UNIT – 4

ILLUMINATION

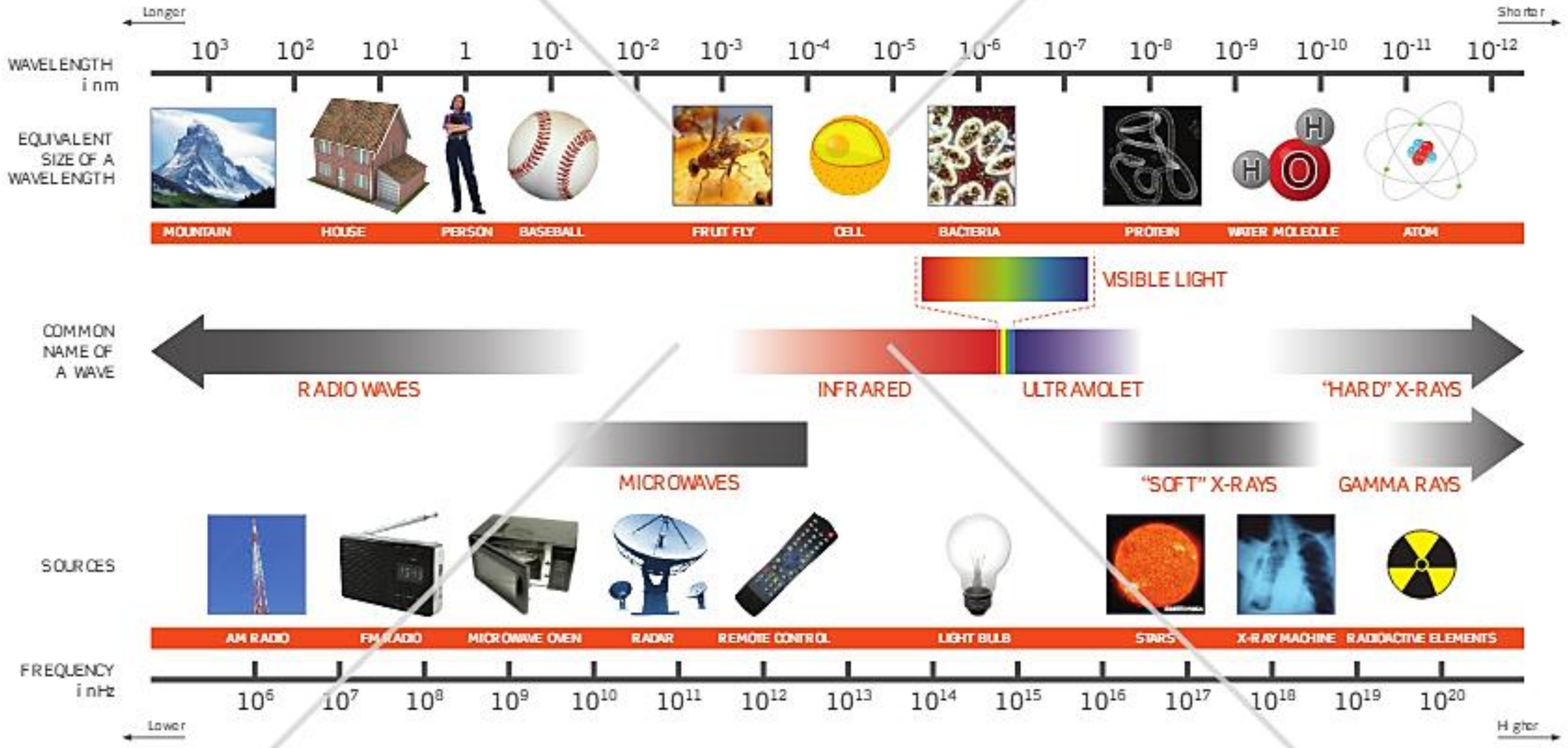
NATURE OF LIGHT, DEFINITIONS and LAWS OF ILLUMINATIONS

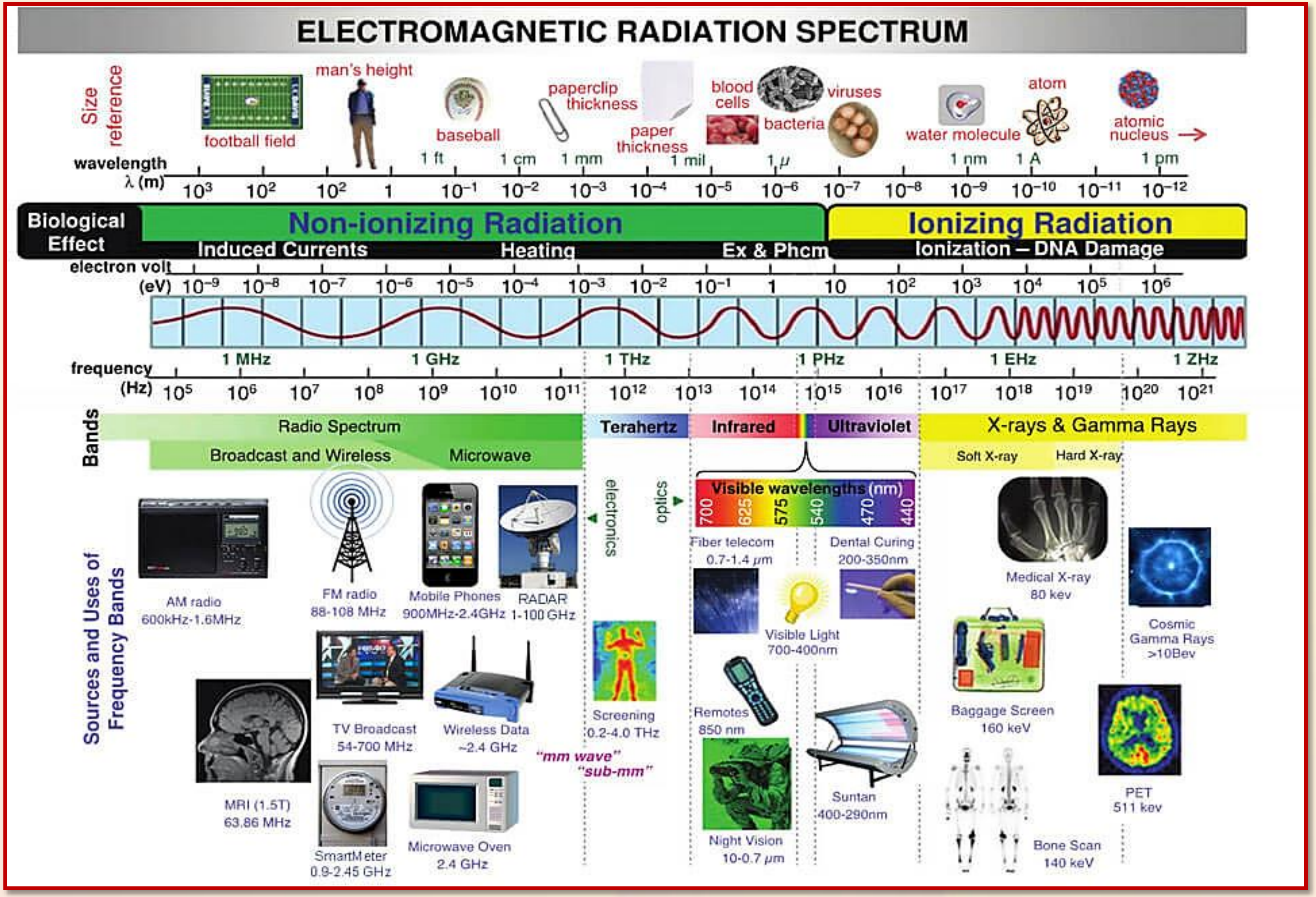
- Illumination is concerned with the transfer of light, or radiation in the generic sense, from the source(s) to the target(s).
- ILLUMINATION, in optics, the intensity of the light falling upon a surface
- Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays. The human eye can only detect only a small portion of this spectrum called visible light.
- The electromagnetic spectrum is comprised of all frequencies of electromagnetic radiation that propagate energy and travel through space in the form of waves. Longer wavelengths with lower frequencies make up the radio spectrum. Shorter wavelengths with higher frequencies make up the optical spectrum. The portion of the spectrum that humans can see is called the visible spectrum.
- Light is a form of electromagnetic energy radiated from a body and human eye is capable of receiving it. Light is a prime factor in the human life as all activities of human being ultimately depend upon the light.
- Various forms of incandescent bodies are the sources of light and the light emitted by such bodies depends upon their temperature.

The electromagnetic spectrum

Our eyes see only a small band of electromagnetic radiation; the band that we term visible light. There are many other forms of electromagnetic radiation, and collectively they make up the electromagnetic spectrum.

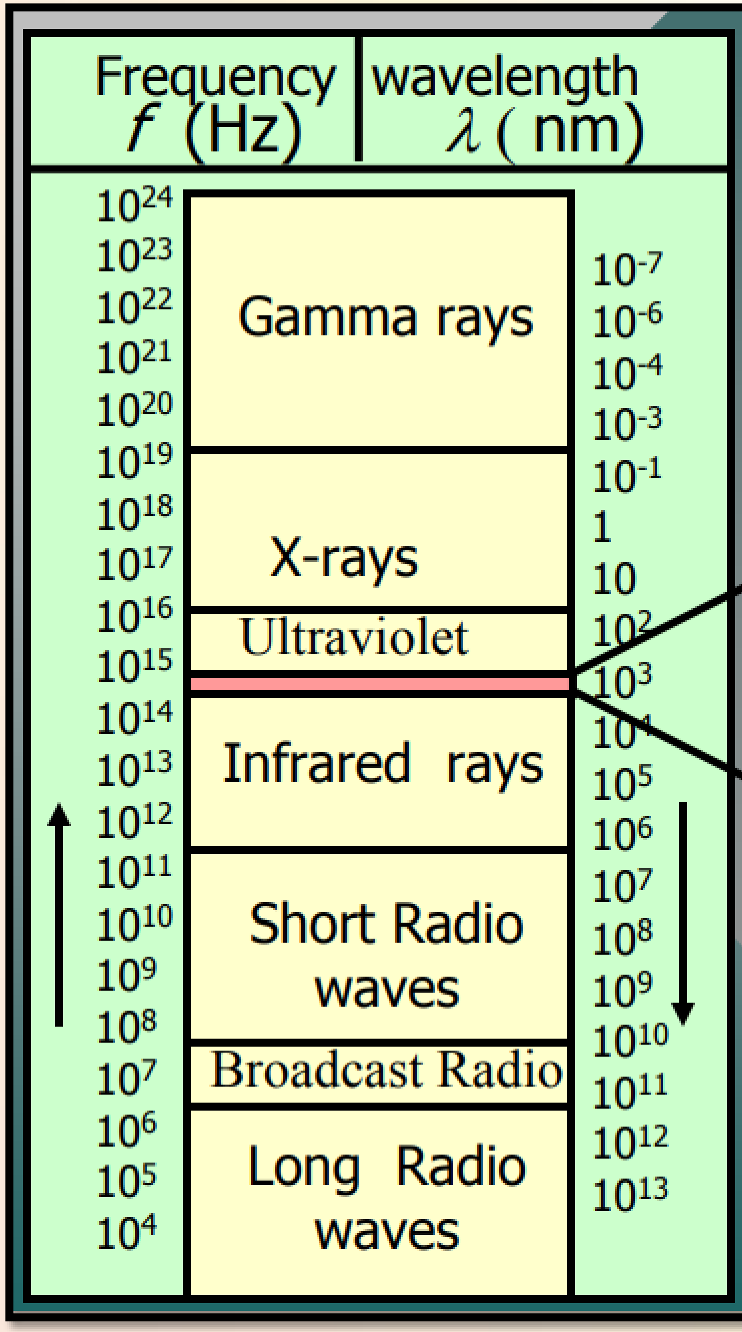
All electromagnetic radiation travels through space at the speed of light and through Earth's atmosphere at virtually the same speed. Different forms of electromagnetic radiation differ in their frequency and wavelength.





ELECTROMAGNETIC RADIATION SPECTRUM
Size reference
football field
man's height
baseball
paperclip thickness
paper thickness
blood cells
bacteria
viruses
water molecule
atom
atomic nucleus
wavelength λ (m)
1 ft
1 cm
1 mm
1 mil
1 μ
1 nm
1 A
1 pm
Biological Effect
Non-ionizing Radiation
Induced Currents
Heating
Ex & Phcm
Ionizing Radiation
Ionization – DNA Damage
electron volt (eV)
frequency (Hz)
1 MHz
1 GHz
1 THz
1 PHz
1 EHz
1 ZHz
Bands
Radio Spectrum
Broadcast and Wireless
Microwave
Terahertz
Infrared
Ultraviolet
X-rays & Gamma Rays
Soft X-ray
Hard X-ray
electronics
optics
Visible wavelengths (nm)
700 625 575 540 470 440
Sources and Uses of Frequency Bands
AM radio 600kHz-1.6MHz
FM radio 88-108 MHz
Mobile Phones 900MHz-2.4GHz
RADAR 1-100 GHz
MRI (1.5T) 63.86 MHz
TV Broadcast 54-700 MHz
Wireless Data ~2.4 GHz
SmartMeter 0.9-2.45 GHz
Microwave Oven 2.4 GHz
Screening 0.2-4.0 THz
"mm wave"
"sub-mm"
Fiber telecom 0.7-1.4 μm
Visible Light 700-400nm
Remotes 850 nm
Night Vision 10-0.7 μm
Dental Curing 200-350nm
Suntan 400-290nm
Medical X-ray 80 kev
Baggage Screen 160 keV
Bone Scan 140 keV
Cosmic Gamma Rays >10Bev
PET 511 kev

The EM Spectrum

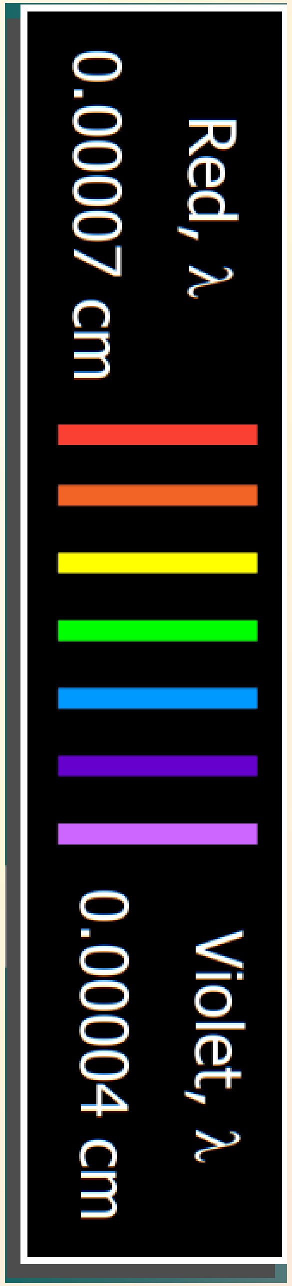


A wavelength of one nanometer 1 nm is:

$$1 \text{ nm} = 1 \times 10^{-9} \text{ m}$$

Visible Spectrum

400 nm → 700 nm



Red 700 nm → Violet 400 nm

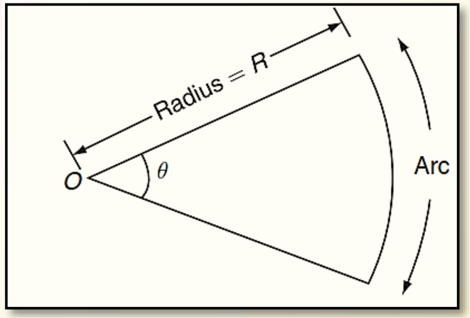
$$c = f\lambda \qquad c = 3 \times 10^{8} \text{ m/s}$$

- The eye discriminates between different wavelengths in this range by the sensation of colour. Radiations of very short wavelength varying from 0.0000156×10^{-6} m to 0.001×10^{-6} m are not in the visible range are called as Rontgen or X-Rays, which are having the property of penetrating through opaque bodies
- **Good illumination ensures increased production, effectivity of work and reduced accidents.**

DEFINITIONS:

- **PLANE ANGLE:** Plane angle is the angle subtended at a point in a plane by two converging straight lines and its magnitude is given by:

$$\theta = \frac{Arc}{Radius}\ radians$$

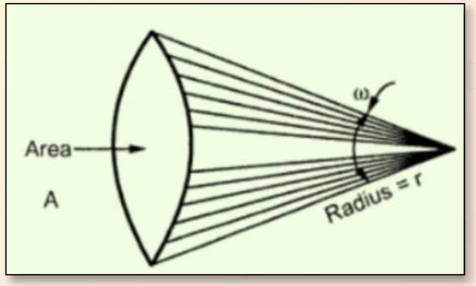


The largest subtended angle at a point is **2π radians**

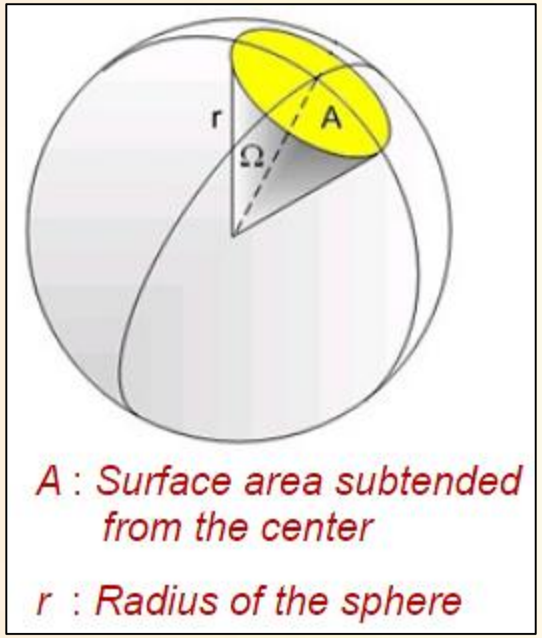
- **SOLID ANGLE:** Solid angle is the angle subtended at a point in space by an area, i.e., the angle enclosed in the volume formed by numerous lines lying on the surface and meeting at the point.

