which the tungsten filament operates in a relatively small space filled with an inert gas and halogen of iodine or bromine.

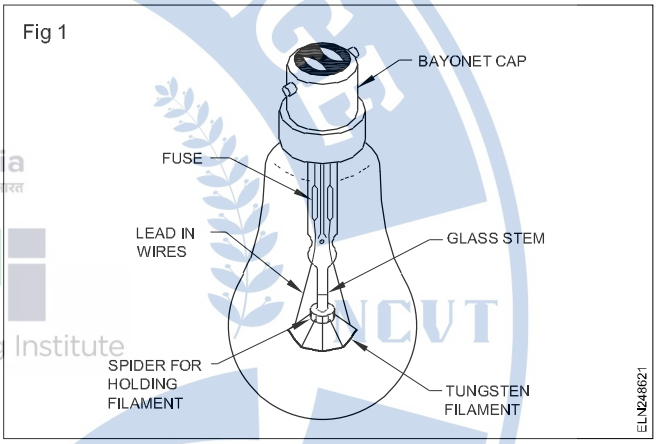
Arc lamp: An electric lamp in which the light is emitted by an arc.

Discharge lamp: An electric lamp in which the light is obtained by a discharge of electricity between two electrodes in gas or vapour.

Tungsten filament lamp: This lamp consists essentially of a fine wire of the metal, tungsten (the filament) supported in a glass envelope and the air evacuated from the glass bulb - hence called a **vacuum lamp**.

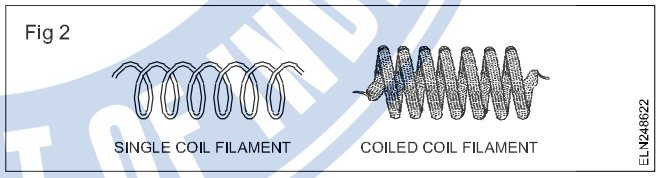
Fig 1 shows the parts of tungsten filament lamp

Fig 1



The two types of filaments (Fig 2) are
- single coil filament
- coiled coil filament.

Fig 2



The main advantage of a coiled coil lamp is the higher light output.

Direct and indirect lighting

Objectives: At the end of this lesson you shall be able to
- **explain direct and indirect lighting.**

Direct lighting type has largest efficiency from energy utilization point of view but glare is always present. Such systems are used for flood and Industrial lighting.

Indirect lighting type designed to avoid glare and recommended for specific purposes.

Semi direct type designed to avoid glare and recommended for offices and other specific purposes.

Semi indirect type designed to avoid glare and recommended for specific purposes.

Low voltage lamps - different wattage lamps in series

Objectives: At the end of this lesson you shall be able to
- **state the purpose of differtent voltage lamps**
- **calculate and compare the hot resistance of the same voltage but of different wattage/current lamps**
- **describe the method of measuring and calculating the 'hot resistance'**
- **state the effects of different wattage lamps in series.**

Purpose: In quite a few places we use low voltage supply i.e. 6V, 12V or 24V, such as in automobile vehicles. Automobile vehicles are equipped with many lights to provide an efficient lighting system for both day and night driving conditions. The various lights require the use of different wattage and types of light lamps to provide the amount of illumination desired.

Glow conditions of low wattage lamps with current flow through it: An electric lamp changes electrical energy into heat and light, when current flows through its filament and causes it to become incandescent. The filament is made of tungsten wire. The low voltage lamps are generally of low wattage because at a low voltage, the current taken by the filament for a given wattage is much more as compared to the domestic light.

Different wattage lamps in series: If the two lamps of different wattage in parallel across in A.C. circuit, it should be same voltage for proper operation. But, if they are connected in series they should have the same current ratings.

All the bulbs in house are probably connected in parallel and they will draw the current it requires, and all the lamps will glow bright.

If two lamps with unequal wattages and same voltage ratings are connected in series they will divide up the available voltage between them.

Low wattage lamp will glow bright, due to high resistance and high voltage drop. High wattage lamp will glow dim, due to low resistance and low voltage drop.

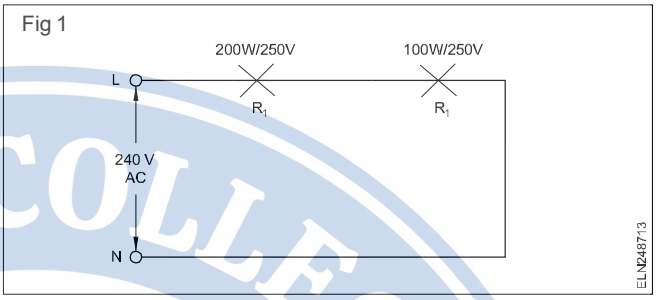
Example

In a circuit the two lamps rated as 200W/ 250V, and 100W/ 250V are connected in series across 240 volt A.C. supply. (Fig 1)

200W (higher wattage) lamp will glow dim and

100W (low wattage) lamp will glow bright.

Fig 1



because,

The resistance of 200W/ 250V lamp,

$$R_1 = \frac{V^2}{W_1} = \frac{250 \times 250}{200} = 312.5\ \Omega$$

The resistance of 100W/250V lamp,

$$R_2 = \frac{V^2}{W_2} = \frac{250 \times 250}{100} = 625\ \Omega$$

Total resistance $R_T = 312.5 + 625 = 937.5\ \Omega$

$$\text{current } I = \frac{V}{R_T} = \frac{240}{937.5} = 0.256A$$

voltage drop in 200W lamp, $= IR_1 = 0.256 \times 312.5 = 80V$

Voltage drop in 100W lamp, $= IR_2 = 0.256 \times 625 = 160V$

Power V X I = 240 X 0.256 = 61.4 W

Hence,

The 100W lamp having high voltage drop due to high resistance it will glow bright than high wattge lamp 200W which is having low voltage drop and low resistance.

Construction details of various lamps

Objectives: At the end of this lesson you shall be able to
- **explain the construction and working of neon sign tubes**
- **explain the colour mechanism of neon signs.**

Neon sign lamp

Gas discharge lamp

A gas discharge lamp is one in which some inert gas is filled in a glass tube having two electrodes sealed into each end, which on heating allows the flow of electron through it. To obtain a continuous flow of electron, gas is first charged but as the supply is disconnected from the bulb, the gas is discharged. Such a lamp is known as electric Gas Discharge Lamp. Electric gas discharge lamps are of two main types:

(i) Cold cathode lamp

(ii) Hot cathode lamp

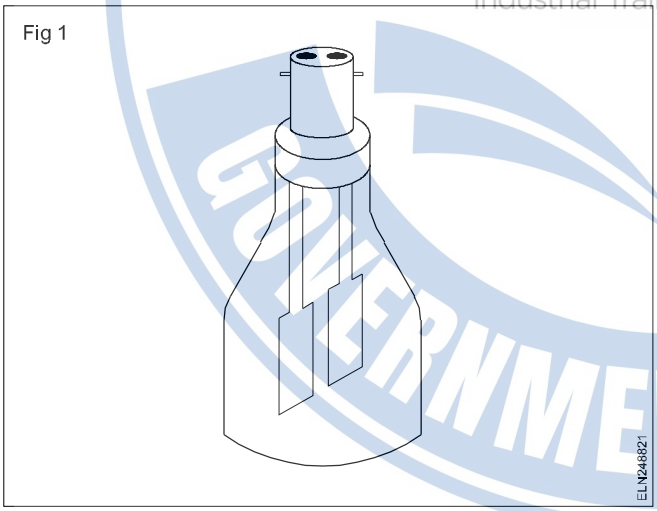
Cold Cathode Lamps (i) Neon lamp, (ii) neon sign tubes, (iii) sodium vapour lamp.

Hot Cathode Lamps (i) mercury vapour lamp (medium pressure), and (ii) fluroscent tube (low pressure mercury vapour lamp)

Types of gas discharge lamps

Neon Lamp This is a cold cathode lamp as shown in Fig 1 Neon gas at low pressure is used in it.

Fig 1



Construction

In this lamp, two flat or spiral electrodes are kept close together in a glass bulb so that the lamp can be operated at low voltage such as 150 V dc or 110 V ac. On giving supply to the electrodes, the gas becomes ionised and emits light which is reddish in colour. In usual practice a 2000W resistance is also connected in series with the electrodes which is placed in the cap of the lamp. This minimizes the fluctuation of current due to large variation of potential difference.

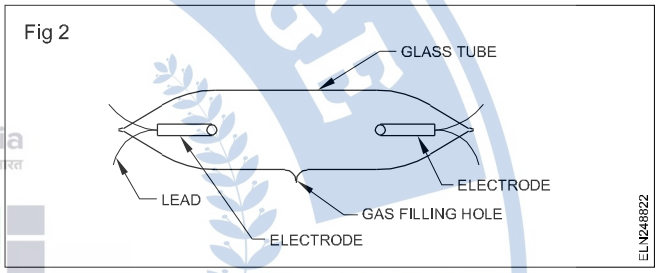
Uses

A neon lamp is generally used as an indicator lamp to indicate the presence of supply. It gives a small quantity of light and can also be used as a night lamp. A neon lamp of this type is also used in the testing pencil which is of 0.5 W.