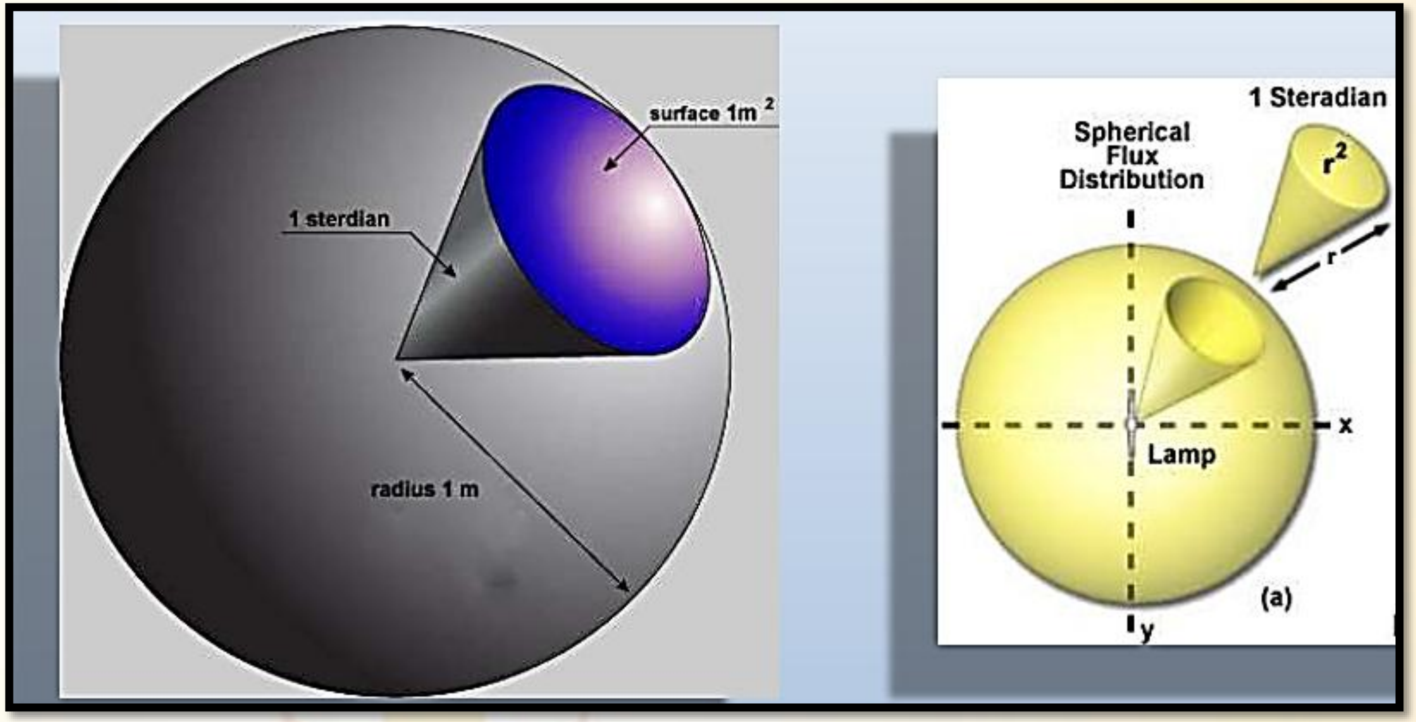
OR

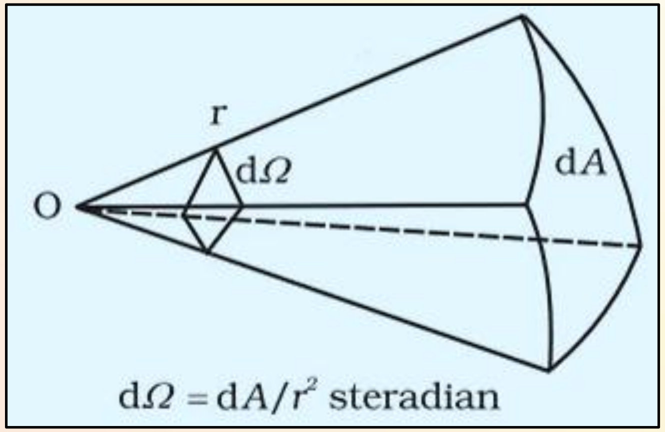
It is the angle generated by the lines passing through the point in space and periphery of the area.



- It is measured in steradians and is denoted by **ω.**





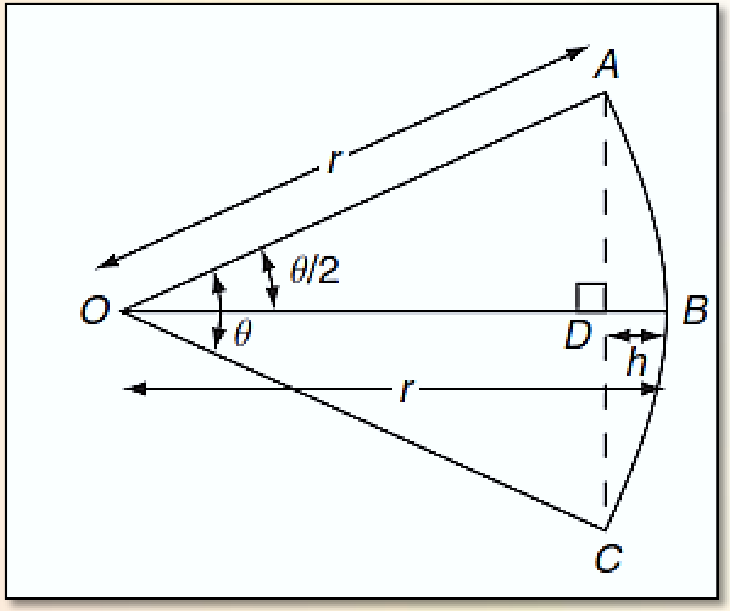


$$\omega = \frac{area}{(radius)^2} \text{ steradians}$$

The largest solid angle subtended at the center of a sphere:

$$\omega = \frac{area\ of\ sphere}{(radius)^2} = \frac{4\pi r^2}{r^2} = 4\pi\ steradians$$

Relationship between Plane and Solid Angle can be obtained as follows



Let us consider a curved surface of a spherical segment ABC of height 'h and radius of the sphere r' as shown in Fig. . The surface area of the curved surface of the spherical segment $ABC = 2\pi rh$. From the Fig.:

$$BD = OB - OD$$

$$h = r - r\cos\left(\frac{\theta}{2}\right) \quad [\because \text{From } \Delta ODA, OD = r\cos\theta/2]$$

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

$\therefore$ The surface area of the segment $= 2\pi rh$

$$= 2\pi r^2\left[1 - \cos\frac{\theta}{2}\right].$$

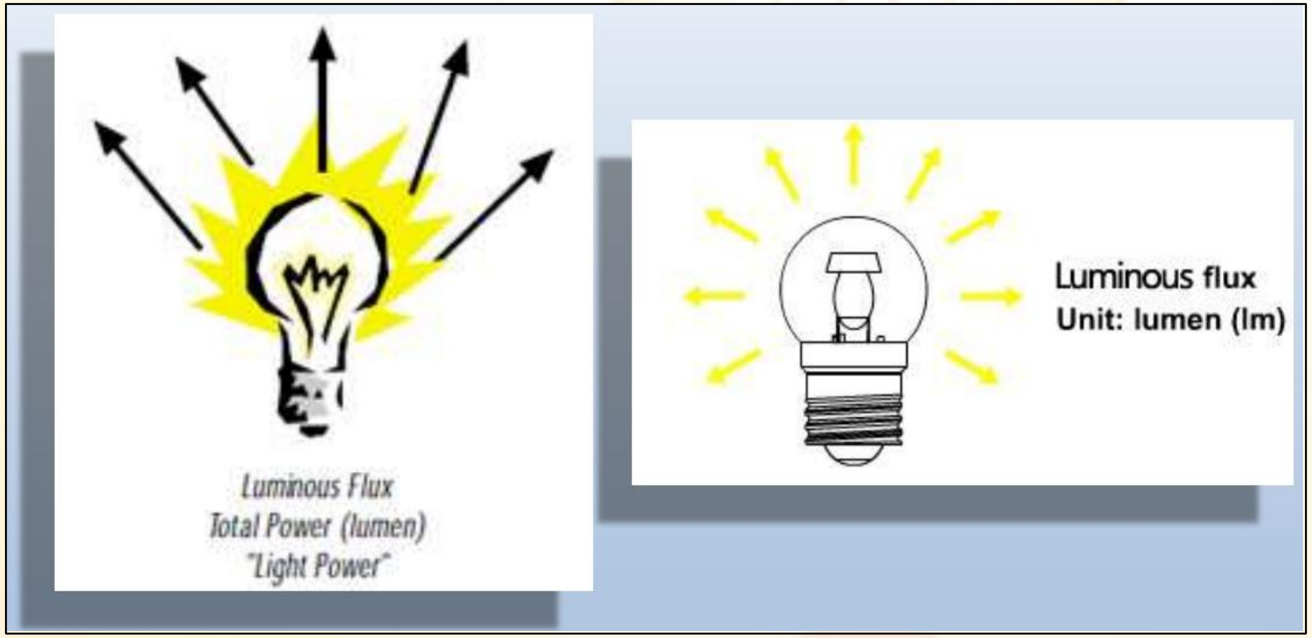
We know solid angle $(\omega) = \dfrac{\text{area}}{(\text{radius})^2}$

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

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

Plane Angle and Solid Angle

- **LIGHT:** It is defined as radiant energy from a hot body which produces the visual sensation on human eye. It is expressed in lumen – hours.
- **LUMINOUS FLUX:** The total quantity of radiant energy per second responsible for visual sensation from a luminous body is called **Luminous Flux**. It is denoted by **F** and is measured in **Lumens**. **The concept of luminous flux assists us to specify the output and efficiency of a given light source. For instance, output of a bicycle lamp is 10 lumen and that of 150 W incandescent lamp is 1940 lumen**



- **LUMINOUS INTENSITY:** Luminous intensity in any particular direction is the luminous flux emitted by the source per unit solid angle in that direction. It is denoted by **I** and its unit is **candela** or lumen / steradian

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

- **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.

  Lumen = Candle power of source × solid angle.

  Lumen = CP × ω

  Total flux emitted by a source of **one candle** power is 4π lumens.

- **CANDLE POWER :** Candle power is the light radiating capacity of a source in a given direction and is defined as the number of lumens given out by the source in a unit solid angle in a given direction.

$$CP\ (Candle\ Power) = \frac{Lumens}{\omega}$$

- **ILLUMINATION:** Illumination is defined as the luminous flux received by the surface per unit area. It is usually denoted by the symbol E and is measured in lux or lumen/m^2 or meter candle or foot candle.

$$Illumination(E) = \frac{F}{A}$$

- **LUX OR METRE - CANDLE:**
- **FOOT- CANDLE:**
- **BRIGHTNESS (OR LUMINANCE):** When the eye receives great deal of light from an object we say it is bright, and "brightness" is an important quantity in illumination. **Brightness or Luminance** is defined as the luminous intensity per unit projected area of either a surface source of light or a reflecting (illuminated) surface and is denoted by **L**.

  If the luminous intensity of source be I candela on an area A, then the projected area is A cos θ.

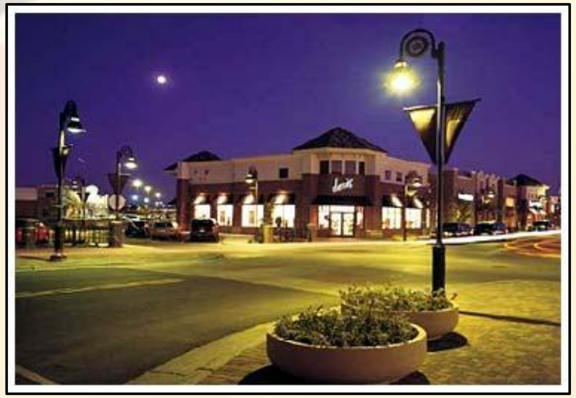
$$\boxed{\therefore \text{Brightness}, L = \frac{I}{A\cos\theta}}$$

Candela / m^2

QUES: Establish the Relationship between Luminous Intensity (I), Illumination (E) and Brightness (L)

$$E = \pi L = \frac{I}{r^2}.$$

- **MEAN HORIZONTAL CANDLE POWER (MHCP):** It is defined as the mean of candle powers in all directions in the horizontal plane containing the source of light.
- **MEAN SPHERICAL CANDLE POWER (MSCP):** It is defined as the mean of candle powers in all directions and in all the planes from the source of light.
- **MEAN HEMISPHERICAL CANDLE POWER (MHSCP):**
- **REDUCTION FACTOR:** $\frac{MSCP}{MHCP}$
- **LAMP EFFICIENCY:** It is defined as the ratio of luminous flux to the power input, expressed as lumens per watt.
- **SPECIFIC CONSUMPTION:** It is defined as the ratio of the power input to the average candle power, expressed in watts per candela.
- **GLARE:** Glare is a visual sensation caused by excessive and uncontrolled brightness. It can be disabling or simply uncomfortable. It is subjective, and sensitivity to glare can vary widely. Older people are usually more sensitive to glare due to the aging characteristics of the eye.



Space to height ratio

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

$$\text{Space to height ratio} = \frac{\text{horizontal distance between two adjacent lamps}}{\text{mounting height of lamps above the working plane}}.$$

Coefficient of utilization or utilization factor

It is defined as the ratio of total number of lumens reaching the working plane to the total number of lumens emitting from source.

$$\text{Utilization factor} = \frac{\text{total lumens reaching the working plane}}{\text{total lumens emitting from source}}.$$

Maintenance factor

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

$$\text{Maintanance factor} = \frac{\text{illumination under normal working condition}}{\text{illumination under every thing is clean}}.$$

Its value is always less than 1, and it will be around 0.8. This is due to the accumulation of dust, dirt, and smoke on the lamps that emit less light than that they emit when they are so clean. Frequent cleaning of lamp will improve the maintenance factor.

Waste light factor

When a surface is illuminated by several numbers of the sources of light, there is certain amount of wastage due to overlapping of light waves; the wastage of light is taken into account depending upon the type of area to be illuminated. Its value for rectangular area is 1.2 and for irregular area is 1.5 and objects such as statues, monuments, etc.

Absorption factor

Normally, when the atmosphere is full of smoke and fumes, there is a possibility of absorption of light. Hence, the total lumens available after absorption to the total lumens emitted by the lamp are known as absorption factor.

$$\text{Absorption factor} = \frac{\text{the total lumens available after absorption}}{\text{the total lumens given out by the lamp}}.$$

Reflection factor or coefficient of reflection

When light rays impinge on a surface, it is reflected from the surface at an angle of incidence shown in Fig. 6.9. A portion of incident light is absorbed by the surface.

The ratio of luminous flux leaving the surface to the luminous flux incident on it is known as reflection factor.

$$\text{Reflection factor} = \frac{\text{reflected light}}{\text{incident light}}.$$

Its value will be always less than 1.

Beam factor

It is defined as the ratio of 'lumens in the beam of a projector to the lumens given out by lamps'. Its value is usually varies from 0.3 to 0.6. This factor is taken into account for the absorption of light by reflector and front glass of the projector lamp.

Ques: The flux emitted by a lamp in all directions is 1000 lumens. Calculate its MSCP

Hint: MSCP = $\frac{F}{4\pi}$

80 - Answer

Ques: A 250V lamp has a total flux of 1500 lumens and takes a current of 0.4 A. Calculate (a) lumen per watt (b) MSCP per watt

Watt = 100 Watts
MSCP = 120
(a) 15
(b) 1.2 Answer

Ques: A 0.4 meter diameter diffusing sphere of opal glass (20% absorption) encloses an incandescent lamp with a luminous flux of 4850 lumens. Calculate the average luminance of the sphere

Hint: Average luminance = $\frac{\text{Flux Emitted}}{\text{Surface area of sphere}}$

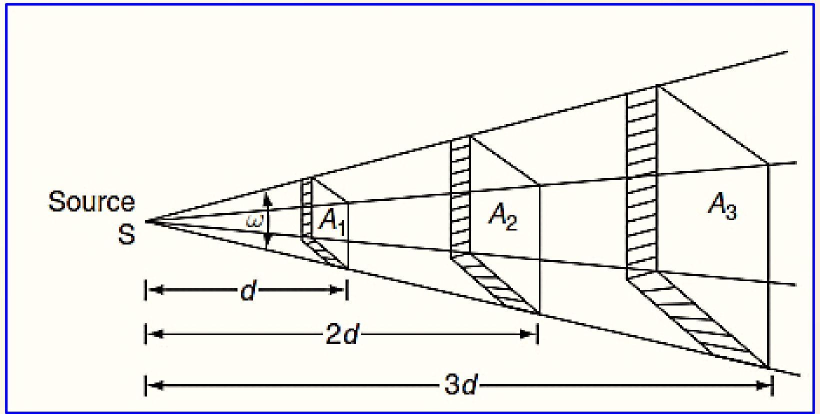
7720 lumens/m^2 - Answer

LAWS OF ILLUMINATION

- Mainly there are two laws of illumination.
  1. **Inverse square law.**
  2. **Lambert's cosine law.**

1. Inverse square law: **This law states that 'the illumination of a surface is inversely proportional to the square of distance between the surface and a point source'.**

Consider surface areas A_1, A_2 and A_3 at distances d, 2d and 3d respectively from the point source S of luminous intensity I and normal to the rays. Let the solid angle subtended be ω.



Total luminous flux radiated = Iω lumens

Illumination of the surface of area A_1

$$E_1 = \frac{I\omega}{A_1} = \frac{I\omega}{\omega d^2} = \frac{I}{d^2} \quad lumens\ per\ unit\ area$$

Illumination of the surface of area A_2

$$E_2 = \frac{I\omega}{A_2} = \frac{I\omega}{\omega (2d)^2} = \frac{I}{(2d)^2} \, lumens\ per\ unit\ area$$

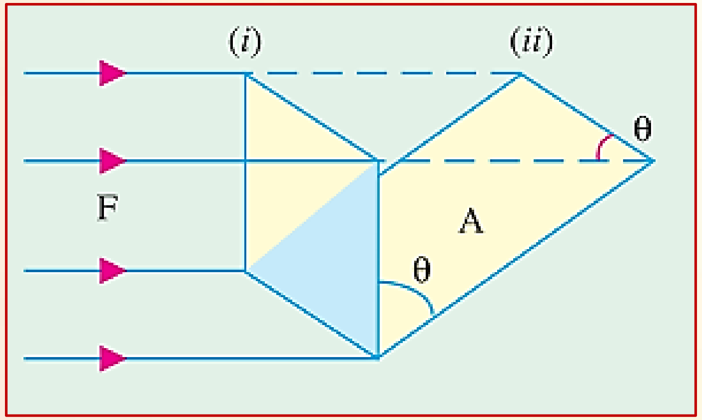
Illumination of the surface of area A_2

$$E_3 = \frac{I\omega}{A_3} = \frac{I\omega}{\omega (3d)^2} = \frac{I}{(3d)^2} \, lumens\ per\ unit\ area$$

Thus, $$\boxed{E_1 : E_2 : E_3 = \frac{1}{d^2} : \frac{1}{(2d)^2} : \frac{1}{(3d)^2}.}$$

Hence, it is concluded that, illumination on any surface is inversely proportional to the square of distance between the surface and the source.

2. Lambert's Cosine Law: **According to this law, " illumination (E) is directly proportional to the cosine of the angle made by the normal to the illuminated surface with the direction of the incident flux"**



Let **F** be the flux incident on the surface of area **A** when in position 1. When this surface is turned back through an angle θ, then the flux incident on it is Fcosθ. Hence, illumination of the surface when in position 1 is $\mathbf{E_1 = \frac{F}{A}}$. But when in position 2, $\mathbf{E_1 = \frac{F\cos\theta}{A}}$

Thus, $E_2 = E_1\cos\theta$

Combining all these factors together, we get

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

NUMERICALS BASED ON INVERSE SQUARE LAW

Ques: Two lamp posts are 16 m apart and are fitted with 100 CP lamp each at a height of 6 m above the ground. Calculate the illumination on the ground

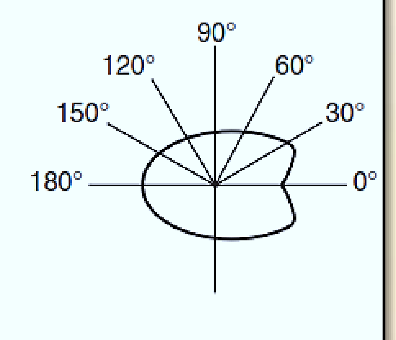
a. Under each lamp

b. Midway between the lamps.

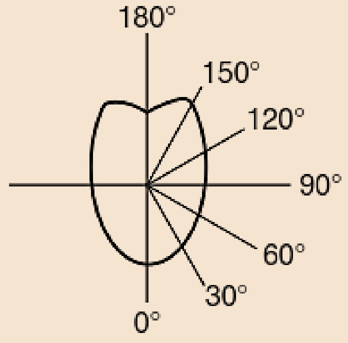
Ques: Four lamps are hung at a height of 10 m from the floor in corner of a square of 20 m × 20 m. If each lamp is of 400 CP, calculate the illumination on the floor at the centre of the square.

DETERMINATION OF LUMINOUS FLUX

- In order to determine illumination of a point according to formula $E = \frac{I\cos\theta}{d^2}$, it becomes essential to know the value of luminous intensity of the source of light in that direction.
- The luminous flux emitted by a source can be determined from the intensity distribution curve.
- The luminous intensity or candle power of any practical lamp is not uniform in all directions due to its unsymmetrical shape.
- The luminous intensity or the distribution of the light can be represented with the help of the **polar curves.**
- The polar curves are drawn by taking luminous intensities in various directions at an equal angular displacement in the sphere. A radial ordinate pointing in any particular direction on a polar curve represents the luminous intensity of the source when it is viewed from that direction.



(a) Horizontal polar curves



(b) Vertical polar curves

- Polar curves are used to determine the actual illumination of a surface by employing the candle power in that particular direction as read from the vertical polar curve. These are also used to determine mean horizontal candle power (MHCP) and mean spherical candle power (MSCP).

LIGHT SOURCES AND THEIR CHARACTERISTICS

Arc Lamps

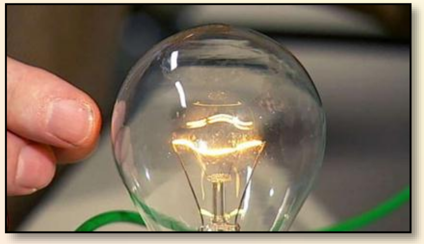
Electric discharge through air provides intense light.
E.g. Arc Lamps

Fluorescent Type Lamps

Certain materials, when exposed to ultraviolet rays, transform the absorbed energy into radiations of longer wavelength lying within the visible range.
E.g.: Fluorescent Lamp

High Temperature Lamps

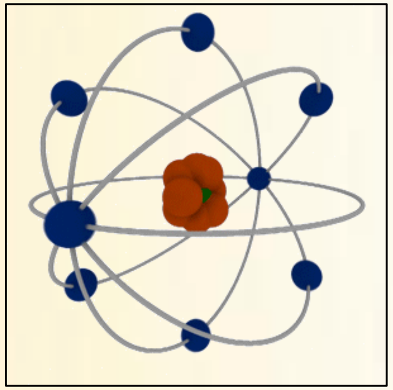
Oil and gas lamps and incandescent type lamps, which emit light when heated to high temperature

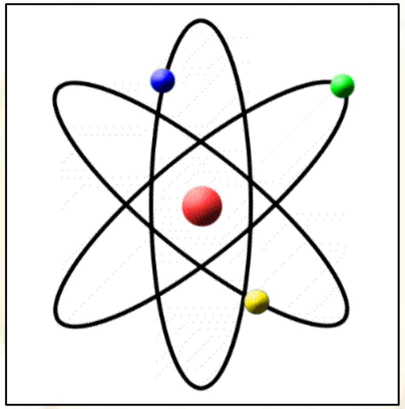


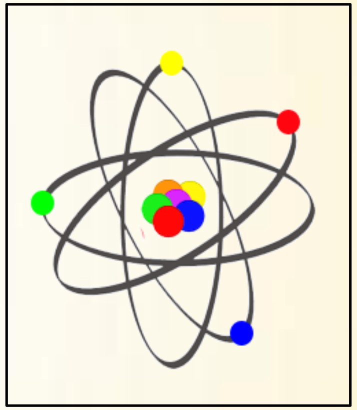
Gaseous Discharge Lamps

Under certain conditions, it is possible to pass electric current through a gas or metal vapour, which is accompanied by visible radiations.
E g.: Sodium vapour lamp and Mercury vapour lamp

LIGHT PRODUCTION BY EXCITATION AND IONIZATION



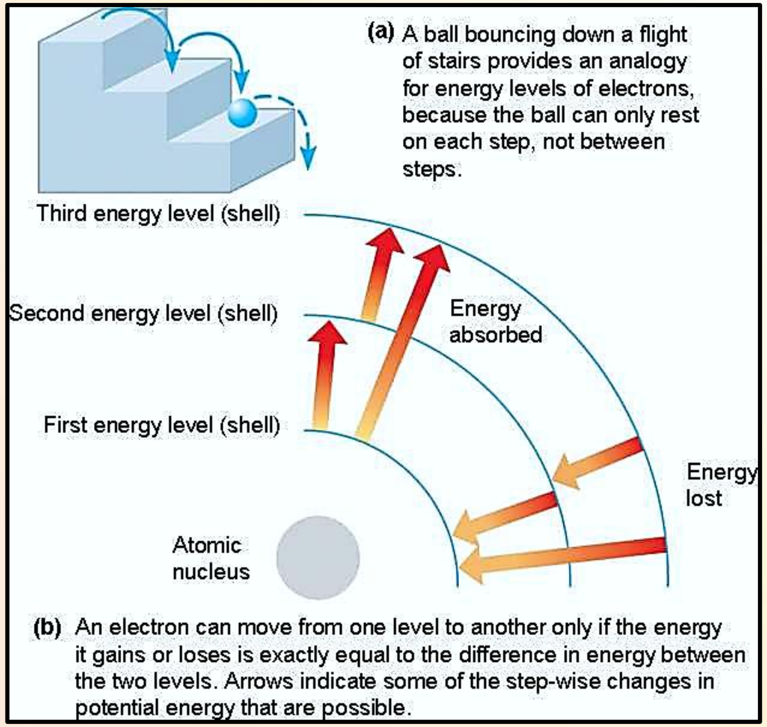




EXCITATION

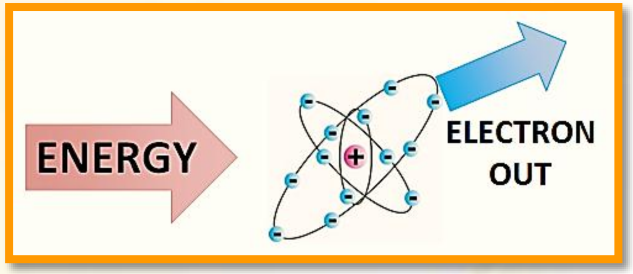
- In any gas or metal, depending upon temperature, there will always be present some number of free electrons which are not attached to any atom and are responsible for the conductivity of that gas or metal.
- If potential difference is applied to two electrodes separated by the gas, the free electrons will acted upon by force and they will move towards anode with velocity which will depend upon the voltage gradient between two electrodes.
- These moving electrons will acquire some kinetic energy and on their way to anode may hit upon the electrons in the outer orbit of the atoms of the gas.

- If the kinetic energy is equal to or above critical value, it may cause one or more electrons to jump from normal orbit to an orbit of larger radius. Atom in this state is said to be excited.
- Displaced electron then comes back to the orbit of smaller radius under the centripetal nuclear force.
- These oscillations of electrons, during excitation period give rise to electromagnetic radiations which may fall within the visible spectrum.



Ques: Why we get radiations of different wavelengths?

IONIZATION



- **Ionization** is the process by which ions are formed by gain or loss of an electron from an atom or molecule. If an atom or molecule gains an electron, it becomes negatively charged (an *anion*), and if it loses an electron, it becomes positively charged (a *cation*). Energy may be lost or gained in the formation of an ion.

- **If the kinetic energy of the colliding electron is very high, it may dislodge one or more electrons from outer shell of the atom. This will liberate one or more free electrons and an ion.**
- **Under the action of voltage gradient, both electrons and ions will move in opposite directions towards anode and cathode respectively.**

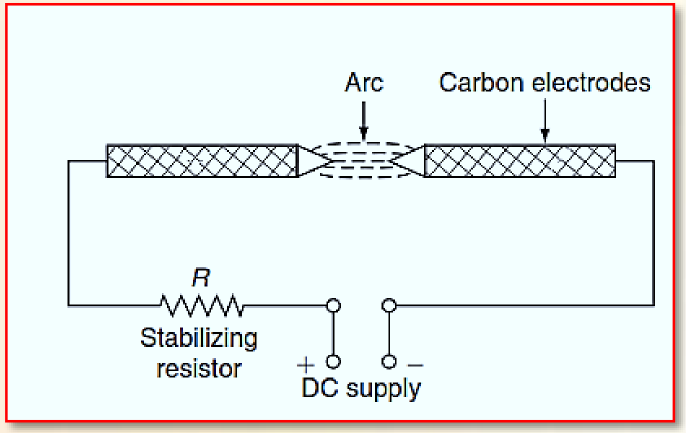
- **Since electron has less mass as compared to ion, it will attain higher speed. Electrons liberated will thus attain higher speed and become a cause of further ionization. In this way, chain action will commence and in no time, the fluorescent tube will conduct current and will give the light**

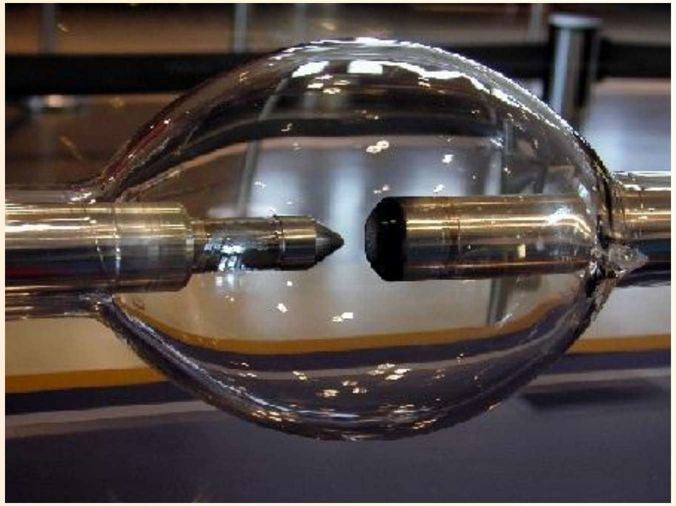
ARC LAMPS and THEIR CHARACTERISTICS

- **An arc lamp is a type of electric lamp which produces light by creating an arc in the space between two electrodes when electrical energy is supplied.**
- In the early 1800s, Sir Humphry Davy invented the first arc lamp. In that first lamp, two electrodes of carbon were used. The arc was produced between the electrodes in the air. It was used in searchlights, movie projectors (high-intensity light).