Neon sign tube

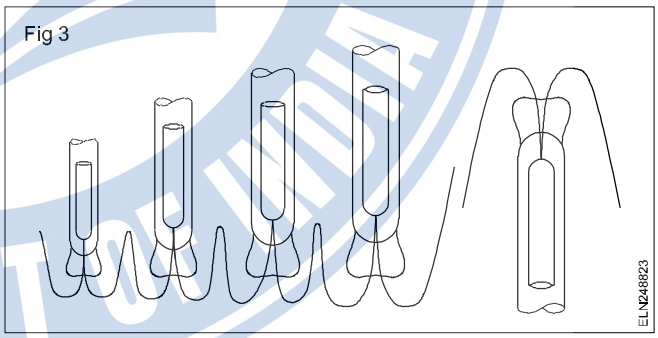
Construction of neon sign tube: Neon sign tube lamps are used mostly for advertising purposes. Fig 2 shows the construction details of a neon sign tube. A neon sign tube is made of glass.

Fig 2



The length of the tube varies from 1 metre to 5 metres, and the diameter varies from 10 mm to 20 mm. The tubes are joined with electrodes which are operated at high voltage. The electrodes are connected with nickel wires for more length or to different letters. (Fig 3)

Fig 3



The shape of the electrode is cylindrical. The electrodes are made of nickel, iron or copper. The electrode consists of:

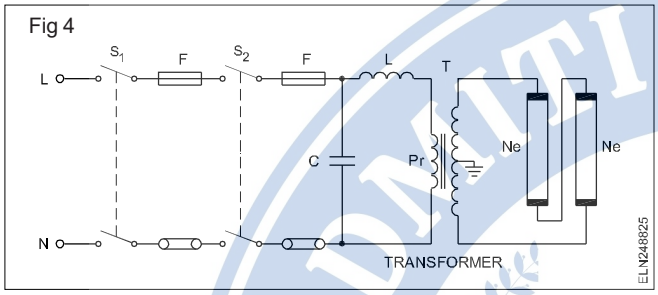
- a glass shell
- a lead in wires
- a glass jacket seal
- a ceramic collar. (heat resisting material)

The electrodes are fitted at the end of the tubes and fused. A vacuum is created in the tube before filling it up with an inert gas, such as neon or helium. After that it will be sealed. The neon sign tube will operate at 2000V to 15000V depend upon the length of the tube.

Working of neon sign tube: The neon sign tube requires a high voltage to operate. (Fig 4) This is obtained by a leakage field transformer (T) which simuntanously limits the current. The colour and the temperature of a neon tube depend on the gas inside, and we can also get various colours by using different fluorescent materials.

When high voltage is applied between the electrodes, the positive ions and the electrons drift towards the cathode and anode respectively. The movement of electrons increases with the potential and attain a very high velocity. The movement of electrons results in collision with the netural atoms, and may detach electrons from them. The high velocity of electrons is responsible for luminous discharge (light). The striking voltage of a neon sign lamp is about 1.5 times higher than the operating voltage, which is controlled by the R.F. choke)'L'.(Fig 4)

Fig 4



Circuit description and operation

Step-up transformer: The step up transformer is used to obtain a high voltage. The centre tap is earthed. The secondary output voltage is connected to the neon lamp.

R.F. choke L is connected in series with the primary of the leakage transformer to limit the surge current of the neon lamp. (Fig 4)

The capacitor C It is connected across the primary of the transformer to improve the power factor.

The fireman switch S2 It is connected alongwith the main switch and is used as an emergency switch. (Fig 4)

Main switches normally 15A 250V ICDP are used to control the circuits.

H.T. cables are used to connect the secondary of the transformer to the neon sign lamp as per IE rule No 71.

Colour mechanism of neon sign lamp: When electric current is conducted by a gas or vapour it produces luminous light. The elements most commonly used in this process of producing light by gaseous discharge are neon or mercury. The neon discharge yields orange-red light which is very popular in making advertising signs. The pressure of neon in the tubes is usually from 3 to 20 mm of the Hg. (millimeter of mercury)

The ultimate colour produced by using fluorescent powders depends not only on the chemical composition of the powders but also on the gas, the pressure at which the gas was filled, the diameter of the tubing and the operating current.

Colour Mechanism - Table

	Basic powder	Colour
1	Calcium tungstate	Blue
2	Magnesium tungstate	Blue-white
3	Calcium silicate	Pink
4	Zinc silicate	Green
5	Zinc beryllium silicate, depending upon the activating agent	Yellow, white, pink
6	Cadmium silicate	Yellow, pink
7	Cadmium borate	Pink

Installation: All equipment to be housed in an earthed metal or substantial containers suitable for high voltage. A notice `Danger-High Voltage' in the type of lettering as stated in 1.E regulation No.71, to be permanently fixed near to the equipment.

Sodium vapour lamp

Objectives: At the end of this lesson you shall be able to
- **state the sodium vapour lamp and its types**
- **describe the construction of low and high pressure sodium vapour lamp**
- **state the functions of the parts in the circuit.**

Sodium vapour lamp and its types: Sodium vapour lamp is a cold cathode gas discharge lamp, which gives a yellow colour light. Sodium lamps are particularly suitable in fog as their yellow light can penetrate fog better.

The average life of a sodium vapour lamp is well over 6000 hours. There are two types of Sodium Vapour lamps as given below:

- low pressure SV lamp
- high pressure SV lamp.

Construction

Low pressure sodium vapour lamp: In the sodium vapour lamps efficiency decreases rapidly as the current density is increased above a certain value. Consequently the lamp has to be operated at a low current density and this necessitates a large surface area of the tube.

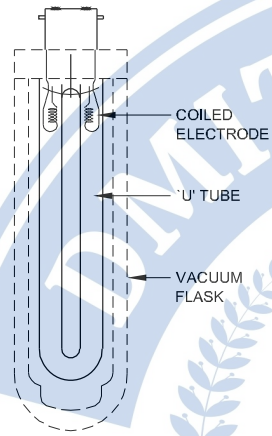
This lamp possesses a brightness of 7.5 candle per sq.cm. Because of these points the length of this tube has to be very long.

As stated above low pressure Sodium Vapour lamps require a long tube, but as there is limit to the practicable size of such a jacket of the vacuum flask type, the long lamp tube is bent to a `U' shape to suit the jacket.

The low pressure Sodium Vapour lamp possesses a `U' shaped glass tube internally coated with fluorescent powder, consisting of Sodium together with Neon and one percent of Argon, the function of the Argon being used to reduce the initializing voltage.

In a cold lamp the Sodium is in the form of solidified drops on the inner walls. The tube contains two Barium and Strontium coated, coiled Tungsten electrodes at both ends. The two ends of the electrodes are fixed to the bayonet cap. (Fig 1) Connection diagram is Fig 3.

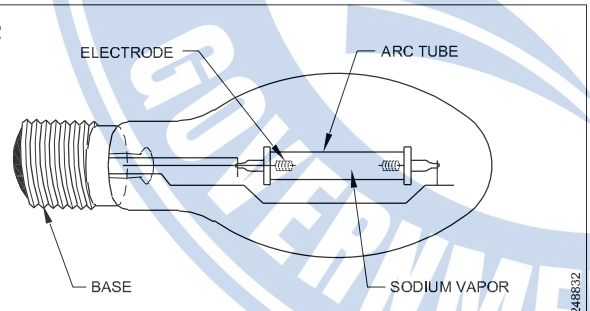
Fig 1



SODIUM DISCHARGE LAMP

High pressure sodium vapour lamp: A high pressure Sodium vapour lamp (Fig 2) operates at a much higher current which flows through a much shorter arc tube (discharge tube).