CARBON ARC LAMP

- The carbon arc lamp was the first widely-used type of electric light and was the first commercially successful form of electric lamp.
- When two hard carbon rods are placed end to end and connected to the terminals of dc supply mains of not less than 45 volts, the current flows through them and **the ends of carbon rods soon becomes incandescence due to high resistance**. If they are slightly pulled (say about 2 or 3 mm), **an arc will be formed between two carbon rods and white light will be produced.**
- **The arc is maintained by transfer of carbon particles from one rod to another one. It is found that these particles travel from the positive carbon rod to negative one.**
- **That's why, the positive rod after sometime of use becomes hollow and negative becomes a pointed pencil.**





Ques: Why X – section of the positive rod is made twice of that of negative one when the lamp is excited from DC supply?

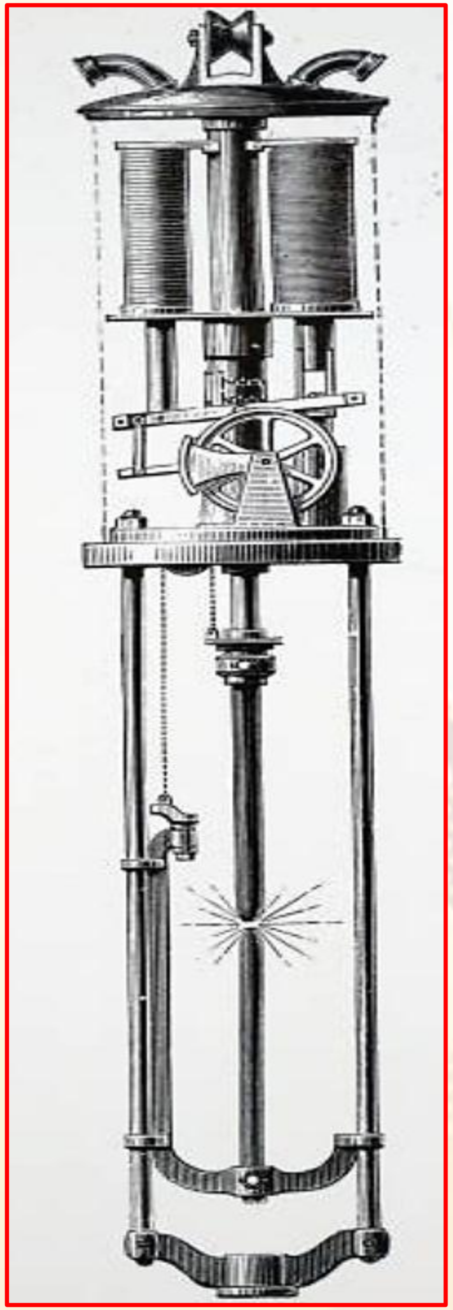
Ques : Why the carbon arc is unstable?

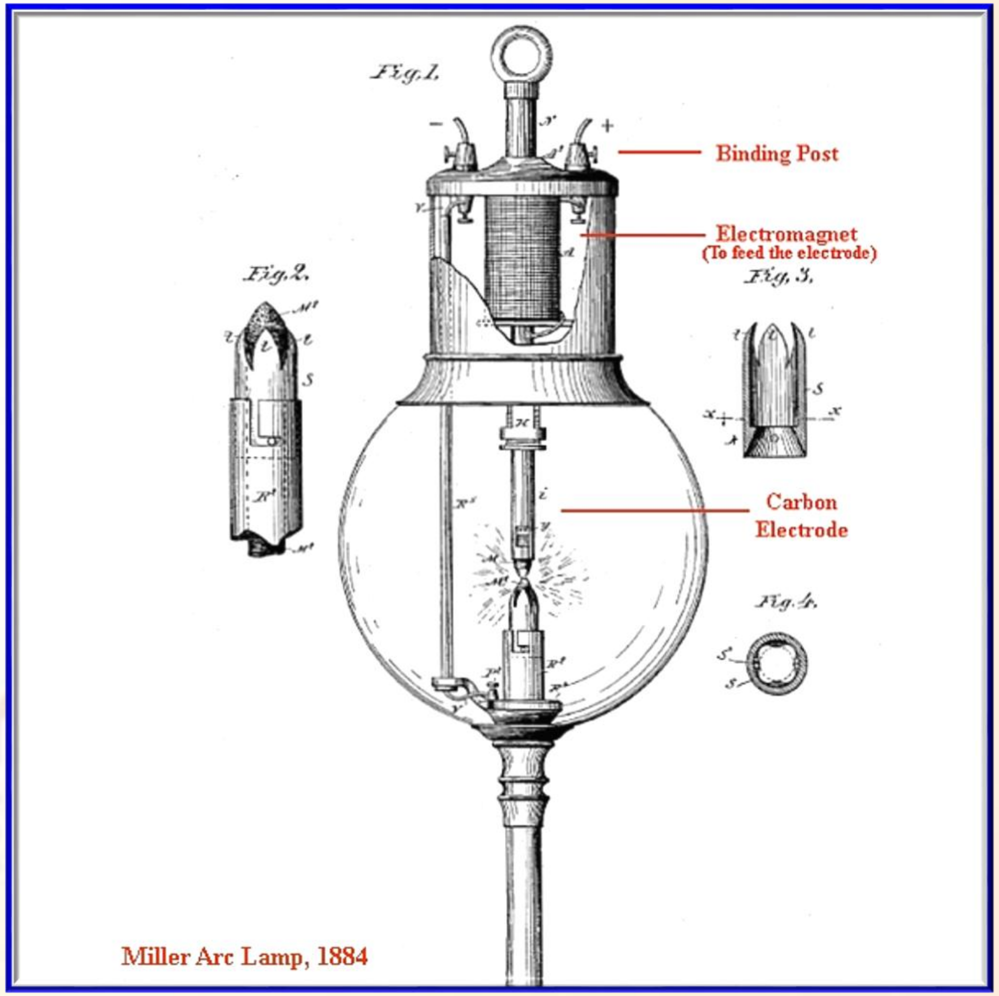
Ques: Why a series resistance is connected in series with the arc lamp?

- In case of AC supply, the rate of burning of both the rods is same and, therefore, they are made of equal x – sections.
- The voltage required for maintain the arc is given approximately by $V = (39 + 2.8\,l)$ where l is the length of the arc in mm.

CHARACTERISTICS OF CARBON ARC LAMP

- The carbon arc is unstable.
- The voltage drop across the arc is about 45 to 60 volts and the supply voltage is about 70 to 100 volts.
- About 85% of light is given out by the positive carbon, 10% by the negative carbon and 5% by the air.
- The temperature of positive carbon is between 35000C and 40000C and that of negative is about 25000C.
- The luminous efficiency of such a lamp is about 12 lumens per watt.

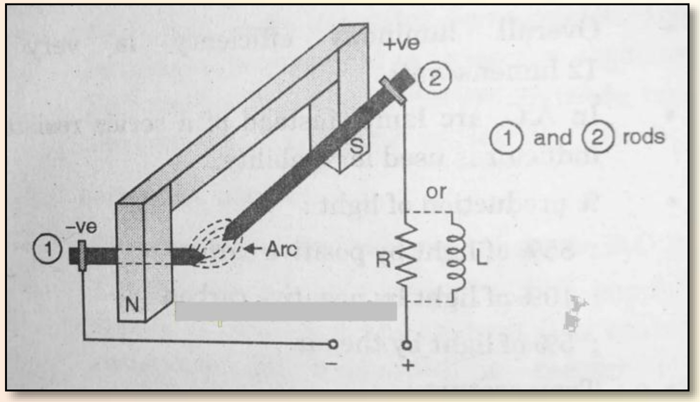




CARBON ARC LAMPS

CARBON ARC LAMP

FLAME ARC LAMP

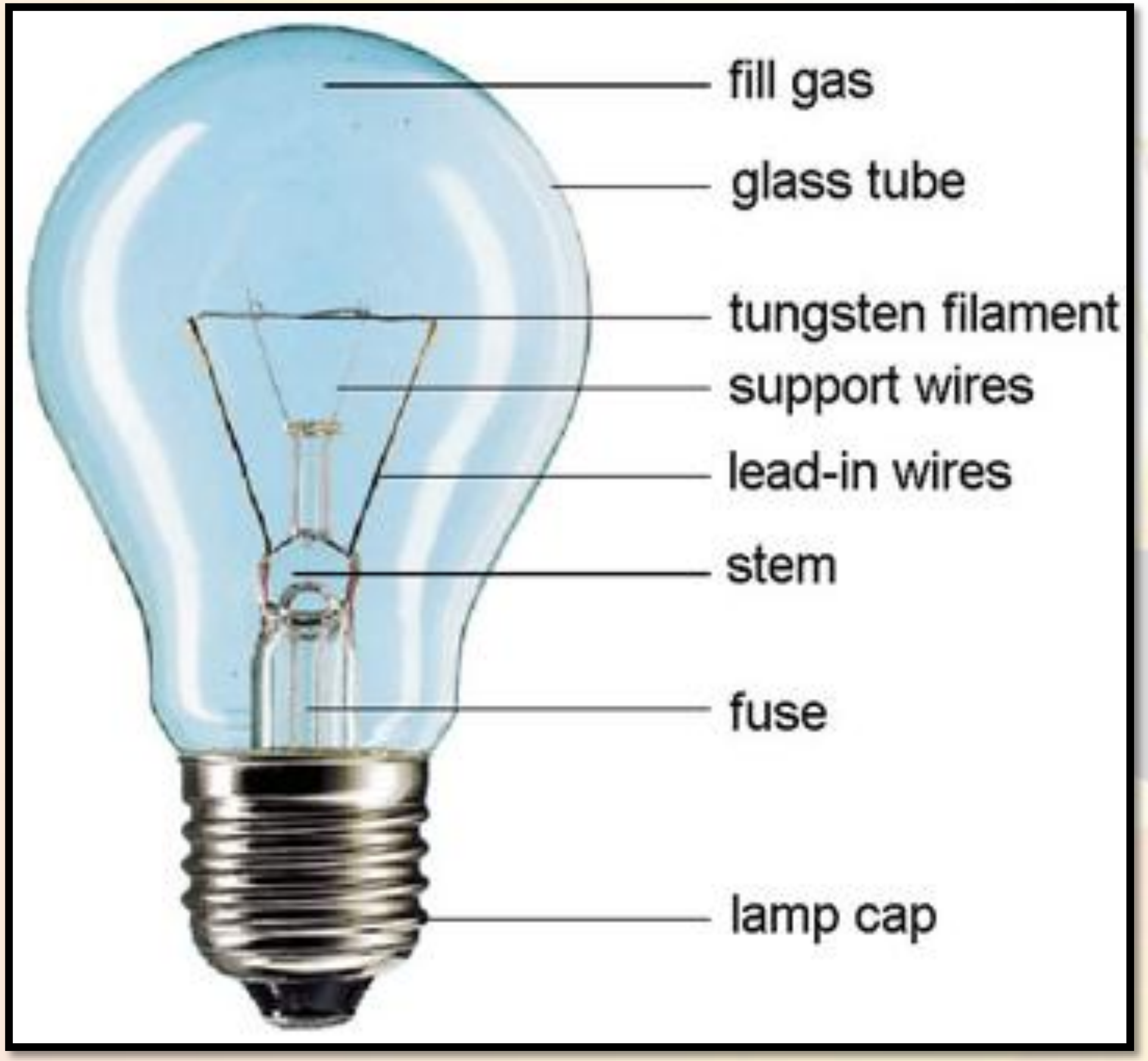


- The principle of operation is similar to that of carbon-arc lamp. The electrodes of such a lamp has 5 to 15% fluoride (called the flame material) and 85 to 95% carbon.
- The fluoride has a characteristic which radiates light energy efficiently from a very high heated arc stream. Fluoride turns into vapour along with the carbon and these fluoride vapours cause a very high luminous intensities.

MAGNETIC - ARC LAMP

- In such a lamp positive electrode made of copper and negative electrode made of magnetic oxide of iron are used. The arc is struck in the similar way as in case of carbon-arc lamp. Such lamps are rarely used.

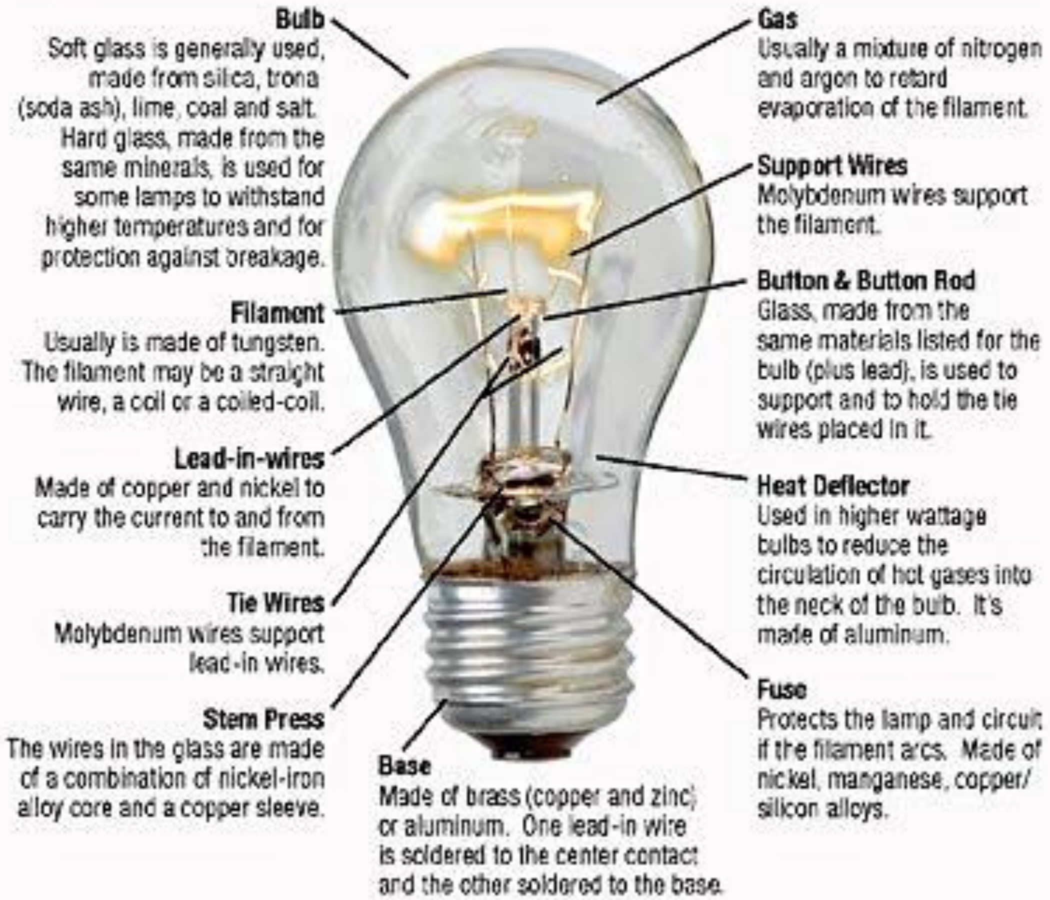
INCANDESCENT (or FILAMENT) LAMPS and THEIR CHARACTERISTICS



- These lamps are temperature – dependent sources.
- When an electric current is made to flow through a fine metallic wire (i.e. *filament*), its temperature increases. At low temperature, it emits only heat energy, but at very high temperature, the metallic wire emits both heat and light energy. The wire is placed inside a glass bulb, which is either at a vacuum or contains an inert gas. / [The operating principle of the incandescent lamp is extremely simple. An electric current is passed through a thin wire of comparatively high resistance so as to heat this to incandescence. The wire is usually heated to a temperature of between 2700 K and 2800 K, at which temperature it emits warm-white light.]