Fig 2

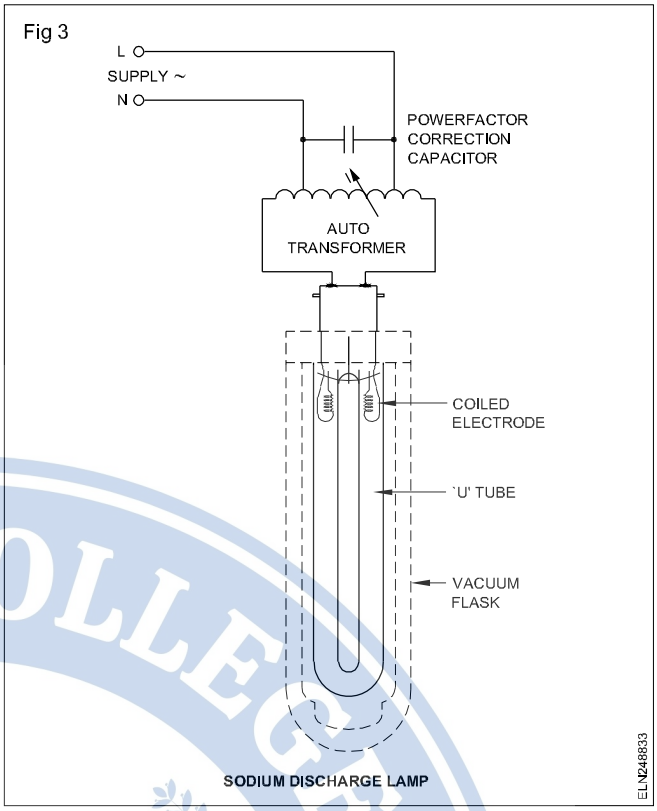


HPSV LAMP

This discharge tube is made of sintered aluminium ceramic discharge arc tube which is resistant to the hot ionised Sodium Vapour up to a temperature of about 1600^0C which transmits over 90% of visible radiation.

The discharge tube operates at a pressure of about half an atmosphere, and is enclosed in an evacuated hard glass envelope of elliptical shape to maintain the tube at the correct temperature. The lamp gives a rich Golden light which enables colours to be easily distinguished. This discharge tube contains Sodium and Mercury, with Argon or xenon added at a low pressure for starting purposes at low pressure.

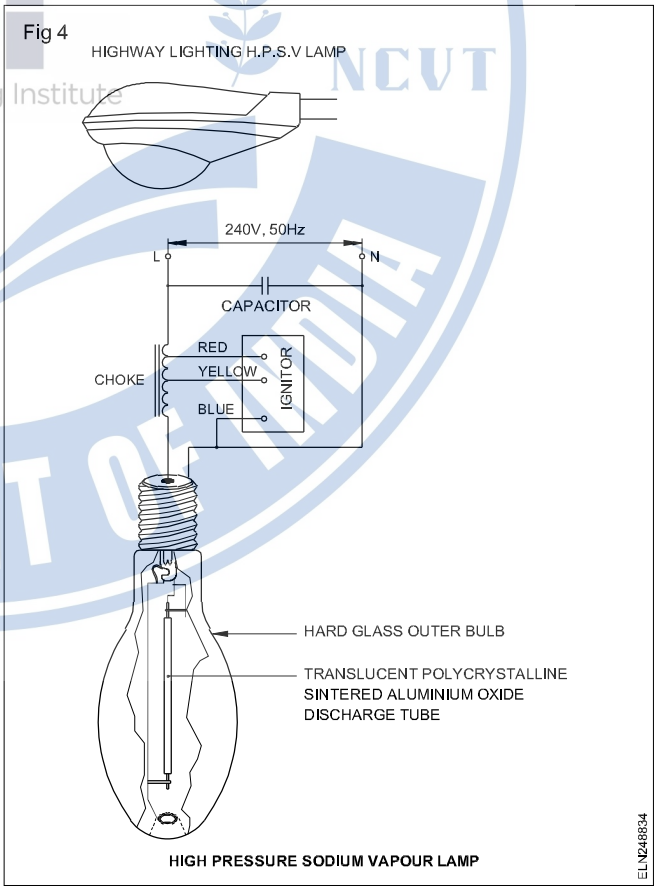
Fig 3



SODIUM DISCHARGE LAMP

A voltage pulse of about 2.5 KV is required to initiate the discharge (Fig 4) in higher pressure Sodium Vapour lamp. This high voltage pulse is generated by high external ignitor or by built in thermal starter.

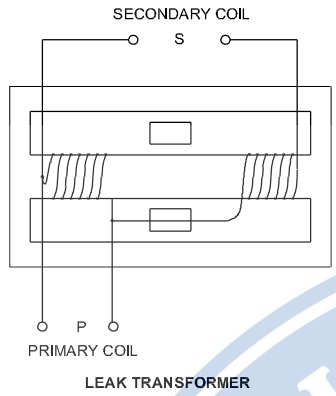
Fig 4



HIGH PRESSURE SODIUM VAPOUR LAMP

Leak transformer: The ignition voltage of sodium lamps varies from 400 to 600V. A `leak transformer' performs the dual role of providing the ignition voltage initially, and acting as a choke for limiting the current subsequently when the lamp starts conducting. The diagram of a leak transformer is shown in Fig 5.

Fig 5



LEAK TRANSFORMER

The primary and the secondary windings are connected in series and placed around the centre limb of a 3-core yoke. Between the coils, a loose iron core is clamped in the yoke on either side, which acts as a shunt for the magnetic field.

Under no-load conditions, the resistance of the shunt is large due to air gaps, with the result the magnetic field moves through the limbs of the yoke, and the device acts as an auto-transformer. But when the lamp ignites and consumes current, a part of the magnetic field leaks away through the shunt due to the counter-acting field of the secondary.

The device now acts as a choke coil reducing the voltage across the lamp electrodes to the required value.

High pressure mercury vapour lamp (H.P.M.V)

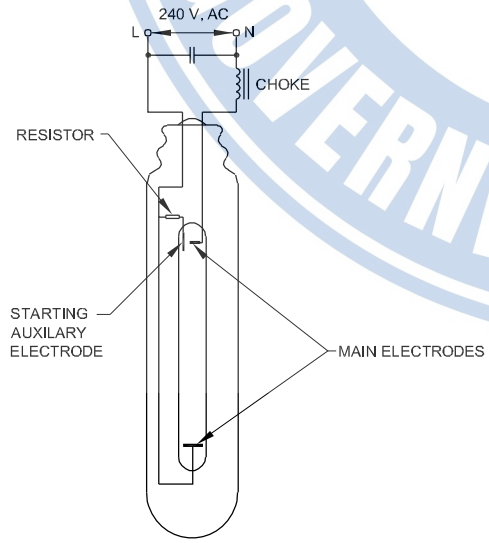
Objectives: At the end of this lesson you shall be able to

- **state the principle of discharge lamps**
- **describe the working of a `high pressure' mercury vapour lamp**
- **explain the different types of mercury vapour lamps.**

All modern discharge lamps operate in a translucent enclosure. The initial discharge is usually struck in argon or neon.

The discharge occurs in an inner tube enclosed in an outer evacuated tube. (Fig 1) The inner tube of glass or quartz contains mercury and a small amount of argon to assist in the starting of the discharge. The electrodes are rich in electron-emittting materials in order to permit ease in the release of electrons.

Fig 1



MA TYPE HPMV LAMP CIRCUIT

HPMV lamps

The lamp operates at high pressure. To start the discharge, an auxiliary electrode is positioned quite close to the main electrode. The auxiliary electrode is connected to the lamp terminal through a high resistor.

The high resistor limits the current. When switched on, the normal mains voltage is not sufficient to start the discharge between the main electrodes but it can start over the very short distance between the main and auxiliary electrodes.

At the beginning, the discharge current passing through the high resistance causes a potential difference to develop between the starting electrode and one of the main electrode through the argon gas. The discharge now spreads rapidly until it takes place between the main electrodes.

The argon discharge then warms up the tube and vaporises the mercury. Soon the gas content is mainly mercury vapour and the argon has less and less effect. The discharge then takes place in the mercury vapour.

Types of HPMV lamps

Three different types of high pressure mercury vapour lamps are:

- MA type (MV lamp with auxiliary electrode)
- MAT type (MV lamp with tungsten filament)
- MB type. (MV lamp with auxiliary electrode and Bayonet cap)

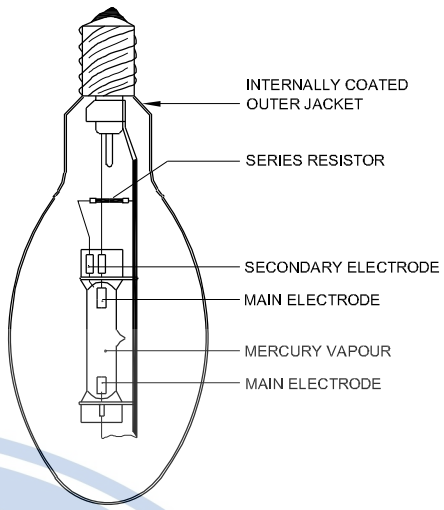
Among the 3 types only MA type is explained below:

MA type HPMV lamp: The discharge tube is made of borosilicate which is quite hard. The tube consisting of the main and auxiliary electrodes is sealed with an inside pressure of one and a half atmospheres. The lamp has a screw cap and is connected to the mains through the choke. (Fig 2) The lamp takes about 5 minutes to start giving full output.

This lamp, once switched off, will not restart again until the pressure developed inside the tube falls back. It takes about 7 minutes to start again. There is no harm in keeping the switch on. The lamp should always be hung vertically, otherwise the inner tube will be damaged.

The efficiency is 45 lm/watt for 400 watts lamp

Fig 2



MA TYPE HPMV LAMP

ELN248842

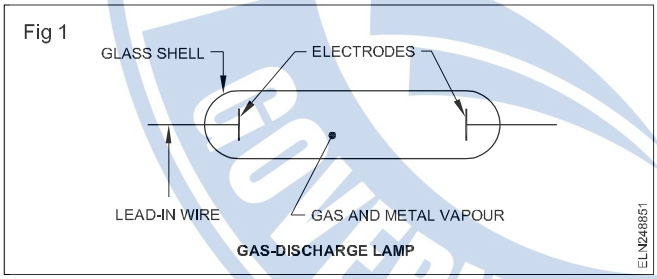
Fluorescent lamp

Objectives : At the end of this lesson you shall be able to

- **state the principle of discharge lamps**
- **describe the construction of single tube fluorescent lamp with its components**
- **state the function of each component in the circuit.**

Principle of a discharge lamp : The basic principle of a gas-discharge lamp is explained in Fig 1. Gases are normally poor conductors, especially at atmospheric and higher pressures, but application of suitable voltage (known as ignition voltage) between two electrodes in a sealed envelope containing gas at low pressure ionises the gas, and current passes from one electrode to the other through the gas medium.

Fig 1



GAS-DISCHARGE LAMP

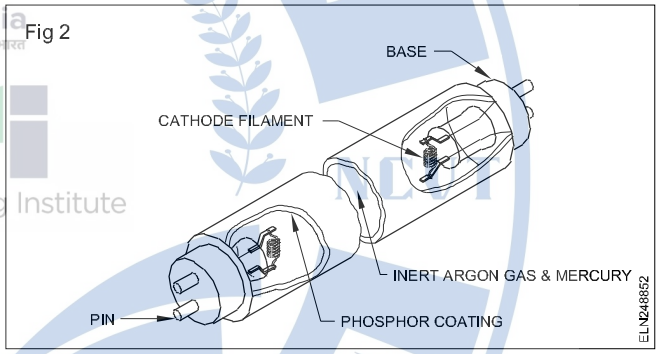
ELN248851

A glass shell with two electrodes apart is connected through lead in wires to the voltage source. The space within the shell is filled with low pressure vapour. When the voltage applied to the electrodes is increased to a certain value, the gas inside gets ionised and starts conducting.

Construction of fluorescent tubes: A fluorescent light bulb is basically a glass tube capped by two bases. (Fig 2) These bases are fitted with pins to carry current to internal components called cathodes. Contained inside the tube are minute droplets of mercury and an inert gas.

The inner surface of the tube is coated with a fluorescent powder or phoshphor. This phosphor emits light when exposed to ultra-violet rays. Cathodes or electrodes are made up of coiled tungsten filaments coated with a mixture of barium and strontium oxides.

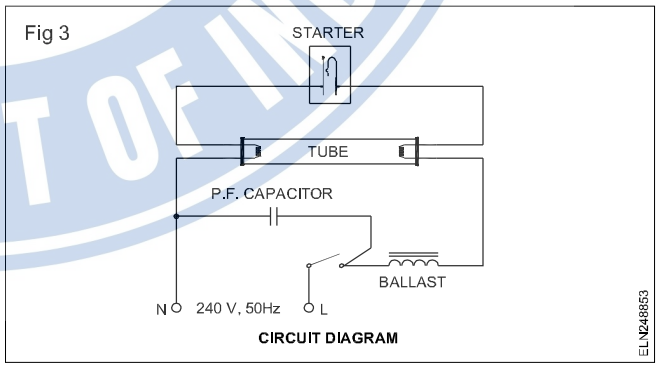
Fig 2



ELN248852

Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is as in (Fig 3)

Fig 3



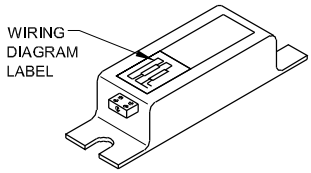
CIRCUIT DIAGRAM

ELN248853

Function of the various parts in a fluorescent light circuit

Ballast (Choke)**:** The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of heavy current to the tube cathodes to keep them from burning out.

Fig 4



Starters: A starter in the fluorescent tube circuit performs two functions.

- It completes the circuit at first for preheating the electrodes.
- It opens the circuit to provide voltage kick for ignition.

There are two types of starters.

- Glow-type
- Thermal type

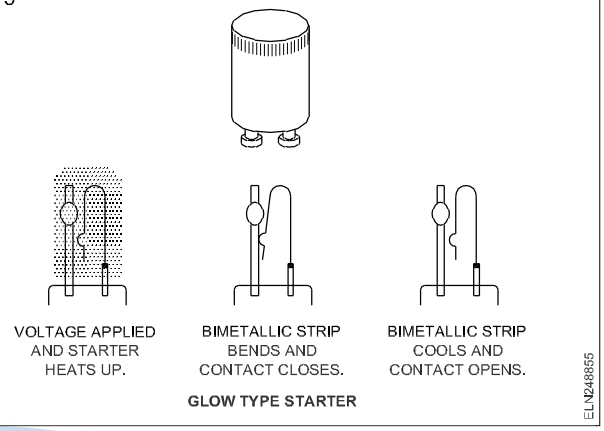
Glow type starters: A glow-type starter switch (Fig 5) is the one most widely used. It consists of a gas-filled glass tube containing two electrodes, one of which is a bimetallic strip. When voltage is applied to the starter, a glow discharge occurs between the two contacts. The heat thus developed causes the bimetallic strip to deflect and close the circuit.

Current for preheating the electrodes starts flowing. At the same time the glow discharge ceases resulting in the cooling of the bimetallic strip. The contacts reopen and the voltage induced in the choke coil provides the ignition voltage.

Thermal type starter: The starter has a bimetalic strip close to the resistance R which produces heat.

Thermal type starters are generally enclosed in a hydrogen - filled glass bulb G. The two switch electrodes E_1 and E_2 are normally closed when the lamp is not in operation. When normal supply is switched on, the lamp filament electrodes A and B are connected together through the thermal switch and a large current passes through them.

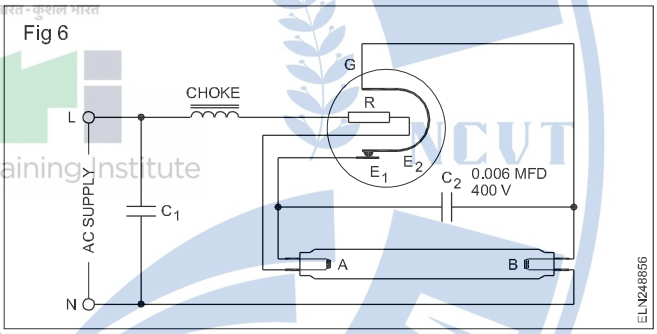
Fig 5



Consequently, they are heated to incandescence. Meanwhile the heat produced in resistance R causes the bimetallic strip E_2 to break contact. The inductive surge of about 1000V produced by the choke is sufficient to start discharge through mercury vapours as explained. The heat produced in R keeps the swtich contacts E_1 and E_2 open during the time as shown in Fig 6.

A 0.006 MFD capacitor (C_2) is connected across the electrodes of the starter contacts (bimetals) in the case of both thermal and glow type starters, to eliminate any radio interference effects that may be caused by the opening and closing of the bimetallic contacts.

Fig 6



Halogen lamp

Objectives: At the end of this lesson you shall be able to

- **explain Halogen lamp construction**
- **describe the principle of tangsten halogen regenerative cycle process**

Construction: Halogen lamps are the most advanced and multi-purpose incandescent lamps. Although they belong to the incandescent family of lamps, they are designed to provide a superior quality of crisp white light, long life, high efficiency and constant lumen maintenance. Due to their reduced size, the halogen lamps allow for the most compact and stylish fixture designs. Halogen lamps operate on the tungsten halogen regenerative principle which eliminates filament evaporation and bulb blackening. As a result, the initial lumens and color temperature are maintained throughout the lamp life. The use of bromine, which is a transparent gas, increases efficiency by 28 -33 lumens/watt as compared with iodine because there is less absorption of light by the filled gas (Fig 1).