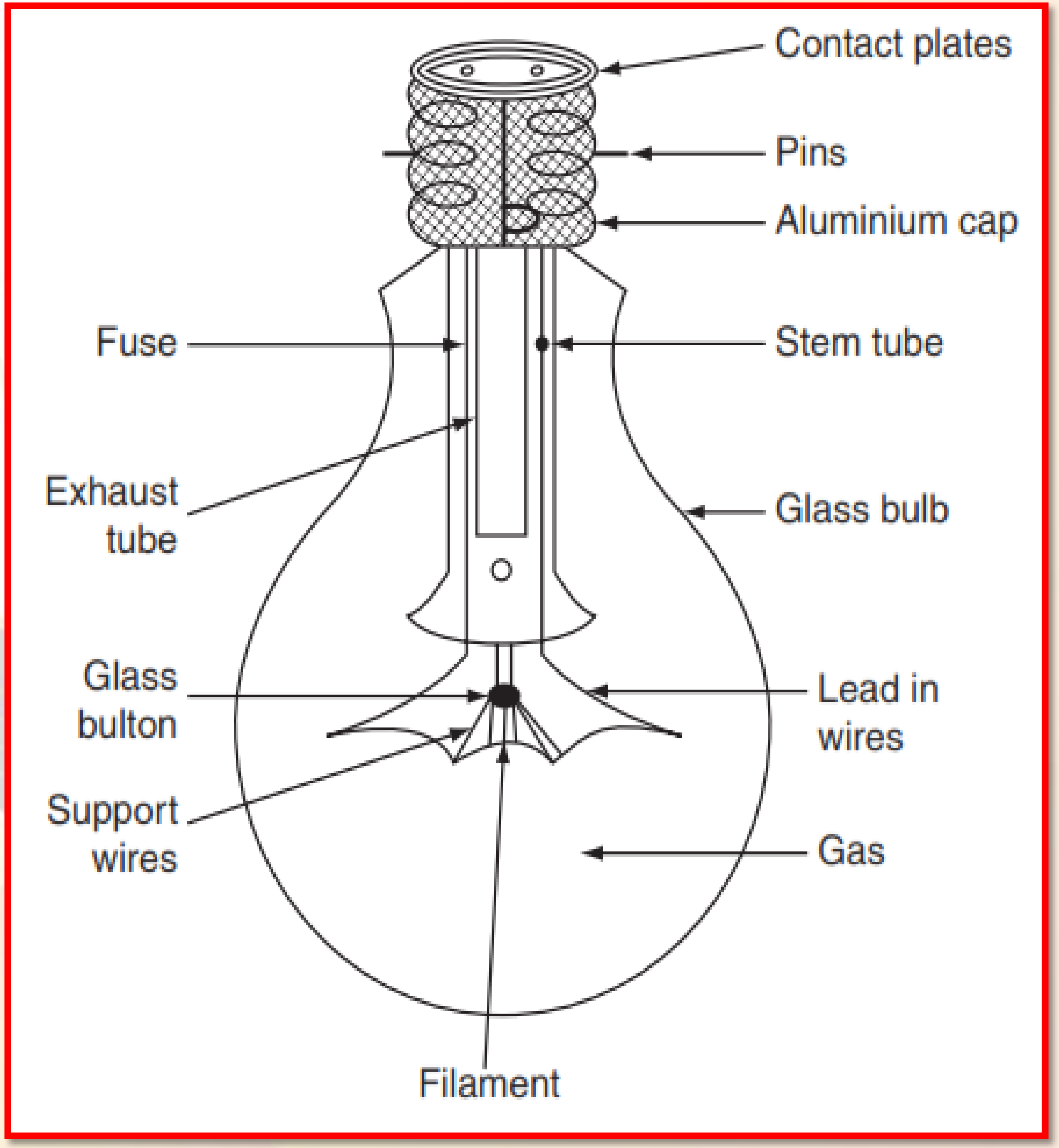
Making A Lightbulb

The Many Minerals and Metals it Takes...



Don't forget the mineral fuels needed to generate the electricity to light up the bulb. In the U.S., these are the sources of our fuels . . .

Coal	Nuclear	Hydro	Natural Gas	Oil	Other
52%	20%	7%	16%	3%	2%



- **Glass bulb** is used to isolate the filament from surrounding air to prevent oxidation of filament and to minimize convection current surrounding the filament hence to keep the temperature of the filament high.
- The glass bulb is either kept vacuum or filled with inert gases like argon **(≈ 85%)** with a small percentage of nitrogen **(≈ 15%)** at low pressure.
- **The use of inert gases (gas filled lamps) results in the possibility of working the filament at higher temperature without any fear of oxidation and evaporation of the filament, and thus increase the lamp life.**
- **Bulbs with rating 40 W and above are usually gas filled whereas below 40 Watts they are vacuum type.**

Choice of Material for Incandescent Lamp Filament

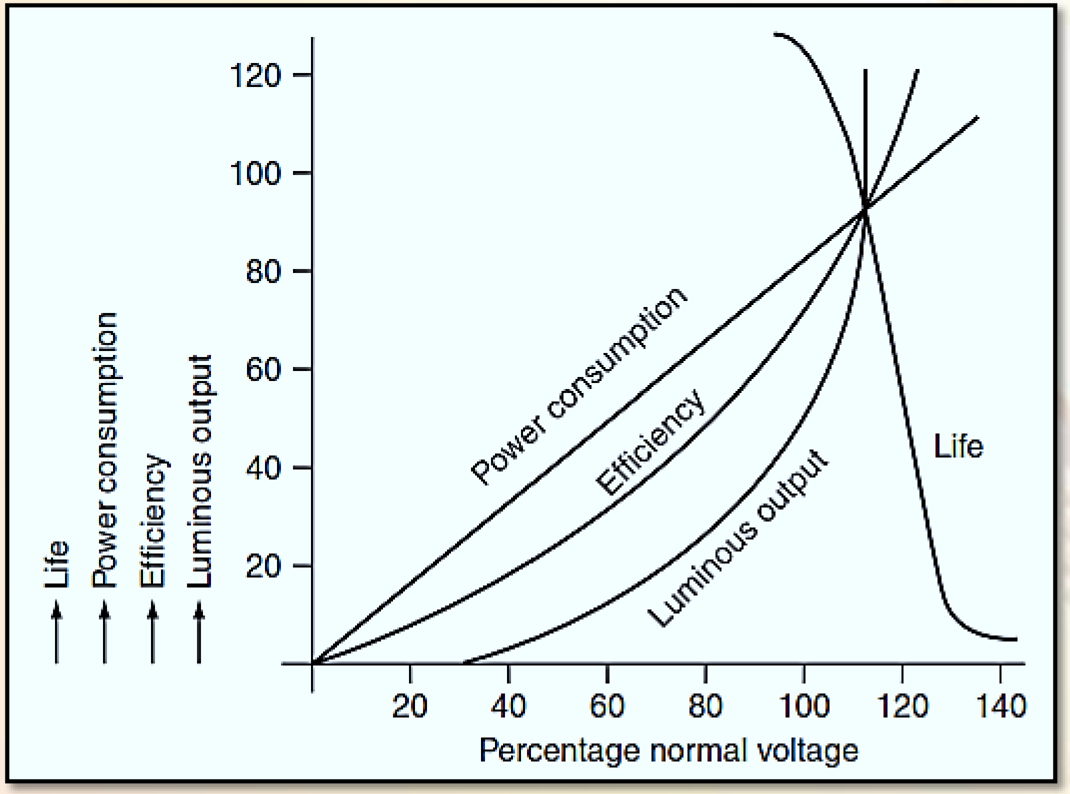
- **High melting point.**
- **Low vapour pressure.**
- **Free from oxidation in inert gas (i.e. argon, nitrogen etc.) medium at operating temperature.**
- **High resistivity.**
- **Low thermal coefficient of expansion.**
- **Low temperature coefficient of resistance.**
- **Should have high young modulus and tensile strength.**
- **Sufficient ductility so that can be drawn in the form of very thin wire.**
- **Ability to be converted in the shape of filament.**
- **High fatigue resistance against thermally induced fluctuating stresses.**

❑ Comparisons of Carbon, Osmium, Tantalum, and Tungsten used for making the filament

CARBON	OSMIUM	TANTALUM	TUNGSTEN
❑ Carbon has high melting point of 3,500°C; even though, its melting point is high, carbon starts disintegration at very fast rate beyond its working temperature of 1,800°C.	❑ The melting point of osmium is 2,600°C.	❑ The melting point of tantalum is 3,000°C, and Resistivity (ρ) is 12.5 μΩ-cm.	❑ **The working temperature of tungsten is 2,500–3,000°C, and its vapour pressure is low when compared to carbon.**
❑ Its resistance decreases with increase in temperature, i.e., its temperature coefficient of resistivity is negative, so that it draws more current from the supply. The temperature coefficient (α) is – 0.0002 to – 0.0008	❑ It is very rare and expensive metal	❑ The main drawback of the negative temperature coefficient of carbon is overcome in tantalum. It has positive temperature coefficient (α) and its value is 0.0036.	❑ **Its resistance at working temperature is about 12–15 times the cold resistance**
❑ The efficiency of carbon filament lamp is low; because of its low operating temperature, large electrical input is required. The commercial efficiency of carbon lamp is 3 – 4.5 lumens/W approximately.	❑ The average efficiency of osmium lamp is 5 lumens/W	❑ The density of tantalum is 16.6.	❑ **It has positive temperature coefficient of resistance of 0.0045 and its resistivity is 5.6 12.5 μΩ-cm.**
❑ Carbon has high resistivity (ρ), which is about 1,000–7,000 μΩ-cm and its density is 1.7–3.5.		❑ The efficiency of tantalum lamp is 2 lumens/W.	❑ **The density of tungsten is 19.3**
			❑ **The efficiency of tantalum when working at 2,000°C is 18 lumens/W.**

Effect of Voltage Variations

- The variations in normal supply voltages will affect the operating characteristics of incandescent lamps. The performance characteristic of an incandescent lamp, when it is subjected to voltage other than normal voltage, is shown

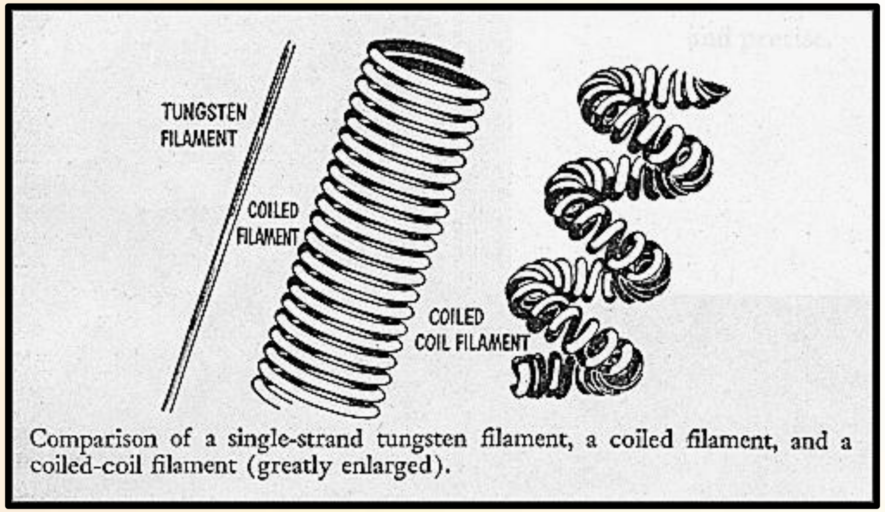


- Lumens output $\propto$ (voltage)$^{3.55}$.
- Power consumption $\propto$ (voltage)$^{1.55}$.
- Luminous efficiency $\propto$ (voltage)^{2}.
- Life $\propto$ (voltage)$^{-13}$ (for vacuum lamps).
- Life $\propto$ (voltage)$^{-14}$ (for gas filled lamps).

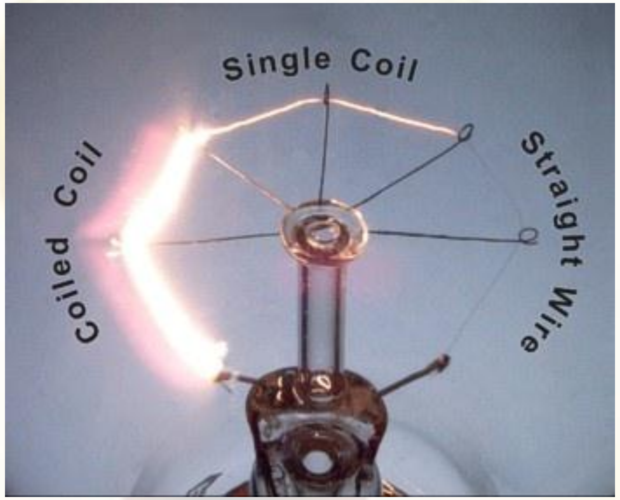
Ques: Derive an expression of Filament Dimensions for an Incandescent Lamp.

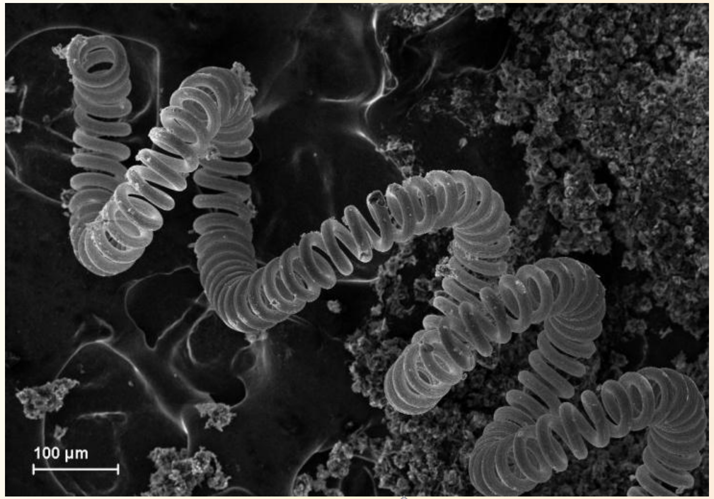
$$I = d^{3/2}\sqrt{\frac{eK\pi^2}{4\rho}(T_1^4 - T_0^4)}$$

- Due to presence of gas there is heat loss due to convection currents. This loss depends upon the surface area of filament. As such coiled coil filaments, which take much less space compared with coiled filaments are used with such lamps.

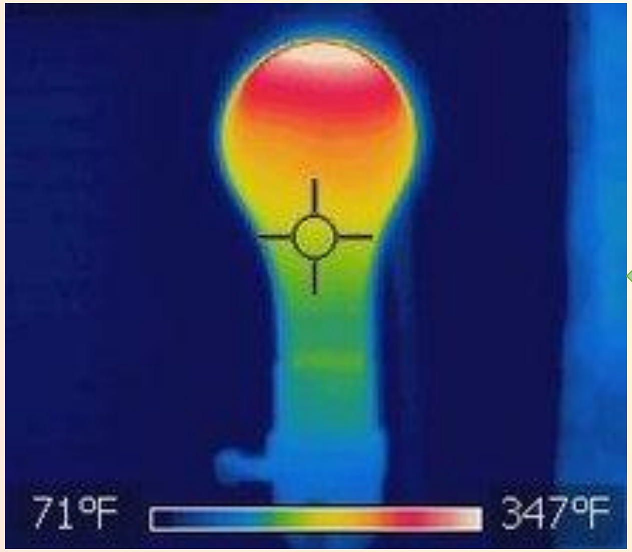


Comparison of a single-strand tungsten filament, a coiled filament, and a coiled-coil filament (greatly enlarged).