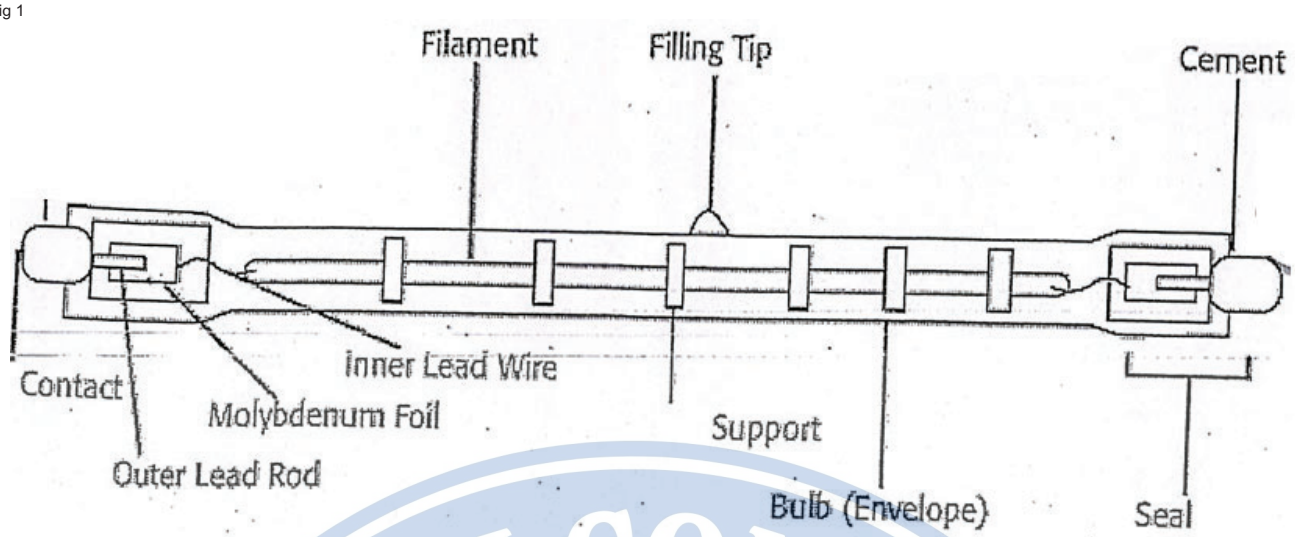
Principle of tungsten halogen regenerative cycle process

1 If the lamp is turned on, tungsten particles evaporate from filament and attach on to bulb wall. At the same time, halogen is decomposed and becomes atomic halogen.

2 Atomic halogen is diffused on the bulb wall and combines with free tungsten particle to become transparent and volatile tungsten halide.

3 Due to the high temperature (over 500°F) on the bulb wall, tungsten halide is volatilized and circulated back to filament.

Fig 1



4 After tungsten halide is decomposed around the filament at a high temperature, halogen gas is released, ready to combine again, and tungsten is re-deposited on the filament, whereby the process is ready to begin again.

The halogen lamp's envelope is made of quartz glass because of the high operating temperature and pressure required to permit the halogen regenerative cycle process. Quartz also renders the lamp extremely resistant to heat impact. The small dimensions of halogen lamps allow accurate control over the light beam for a better focused and precise light.

Tungsten Halogen Lamp

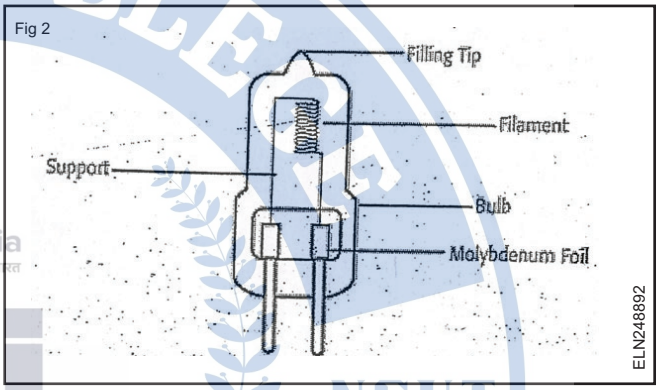
Halogen is the name given to group of gaseous elements like flourine, chlorine, bromine and lodine.In incandescent lamp the life of filament is affected by evaporation of tungsten.

To prevent this a small amount of halogen gas (say iodine) is added to the argon gas filling of the lamp. Evaporated tungsten iodine is very volatile and suffers thermal diffusion in direction of filament and gets decomposed into tungsten and halogen.

Tungsten so relesed is deposited back on filament restoring its strength. Thus addition of halogen results in formation of a regenerative cycle and evaporation of tungsten is prevented. This also results in increased efficiency as tungsten filament can now be heated to much more temperature (Fig 2).

To maintain this regenerative cycle, it is necessary that the wall temperature is maintained high to 2500^{0}C. The lamp envelope is therefore made of quartz due to which it is possible to miniaturise, as filling gas can now be filled at high gas pressure.

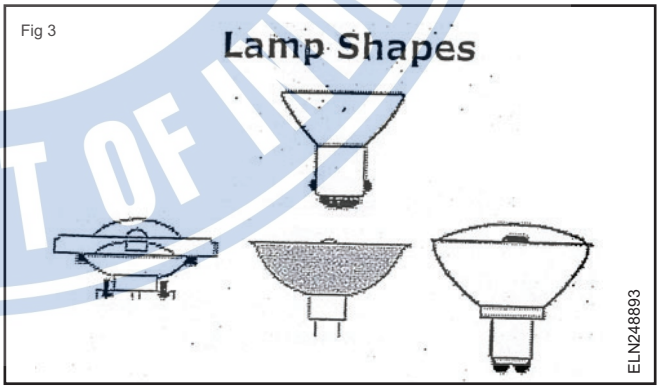
Fig 2



The efficacy of this lamp is 50% more as compared to GLS for equal watage and life is just double. These lamps have better colour rendition. These are available in sizes of 500 W to 5kW. Halogen lamp with much better efficiency and lesser sizes but having very less life are manufactured for TV photography and film camera purpose.

The Fig 3 shows the different shapes of halogen lamps.

Fig 3



Compact Fluorescent Lamp (CFL)

Objectives: At the end of this lesson you shall be able to
- **explain the construction of CFL**
- **describe the working principle of CFL**
- **state the types of CFL's and tubes.**

CFL Lamp

Construction: A compact fluorescent lamp (CFL), also called compact fluorescent light, energy-saving light, and compact fluorescent tube, is a fluorescent lamp designed to replace an incandescent lamp; some types fit into light fixtures formerly used for incandescent lamps. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and a compact electronic ballast in the base of the lamp (Fig 1)

Fig 1

A CFL has a higher purchase price than an incandescent lamp, but can save over five times its purchase price in electricity costs over the lamp's lifetime.

Working principle : The principle of operation in a CFL bulb remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating on the bulb (as well as into heat when absorbed by other materials such as glass).

CFLs radiate a spectral power distribution that is different from that of incandescent lamps. Improved phosphor formulations have improved the perceived color of the light emitted by CFLs, such that some sources rate the best "soft white" CFLs as subjectively similar in color to standard incandescent lamps.

Types of CFL

There are two types of CFLs:

1 Integrated lamps

2 Non-integrated lamps.

Integrated lamps: Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs. Integrated CFLs work well in many standard incandescent light fixtures, reducing the cost of converting to fluorescent.

Non-integrated lamps: Non-integrated CFLs have the ballast permanently installed in the luminaire, and only the lamp bulb is usually changed at its end of life. Since the ballasts are placed in the light fixture, they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the bulb reaches its end-of-life. Non-integrated CFL housings can be both more expensive and sophisticated.

Light Emitting Diodes (LEDs)

Objectives: At the end of this lesson you shall be able to
- **state the advantages of LEDs over-conventional bulbs**
- **explain the principle of working of LED**
- **state the popular types of LED.**

Light emitting diodes (LED)

One of the most common and popular of new devices in the optical electronics is the **Light Emitting Diode** abbreviated as **LED**. These LEDs are now used as indicators in almost all electrical and electronic circuits and equipments.

The advantages of LEDs over incandescent bulbs are listed below:

1 LEDs have no filaments to heat and so require less current to glow.

2 LEDs require lower voltage level (typically 1.2 to 2.5 V) than the conventional bulbs.

3 LEDs last much longer - upto several years.

4 Because there is no filament to heat up, LEDs are always cool.

5 LEDs can be switched ON and OFF at a much faster rate compared with conventional lamps.

Principle of working of LEDs

Although LED is also a type of diode, it cannot and should not be used for the purpose of rectifying AC to DC.A LED is a semi conductor device which emits visible ligt when it is property connected with the electric supply.

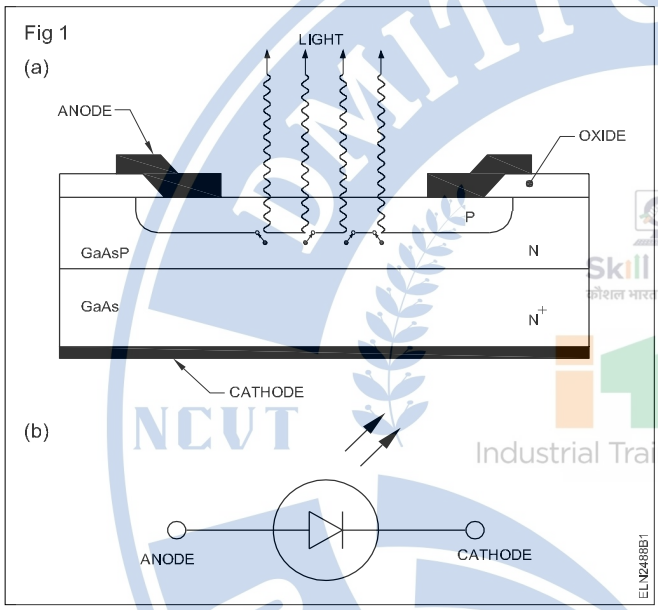
Recall that a general purpose diode or a rectifier diode conducts when energy is supplied to the electrons (Si=0.7V, Ge=0.3V) to cross the barrier junction. Each electron, after acquiring the supplied extra energy, crosses the junction and falls into the hole on the P side of the junction while the electron recombines with a hole, the electron gives up the extra energy by it. This extra energy is dissipated in the form of heat and light.

In general purpose diodes because the silicon material is not transparent(opaque), the light produced by the electrons does not escape to the outer environment. Hence, it is not visible. But LEDs are made using semi-transparent materials instead of silicon.

Because the material used in making LEDs is semi-transparent, some of the light produced by the electrons escapes to the surface of the diode, and, hence, is visible. (Fig 1a)

LEDs are typically doped with gallium arsenic, gallium phosphate or gallium arseno-phosphate. Different dopes cause the LED to emit light of different colours (wave-lengths) such as red, yellow, green, amber, or even invisible infrared light.

The schematic symbol of LED Non-integrated lamps is as shown in (Fig 1b). The arrows are used to indicate that light is radiated from the device.



Types of LEDs

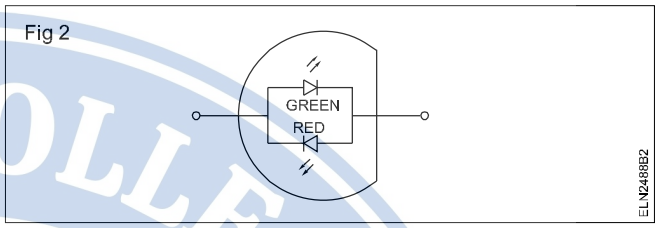
Single colour LEDs: Most of the commercially available and commonly used LEDs are single colour LEDs. These LEDs radiate one of the colours such as red, green, yellow or orange. Different coloured LEDs will have different forward voltages as given in the table below:

Colour of LED	Red	Orange	Yellow	Green
Typical Forward voltage drop	1.8V	2V	2.1V	2.2V

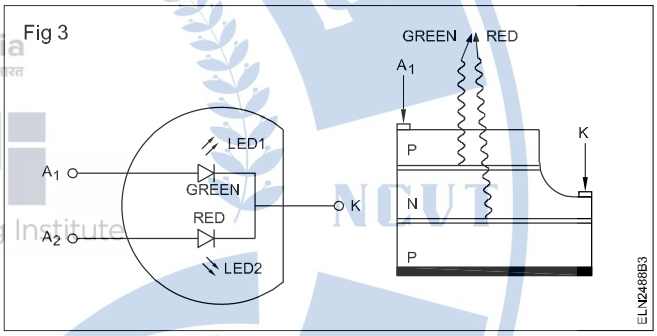
These typical forward voltage drops are at a typical LED forward current I_f = 20 mA.

Two colour LEDs: These LEDs can give two colours. Actually, these are two LEDs put in a single package and connected . (Fig 2)

In a two-colour LED, two LEDs are connected in inverse parallel, so that one of the colour is emitted when the LED is biased in one direction and the other colour is emitted when the LED is biased in the other direction. These LEDs are more expensive than the single colour LEDs. These LEDs are useful to indicate +ve, –ve polarities, GO-NOGO indication, null detection etc.



Multicolour LEDs: These are special types of LEDs which can emit more than two colours. These LEDs comprises of a green and a red LED mounted in a three-pin common cathode package. (Fig 3)



Output colour	Red	Orange	Yellow	Green
LED-1 current	0	5mA	10mA	15mA
LED-2 current	15mA	3mA	2mA	0

This LED will emit green or red colour by turning ON only one LED at a time. This LED will emit orange or yellow by turning on the two LEDs with different current ratios as shown in the table given above.

High pressure metal halide lamps

Objectives: At the end of this lesson you shall be able to
- **describe the working principle of metal halide lamp (M.H.L)**
- **explain the starting of M.H lamp**
- **state the parts of MH lamp and its starting methods.**

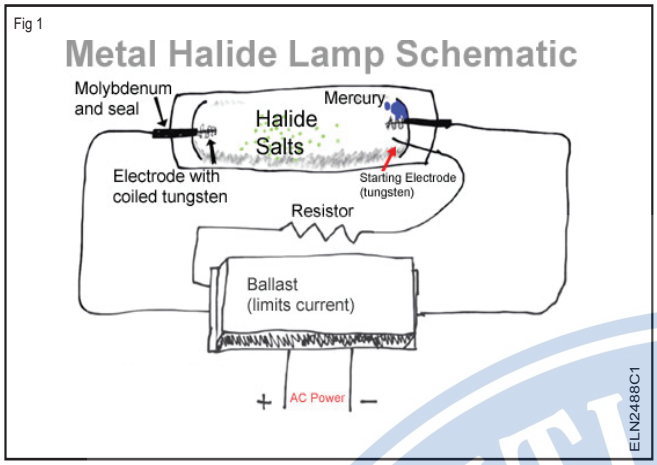
Metal halide lamps

This type of lamp is also known as an `MH' lamp. It is an HID lamp (High intensity Discharge), which means it provides most of its light from the electric arc within a small discharge tube. It is becoming increasingly popular due to its good quality white light and good efficiency. The most prominent use of the MH lamp is in stadiums and sports fields. It is also used widely for parking lots and street lighting in urban areas.

Working Principle

Fig 1 shows the schematic connection diagram of a metal Halogen lamp in to the AC supply. A resistor is connected to limit the current so as to increase the life of ballast.

Fig 1



When the lamp is cold the halides and mercury are condensed on the fused quartz tube. When the lamp is turned on current passed through the starting electrode and jumps the short distance to the main electrode (Fig 1), this is aided by argon gas. The argon strikes an arc at low temperatures.

After the initial small arc the tube heats up and the mercury is vaporized. Electric arcs fight to works through the distance of a gas, but over time more molecules of the gas become ionized. This makes it even easier for more electric current to pass through, so the arc gets wider and hotter.

In the lamp as the first arc heats up, it begins to turn the solid mercury into a vapor, soon the arc is able to travel through the mercury vapor to reach the other main electrode on the opposite side of the discharge tube. There is less resistance on this path now and current stops flowing through the starting electrode, just as a river changes course to a path of least resistance, drying out the previous channel.

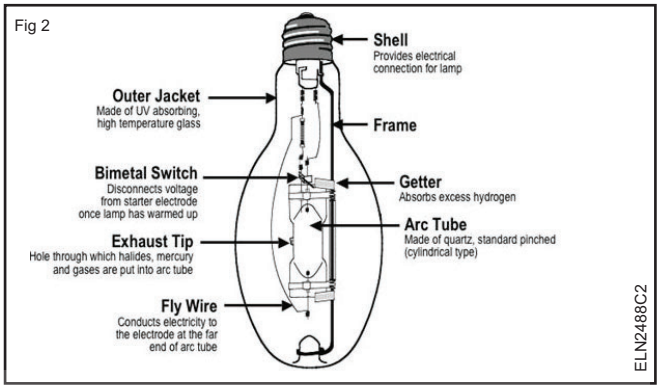
Parts of Metal Halide lamps.

Fig.2 shows the inner parts and its various function of a metal halide lamp. The inner tube contains the electrodes and various metal halides, along with mercury and inert gases that make up the mix. The typical halides used are some combination of Sodium, Thallium, and Scandium and Dysprosium Iodides. These iodides control the lamp's spectral power distribution and provide color balance by combining the spectra of the various iodides used.

Light is generated by creating an arc between the two electrodes located inside the inner arc tube. The inner arc tube is typically made of quartz, and this is a very harsh environment, with high temperatures approaching 1000°C and pressure of 3 or 4 atmospheres.

To start a metal halide lamp, a high starting voltage is applied to the lamp's electrodes to ionize the gas before current can flow and start the lamp. The outer jacket is usually made of Borosilicate glass to reduce the amount of UV radiation emitted from the lamp.

Fig 2



Starting Metal Halide Lamps

A metal halide lamp's starting requirements are important because they impact the type of ballast that the lamp requires. Two methods are used to start MH lamps: probe start (standard start) and pulse start.