An SEM image of the tungsten filament of an incandescent light bulb



Thermal Image of an Incandescent Bulb

HALOGEN LAMP

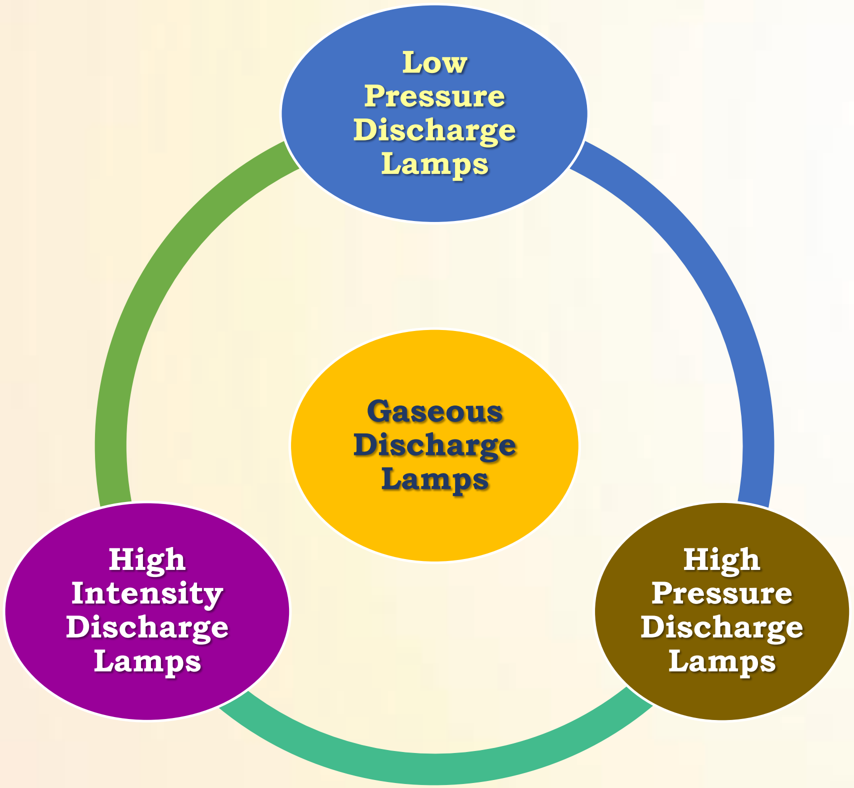
- The halogen lamp is the latest member in the family of incandescent lamps.
- In a halogen lamp, the bulb is filled with a noble gas such as krypton or xenon, plus a tiny amount of a halogen gas such as iodine or bromine, which is at a higher temperature and pressure than in a normal bulb.
- The halogen constantly regenerates the tungsten filament, effectively "bouncing back" tungsten atoms to rebuild the filament when it starts to disintegrate. This means the filament lasts much longer than it does in a normal lamp. [The addition of a small amount of halogen vapour to the filling gas restores part of the evaporated tungsten vapour back to the filament by means of a chemical reaction, i.e., there is a sort of 'regenerative cycle']

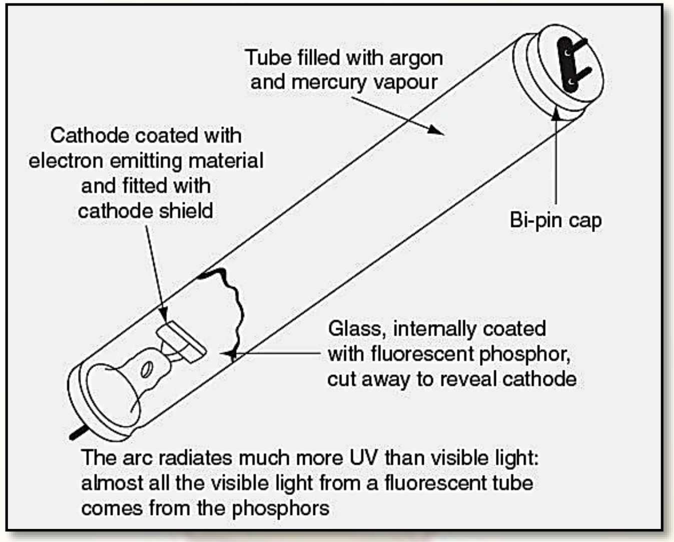
INCANDESCENT LAMPS	HALOGEN LAMPS
❑ These lamps are available in various shapes and sizes. ❑ These are operating at unity power factor. ❑ These lamps are not affected by surrounding air temperature. ❑ Different colored light output can be obtained by using different colored glasses. ❑ Direct operation on standard distribution voltage ❑ Good radiation characteristic in the luminous range	❑ No blackening of lamp, hence no depreciation of lumens output. ❑ High operating temperature with increased luminous efficiency varying from 22 lumens per watt to 33 lumens per watt. ❑ Reduced dimensions of lamps-miniature size. ❑ Long life—2,000 hours. ❑ Better colour rendition. ❑ Halogen lamps, which are being manufactured in sizes up to 5 kW, are suitable for outdoor illumination of buildings, playing fields, large gardens, fountains, car parks, airport runways etc. and for lighting of public halls, factories, sport-halls, photo film and TV studios etc.

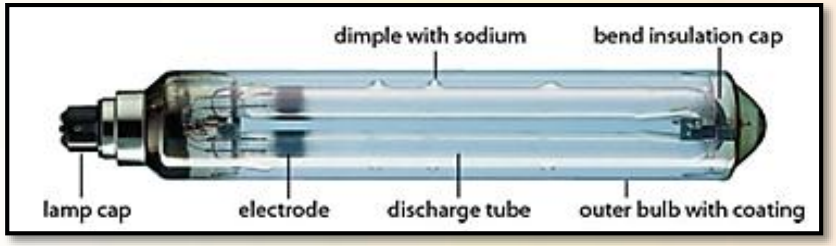
GASEOUS DISCHARGE LAMPS and THEIR CHARACTERISTICS

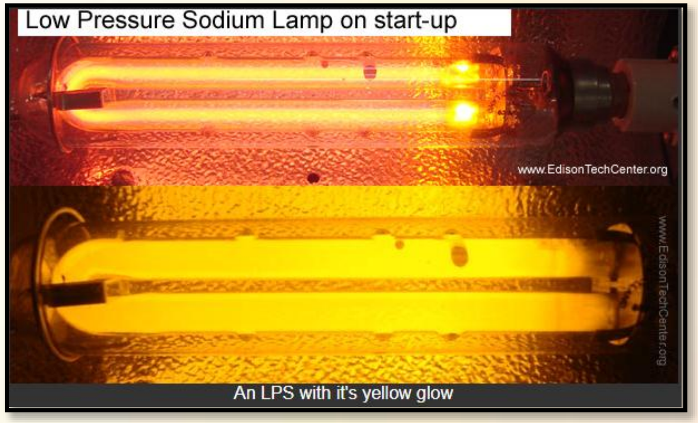
- Discharge tubes were made as early as 1856, but commercially discharge lamps came into the market only in the 1930s.
- Gas-discharge lamps are a family of artificial light sources that emit light by sending an electrical discharge through an ionised gas, i.e. plasma.
- Such lamps are filled with a noble gas (argon, neon, krypton and xenon) or a mixture of these gases. Most lamps are filled with additional materials, such as mercury, sodium, and metal halides.
- When the gas is ionised, free electrons are accelerated by the electrical field in the tube and collide with gas and metal atoms. Some electrons in the atomic orbital of these atoms are excited by these collisions to a higher energy state. When the excited atom falls back to a lower energy state, it emits a photon of a characteristic energy, resulting in infrared, visible light, or ultraviolet radiation. Some lamps convert the ultraviolet radiation to visible light with a fluorescent coating on the inside of the lamp's glass surface (e.g. Fluorescent Tube).

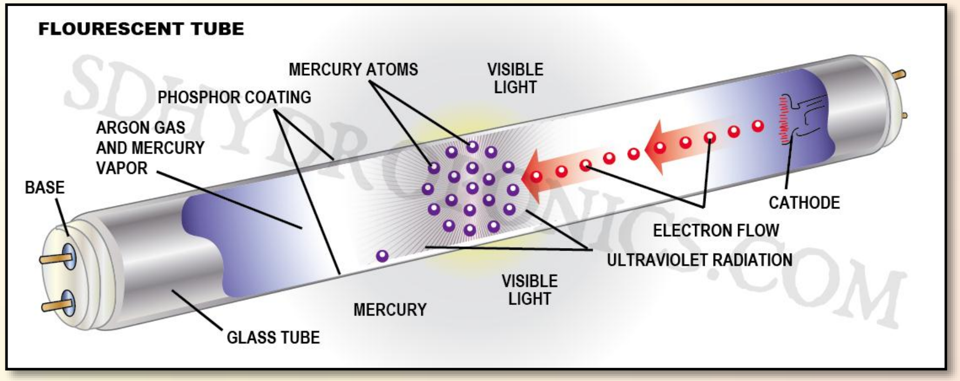
https://www.rp-photonics.com/gas_discharge_lamps.html - **Excellent Website for DISCHARGE LAMPS**











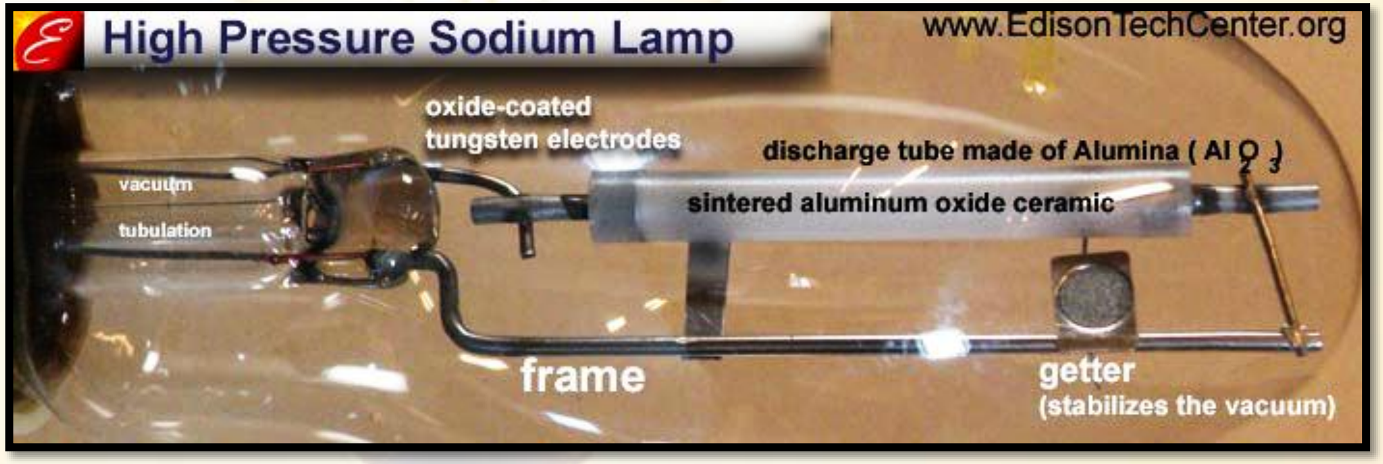
Low Pressure Discharge Lamps

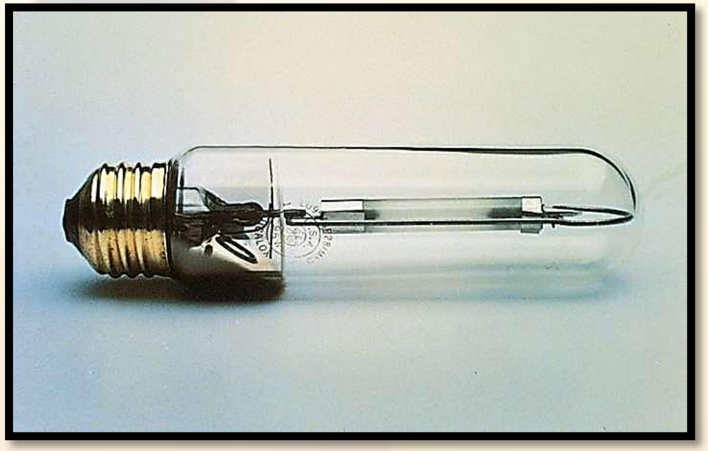
http://my.ilstu.edu/~gjin/p2/Lighting_P2_in_Energy/Lighting_P2_in_Energy7.html – **Sodium Vapour Lamps**

http://edisontechcenter.org/SodiumLamps.html – **Sodium Vapour Lamps**

SODIUM LAMP

- Sodium Lamps were first produced commercially by Philips in Holland in 1932.
- There are two kinds of sodium lights: **Low Pressure (LPS)** and **High Pressure (HPS).** These lamps are mostly used for street lighting as well as industrial uses.
- **The lamp works by creating an electric arc through vaporized sodium metal. Other materials and gases are used to help start the lamp or control its color.**





- Practically the sodium vapour discharge lamp consists of a bulb containing a small amount of metallic sodium, neon gas, and two sets of electrodes connected to a pin type base.
- **The presence of neon gas serves to start the discharge and to develop enough heat to vaporize the sodium.**
- **Since long discharge paths are necessary, therefore, the discharge envelope is usually bent into U shape.**
- **The lamp operates at a temperature of 300^{0}C and in order to conserve the heat generated and assure the lamp operating at normal air temperature, the discharge envelope is enclosed in a special vacuum envelope.**
- **The lamp must be operated horizontally, or nearly so, to keep the sodium well spread along the tube.**

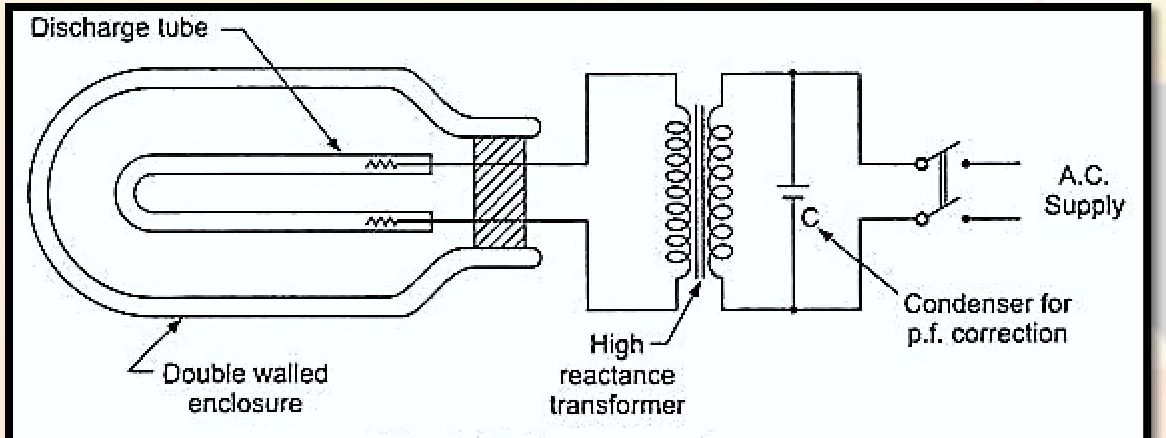


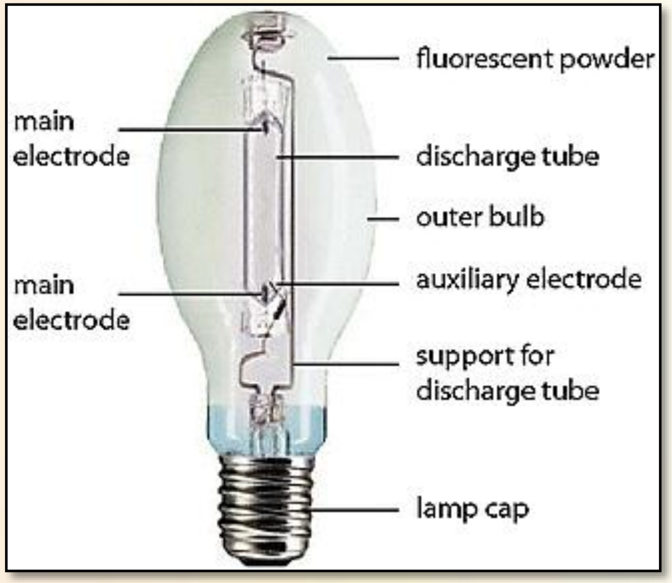
Fig. 7 *Sodium vapour lamp*

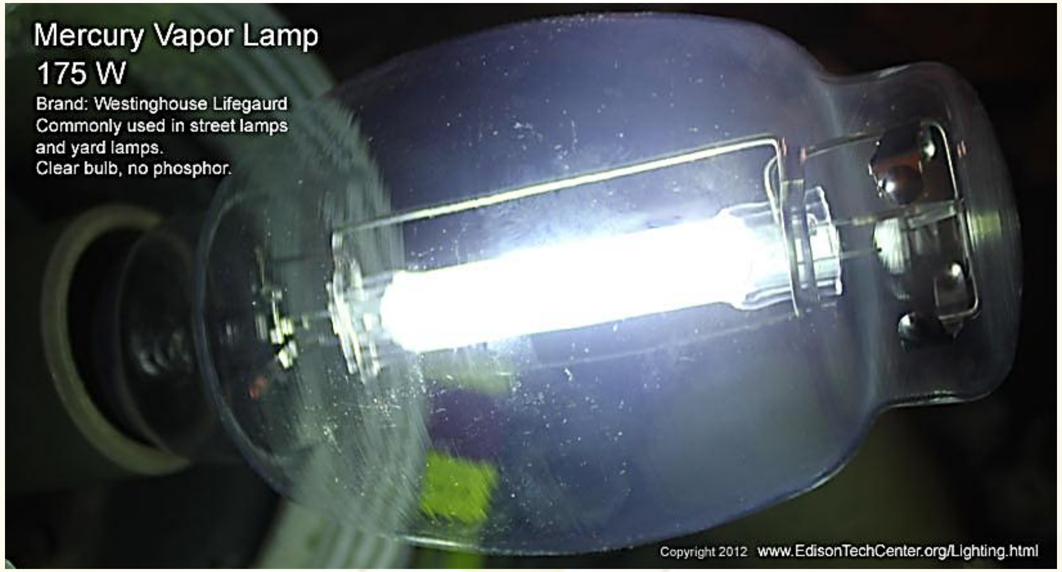
- When the lamp is not in operation, the sodium is usually in the form of solid deposited on the side walls of the tube, therefore, at first when it is connected across the supply mains the discharge takes place in the neon gas and gives **red** – **orange** glow.
- **The monochromatic sodium gradually vaporizes and then ionizes, thereby producing the monochromatic yellow light.**
- **The lamp will come upto its rated light output in approximately 15 minutes.**