Probe start refers to the method used to ignite the arc in the tube. A traditional or probe start metal halide lamp has three electrodes - two for maintaining the arc and a third internal starting electrode, or probe.

A high open circuit voltage from the ballast initiates an arc between the starting electrode and the operating electrode at one end of the arc tube. Once the lamp reaches full output, a bi-metallic switch closes to short out the probe, thereby discontinuing the starting arc.

Pulse-start MH lamps do not have a starting probe electrode. An igniter in the pulse start system delivers a high voltage pulse (typically 3 to 5 kilovolts) directly across the lamp's operating electrodes to start the lamp, eliminating the probe and bi-metallic switch needed in probe start lamps.

Without the probe electrode, the amount of pinch (or seal) area at the end of the arc tube is reduced, which allows for increased full pressure and reduced heat loss. Furthermore, using an ignitor with a lamp reduces tungsten sputtering by heating up the electrodes faster during starting, reducing the lamp's warm-up time.

Advantages of MH Lamps

- Excellent Color Rendering
- Compact Size
- Versatility
- High Efficiency
- Positive Environmental Impact
- Long Life
- Better Light Quality
- Designable Color

Lighting for decoration - Serial set design - Flasher

Objectives: At the end of this lesson you shall be able to
- **state the methods used for decoration**
- **state the names of flasher and their function.**

Use of decoration lights

Electric light decoration for special occasions like wedding parties, festivals and fairs is a common feature nowadays. Special electric light sign circuits add much colour, fun and pleasure on the occasion. Electric signs, particularly neon signs, are extensively used in advertisements which have tremendous eye catching effects. Decoration with electric signs improves the appearance of a building and makes the place more attractive.

Two methods are mainly used for decoration.

- Signs employing miniature low voltage incandescent lights which can be switched on and off in sequence to produce the desired effect.
- Neon signs employing tubes shaped to produce designs in various colours, the colour being determined by the type of gas used in the tube.

Miniature incandescent lamps: Miniature incandescent lamps are normally available with 6V, 9V, 12V & 16V ratings with different colours which may be grouped in series or series parallel combinations for operation in available 240V supply.

For getting different messages and decoration effects the following types of flasher signs are used.

Speller type flashers are used for spelling out signs letter by letter or word by word for building up or down, plain on-off flashing, with changing colour.

Speed type flashers are used for operating spectacular signs such as lighting waving-flags, - flame, revolving wheels etc.

Script type flashers as the name implies are used when the effect of handwriting in script letters is desired.

An example of a speed type flasher for revolving is shown in Fig 1. The speed of running light/ rotating light can be adjusted. In this three-point running light (the sign flasher) there are three groups of lamps, each group switched on and off, in sequence, for running effect (Fig 2) with the help of a small induction motor which is running on eddy current principle and is connected to 240V/115V 50 Hz. Cans or drums are mounted on a shaft which is rotated by the motor.

Fig 1

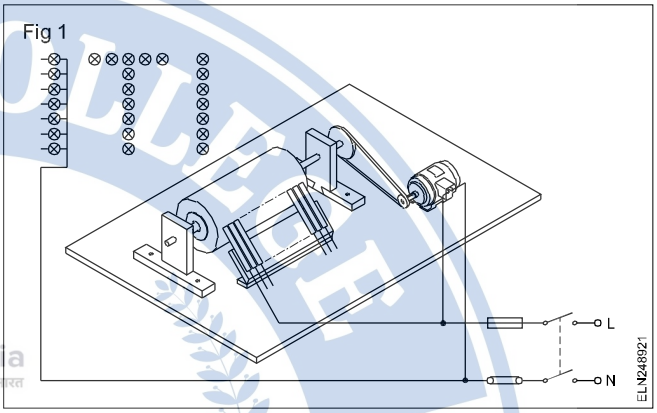
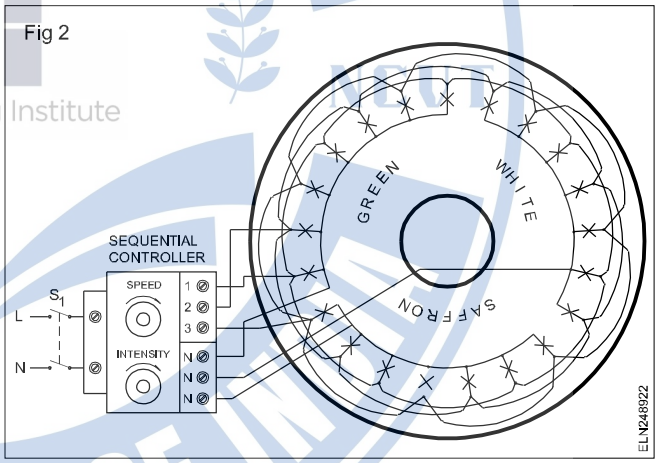


Fig 2



The circumference of the cans or the drums are so cut that the brushes will make contact only during the fixed portion of the revolution, thus completing the circuit. We can make three independent circuits by the 3-point sign flashers which are switched 'ON' and 'OFF' successively.

Designing a decorative serial lamp for a given supply voltage

Objectives: At the end of this lesson you shall be able to
- **calculate the number of bulbs to be connected in series for a given supply voltage.**

Serial set design

We have to design a row of 6 or 9 volts lamps. If these lamps are connected directly to the 240V supply, the lamps will get fused immediately. Therefore the lamps are to be connected in series. The calculation as shown will be -

1 For 6 volts lamps

$$\text{Total No. of lamps required} = \frac{240}{6} = 40 \text{ lamps.}$$

Taking 5% allowance for fluctuations in the supply

voltage

Total No. of lamps = 40 + (5% of 40)

= 40 + 2 = 42 lamps.

2 For 9 volts lamps

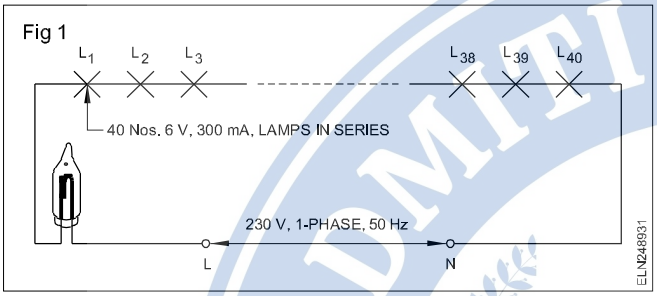
Total No. of lamps required= $\frac{240}{9} = 26.6 \text{ or } 27 \text{ lamps}$

Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 27 + (5% of 27)

= 27 + 2 = 29 lamps.

The circuit for a series lamp connection of 6V lamp and supply voltage 240V. (Fig 1)

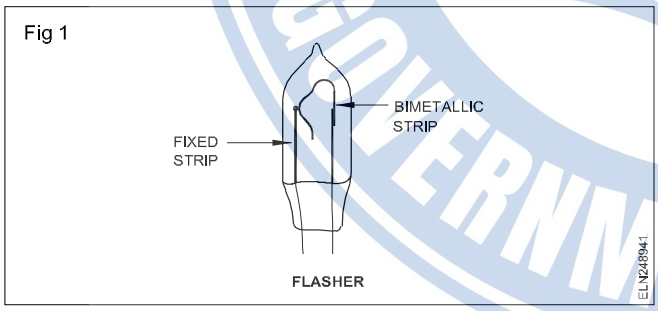


Flasher

Objectives: At the end of this lesson you shall be able to

- **state the purpose of the flasher in the series lamp circuit.**

Flasher: In the row of lamps of low voltage, a small lamp (flasher) of filament type is connected in series with the other lamps. This lamp (flasher) does not give light but acts as a switch for the other lamps. This lamp contains a bimetal strip, which is in contact with a fixed strip (Fig 1).



When the row of lamps is connected across the supply and switched ON, the bimetal strip gets heated up, this breaks the contacts and disconnects supply to the other lamps, making the lamps OFF.

After a few seconds, the bimetal strip cools down and makes contact. The supply to the other lamps is ON and the lamps light up. This is a twinkling type row of lamps used for decoration (Fig 2).

The rating of the flasher in each row of (small) low voltage lamps must be the same as that of the other lamps in that series circuit. If the lamps are of different ratings, then the flasher should be of the lowest current capacity in that circuit.

Precautions

- Never connect the low volt lamps directly to the mains.
- Never touch the exposed wires.

In the above case we discussed for 6V and 9V lamps. In the market we get for 6 volts different current ratings viz. 100mA, 150mA, 300mA, 500mA. The shape of the lamp for the above current ratings however remains the same.

For the series lamps to work satisfactorily the current rating of all the lamps should be the same.