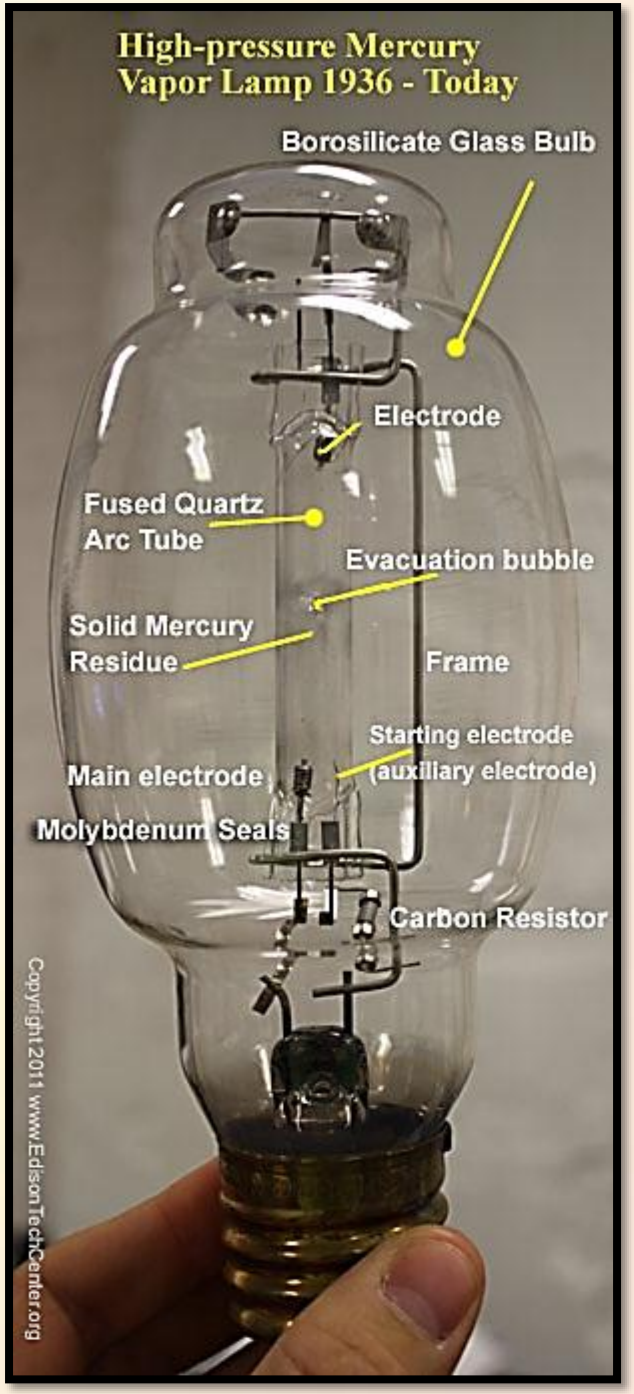
Characteristics:

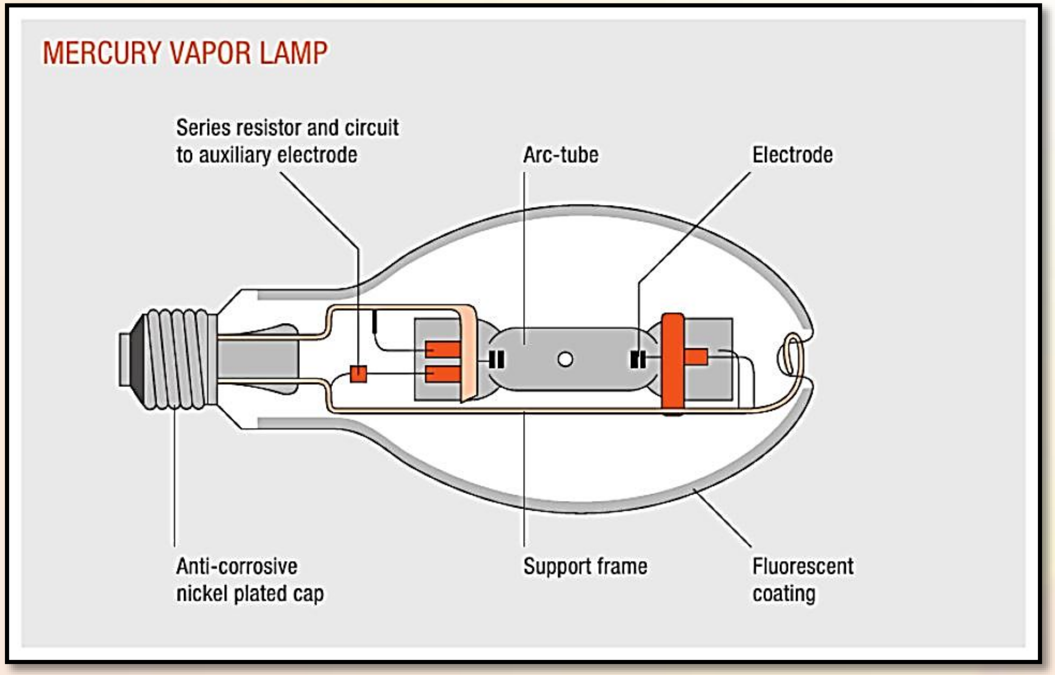
- It has an average life of 18000 - 24000 working hours.
- Lamp efficacy of 67 – 139 lumens per watt.
- Fairly good colour rendering.
- Low power consumption and running costs.
- Lamp takes time to reach its full brilliance.
- The uncorrected power factor is very low, about 0.3.

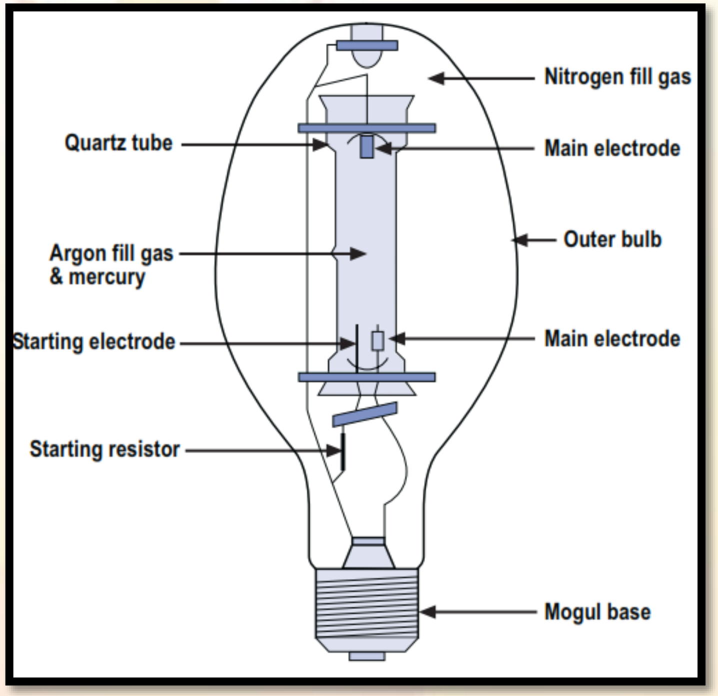
HIGH PRESSURE MERCURY VAPOUR DISCHARGE LAMP

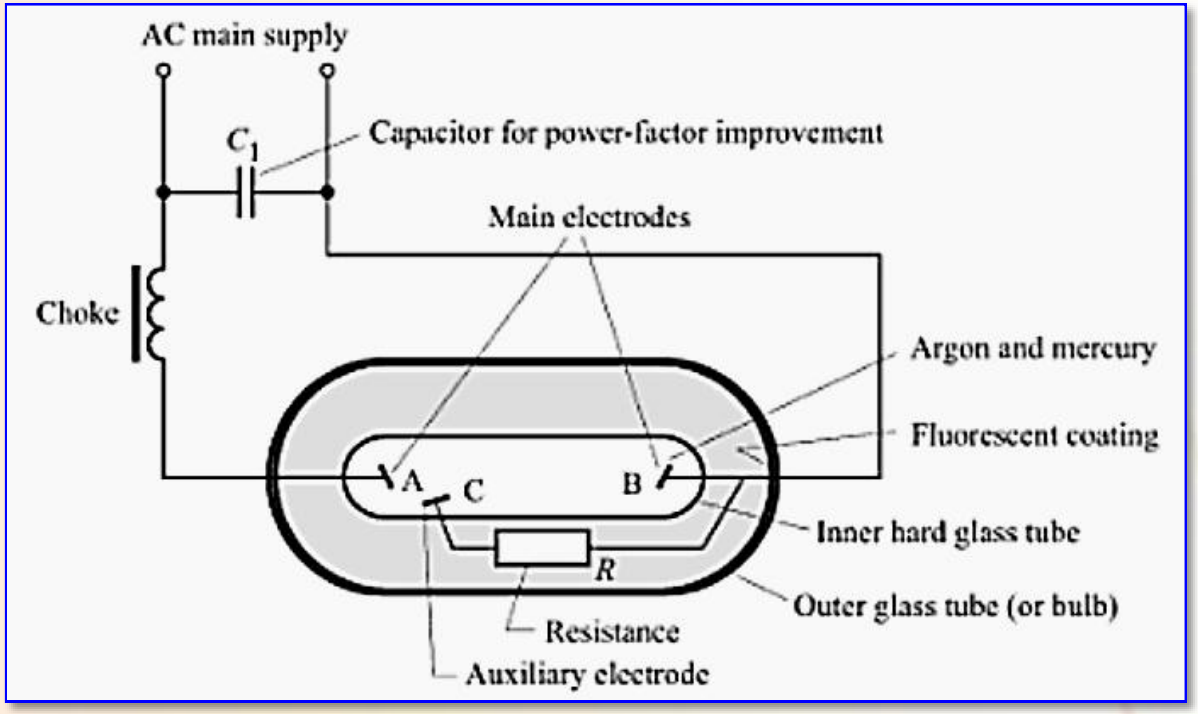


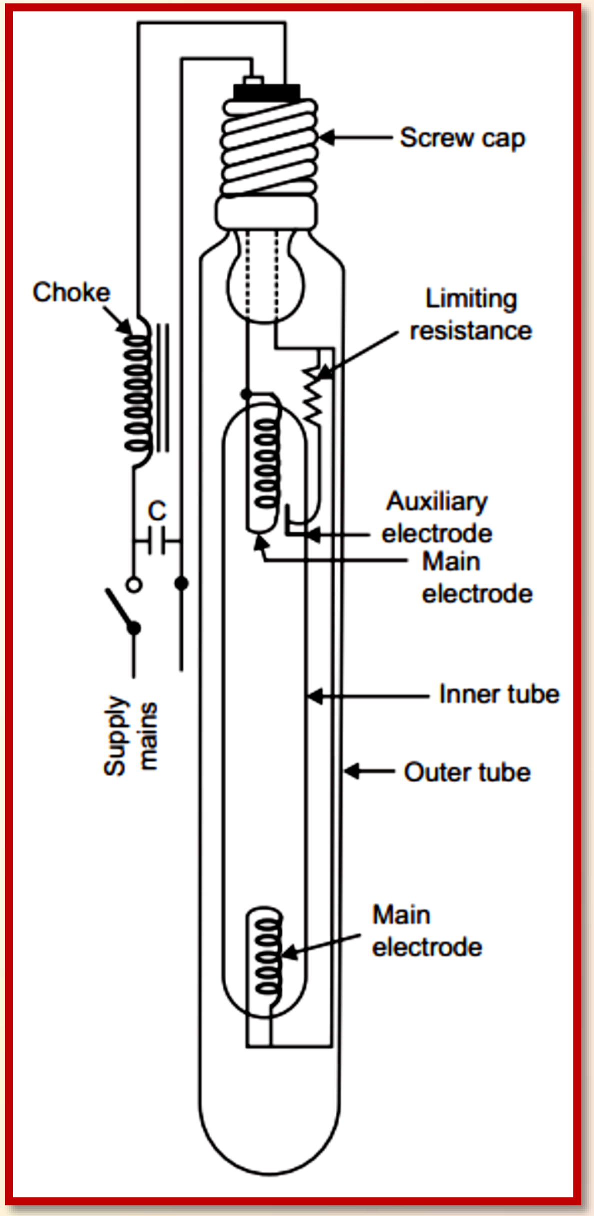












- It consists of two tubes, one inside the other.
- The smaller inner tube is made of hard glass (or quartz) and is surrounded by the large glass tube or bulb.
- The space between the two tubes is completely evacuated to prevent heat loss.
- The outer bulb absorbs harmful ultra violet rays.
- The inner bulb contains argon and certain quantity of mercury. In addition to two main electrodes, an auxiliary or starting electrode having a high resistance in series is also provided.
- The main electrodes are made of tungsten wire in helical shapes

OPERATION:

- When the supply is switched ON, full mains voltage is applied between the auxiliary electrode and neighbouring main electrode.
- This voltage breaks down the gap and a discharge through argon gas takes place. This enables the main discharge to commence. As the lamp warms up, mercury is vaporized, which increases the vapour pressure.
- This discharge, later on, takes up the shape of an intense arc. After 4–5 min, the lamp gives full brilliance. It gives greenish blue colour light and its efficiency is about 40 lumen/ watt

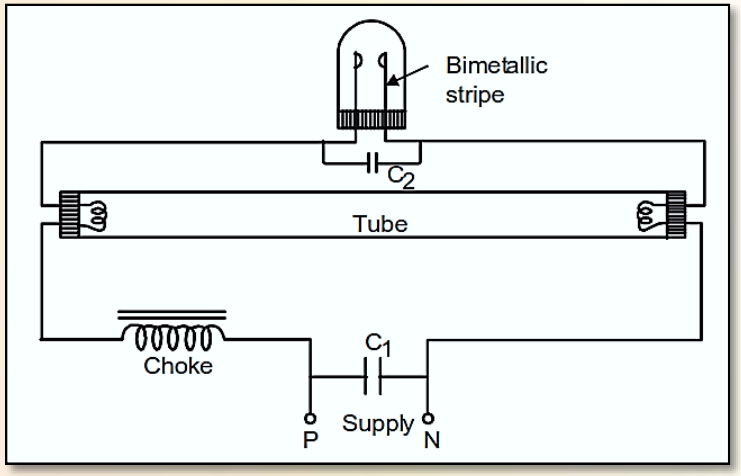
Characteristics:

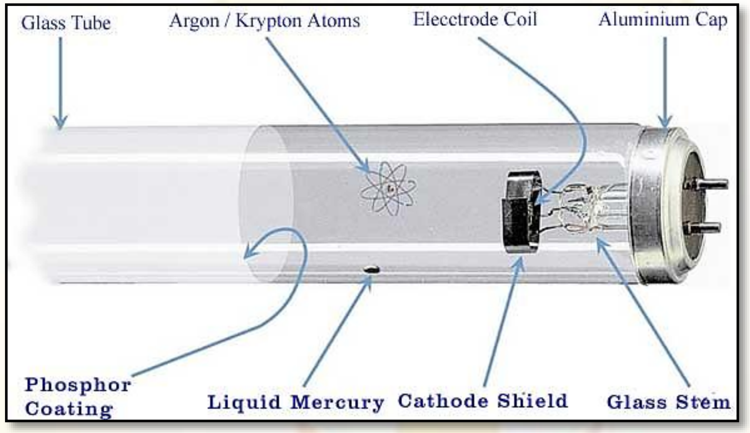
- It has an average life of 22000 working hours.
- Lamp efficacy of 34 – 60 lumens per watt.
- Adequate colour rendering.
- Lamp takes time to reach its full brilliance.
- Available in 40 – 1000 W.