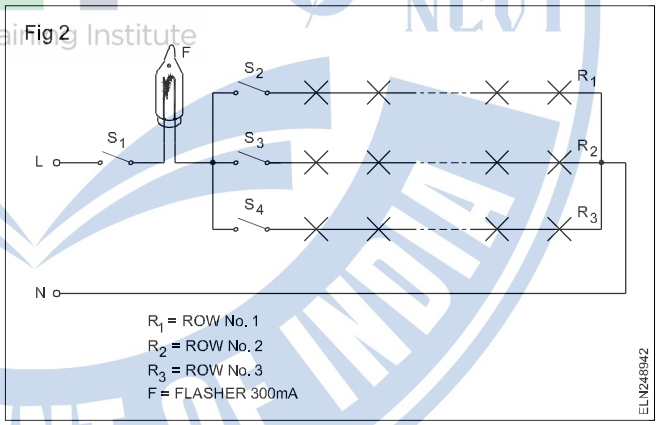
We can prepare serial lamps with different voltages but of the same current rating.

Example

You have 25 lamps of 6V, 300mA rating and 20 numbers of 9V,300mA lamps. How will you design a 'serial lamp' circuit for 240V supply mains

a using all the available 6V lamps and for the rest of 9V lamps.

b using all the available 9V lamps and for the remaining 6V lamps.



Though the flasher can be connected anywhere in the series circuit, it should be connected at the supply (phase) considering it as a switch.

The operating condition of the flasher can be decided by observation. If the bimetal strip is found welded to a fixed strip, then the flasher is not useful and if it is in an unserviceable condition. It can also be found out by connecting in circuit and tested for its condition, i.e. whether it is operating or not.

When a number of series lamp rows are connected in parallel the flasher should be connected at the input of supply as shown in Fig 2.

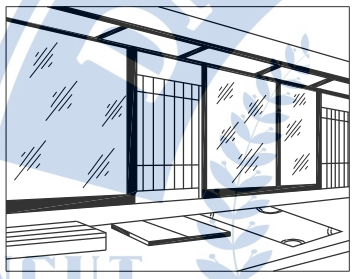
Show case lights and fittings - calculation of lumens efficiency

Objectives: At the end of this lesson you shall be able to
- **state the types of bulbs for illumination**
- **explain direct and indirect lighting and showcase lighting**
- **explain the luminuous efficiency calculation.**

Show case lighting: A number of commercial establishments use visual representation to their products, using a lighting system called show case lights. Some of them are discussed below.

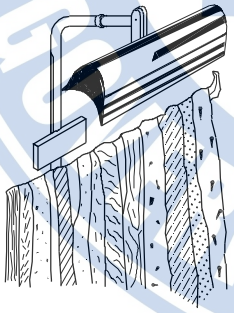
Counters and dealing shelves: In bank cages and ticket offices supplementary trough lighting equipment is usually located at the top of the cages to produce a band of light lengthwise on the counter. Troughs may be covered with diffusing glass or fitted with longitudinal louvers to shield the lamps. Sixty watt lamps on 15 to 18 inch centres will generally be adequate. (Fig 1)

Fig 1



Small metal bracket type reflectors luminary or regular 25 or 40 watt tubular lamps effectively illuminate small vertical display racks, stands and cabinets. (Fig 2)

Fig 2



Small compact lens posts available in both 250 and 400 watt size, mounted on columns or ceiling brackets, give sales emphasis to small counter or table displays. Adjustable in spot size for 12 to 48 inches diameter spot at 10 ft. a 250 watt unit at 10 ft. will deliver 200 to 250 feet candles, with a 12 to 15 inches spot size: the 400 watt unit will give 350 to 400 foot candles. (Fig 3)

For extended vertical surface displays - rungs, tapestries, draperies, paintings - a series of 150 or 200 watt lens plate units at the ceiling is suitable for fixed display locations. Bracket type parabolic, polished metal troughs produce equivalent results and have some advantage in greater mobility. (Fig 4)

Fig 3

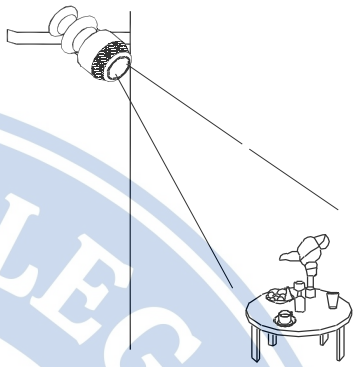
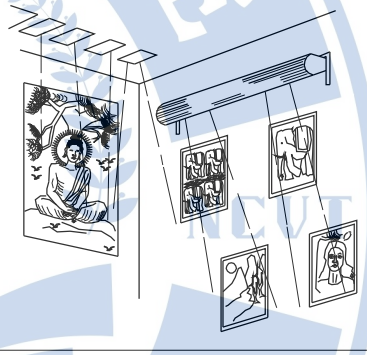


Fig 4



For necessity and impulse items such as groceries, where attention rather than critical seeing is the requirement, less engineering refinement is needed in shelf lighting equipment. Concentrating trough reflectors which incorporate luminous panels for changeable advertising copy are satisfactory. Sockets 30 cms apart may be fitted with 40 to 100 watt lamps, as conditions dictate. (Fig 5)

Fig 5

For lighting displays on columns or built-in shelving a metal nosing along the front edge of each shelf effectively conceals small 25 watt tubular lamps as shown in the sketch. Lamps should be spaced not more than 30 cms apart. Lumiline lamps are, of course, equally suitable in many cases.

Displays of glassware and bottled goods are highly attractive and colourful if lighted by transmitted light as shown in Fig 5. An opal glass panel, illuminated uniformly from behind the lamps spaced not more than 1½ times their distance at the back of the glass will provide a suitable luminous background.

Circline tubes used for window show case: For circline tubes the ballasts are specially designed and are easily adaptable to assembly on the stem of portable lamps and in shallow wall and ceiling fixtures, and in some designs they can be mounted within the circle of the tube.

Ballast equipments designed for use with the 8¼ inch 22 watt, 12-inch 32 watts. circle line include two single lamp ballasts, one with uncorrected power factor. The other with high power factor. Many of the portable lighting equipments - dressing table, desk lamp, vanity mirror, tie rack, display unit and boudoir lamps such as Fig 6 and 7 - in which the 8¼ inch circline will be used which have small thin bases and slender stems.

Fig 6

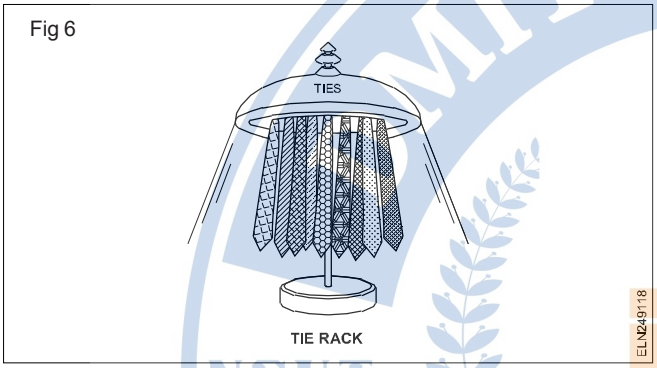
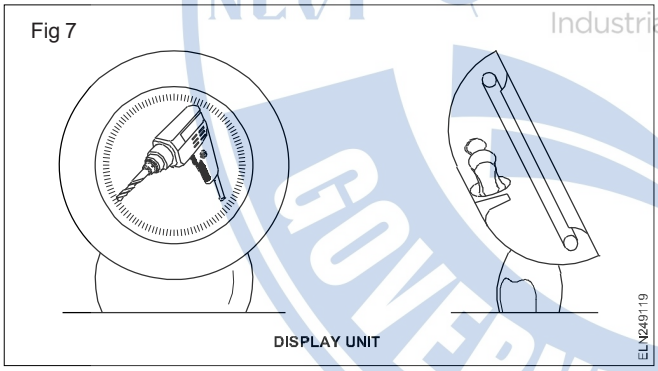


Fig 7



There are varieties of goods which are being displayed in showcases of different colours, size, shape, fineness etc. Hence Different shades and colour layers will be used to get the proper colour of goods or fineness of detail or both by proper illumination.

Precaution should be taken while putting the merchandise in showcases so that wiring will not be damaged. Also the wiring and merchandise should not get damaged due to the excessive heat of lamps.

Luminous Efficiency Calculation

Luminous Efficiency: Luminous efficiency is a measure of how will a light source produces a visible light. It is a quantity of measurement for light source and it is defined as the ratio of luminous flux to power of the lamp in watts. It's unit is **lumen/watt** in SI unit.

$$\text{Luminous efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

This is important, it describes how much light is being given compare to the amount of electricity is used.

Purpose of calculating luminous efficiency

Typical house hold spends 30% of the electricity bill in lighting. Money can be saved by bringing the most cost efficient lighting option in home needs.

For example : A 60w light bulb usually produces 860 lumens. Calculate the luminous efficiency.

$$\text{So, efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

$$= \frac{860}{60} = 14.3 \text{ lumen/watt}$$