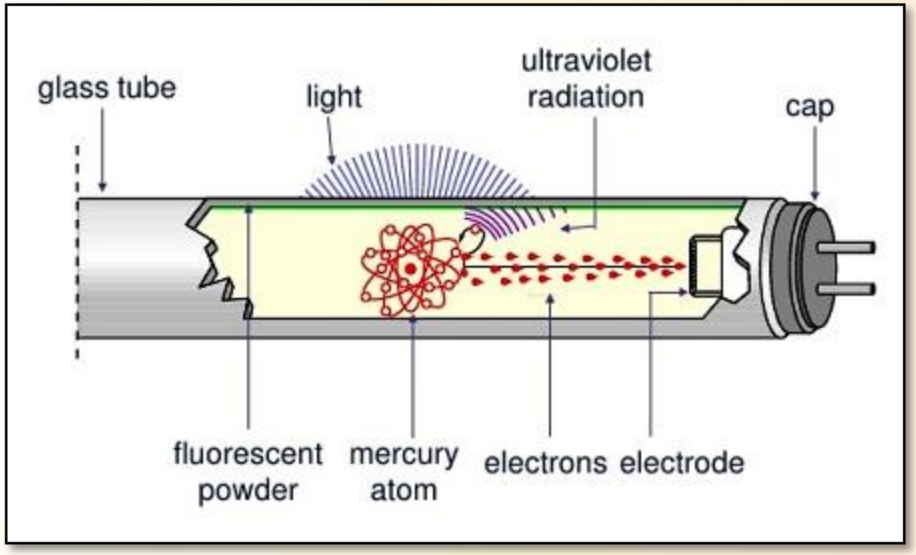
Ques: Why mercury vapour lamp is always suspended vertically?

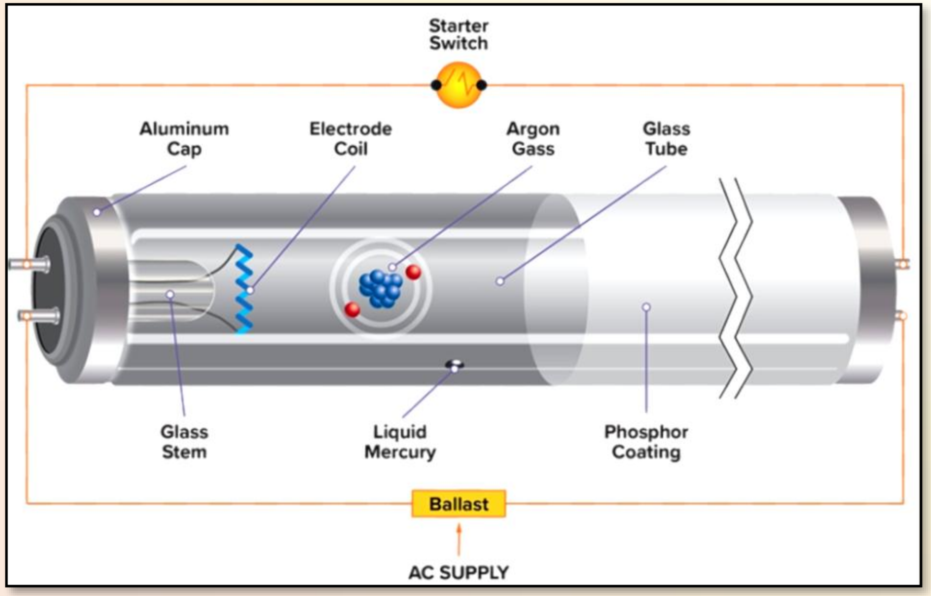
Ques: Describe the construction, operating principle, characteristic and advantages of NEON LAMP.

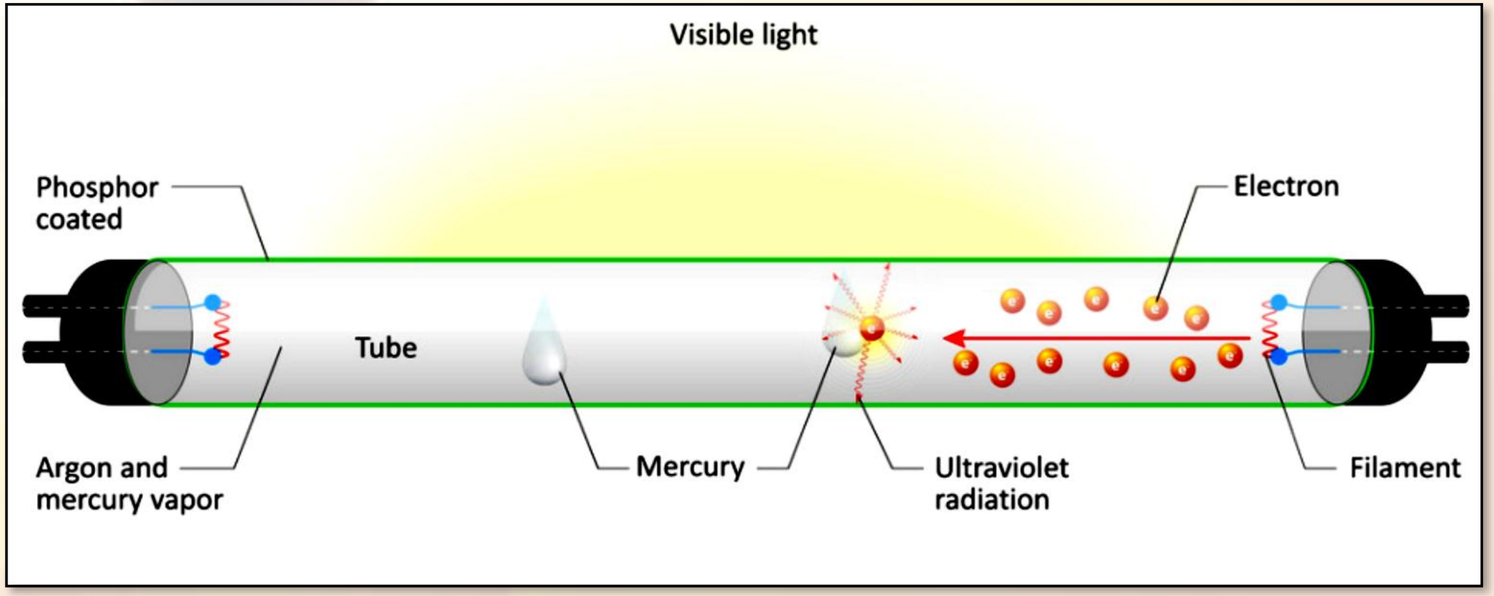
❑ FLUORESCENT TUBE LIGHT





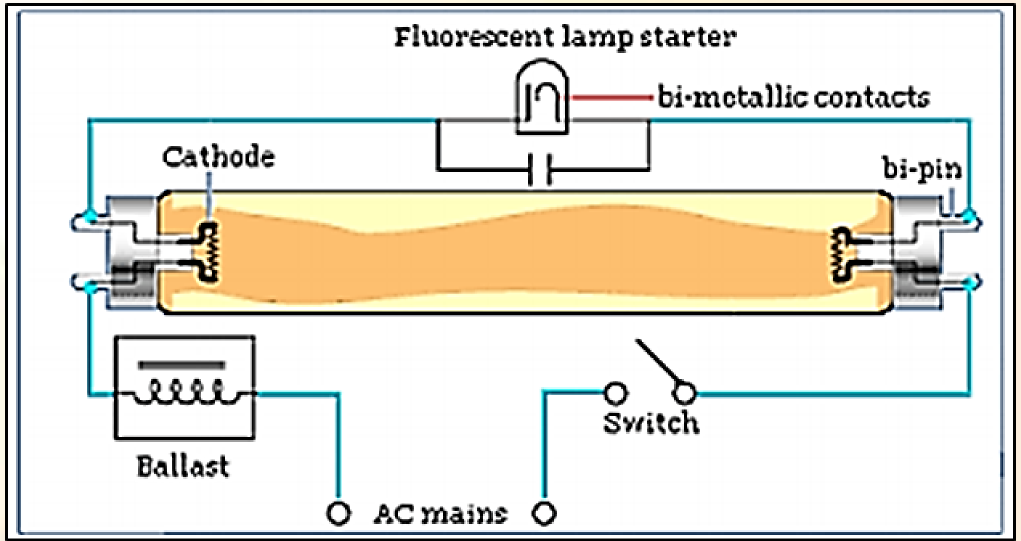






OPERATION:

- The inside of a fluorescent tube is coated with a thin layer of a phosphor substance (such as calcium tungstate, zinc silicate, calcium borate etc.) in the form of powder. A phosphor possess property of absorbing ultraviolet radiations incident on its surface, and then again radiating its substantial portion in the form of visible light. This property is known as *fluorescence.*
- Each phosphor gives light of its characteristics wavelength (or colour).
- ***The best source of ultraviolet radiation is an electric discharge through a gas at low pressure. So, the tube is filled with small quantity of argon gas at a pressure of 2.5 mm of mercury, one or two drops of mercury.***
- The heating filaments (or electrodes for the gas discharge) are made of tungsten coated with an emissive material, so that enough electrons are emitted on heating.
- The glow-type starter is a voltage-operated device and consists of two bimetallic electrodes enclosed in a glass bulb filled with a mixture of hydrogen and helium. Normally, the contact between the bimetallic strips is open as shown in Figure



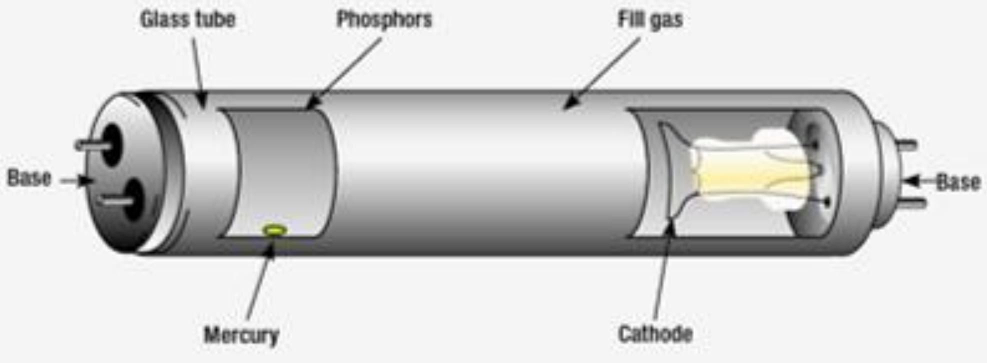


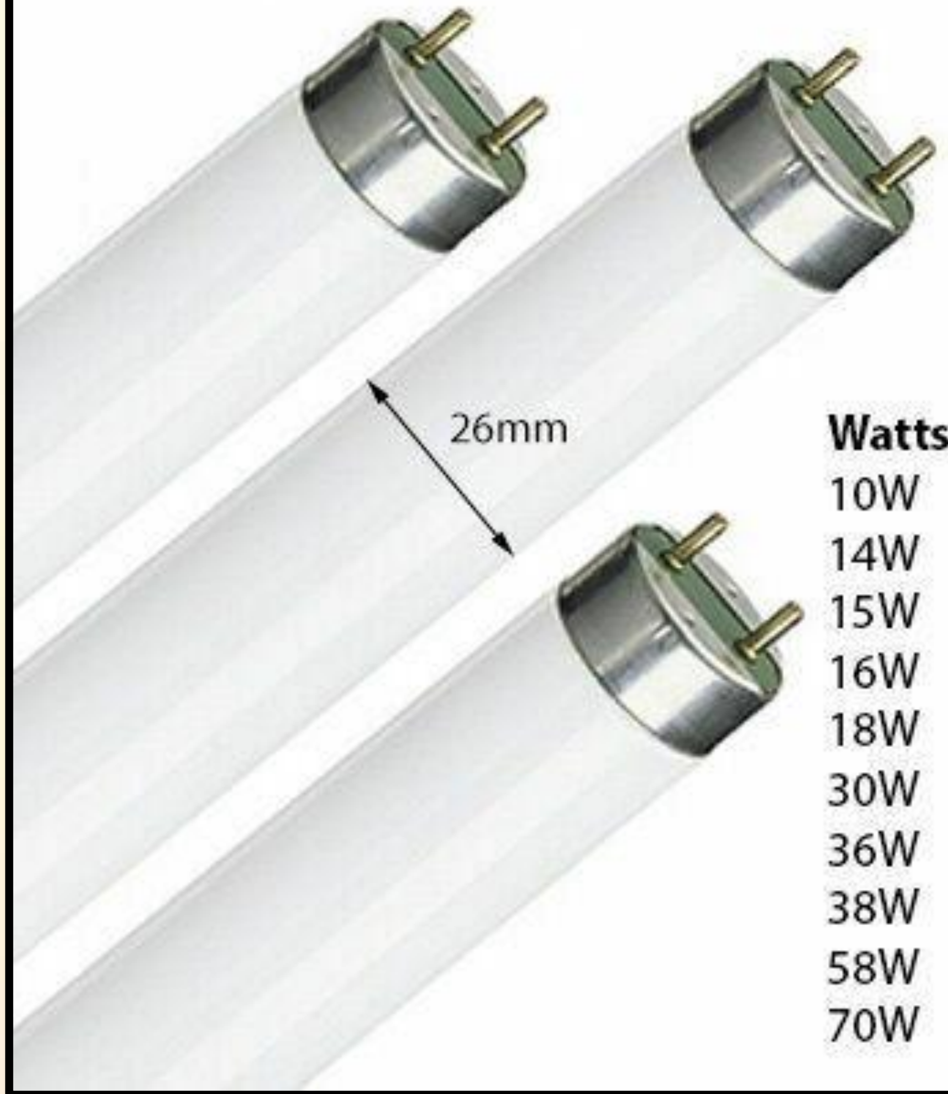
Figure 1: Typical construction of a linear fluorescent lamp

- When supply is switched ON, the full mains voltage appears across the two bimetallic electrodes which causes a glow discharge in the glow switch. Due to this discharge, a small amount of heat is produced which in turn causes the bimetallic strips to bend in such a way so as to make contact with each other.
- At this instant, an appreciable amount of current flows through the choke, electrodes, and strips, which raises the temperature of tube electrodes to ***incandescence***.
- After one or two seconds, the strips get cooled down and the contact is again opened. The opening of the contact in series with the choke provides a momentary high voltage across the electrodes which is sufficient to start the discharge.
- *The starter cannot glow after the tube has started operating because the potential available across the strips does not remain too high to cause glow discharge. During operating condition, the starter does not consume any power, even if it is removed, it does not affected the working of the lamp.*

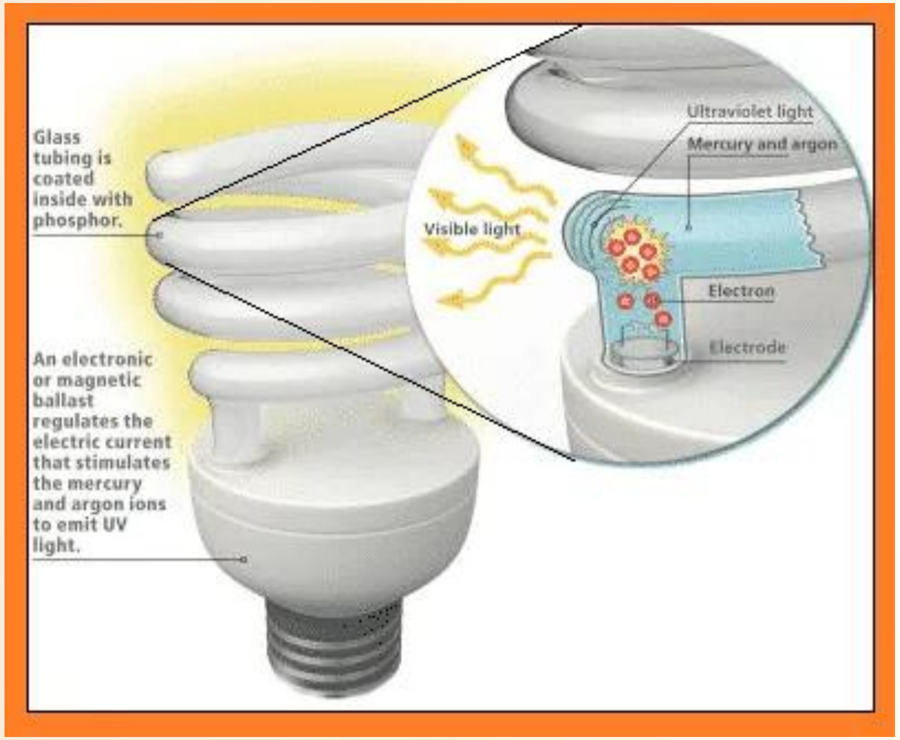
Characteristics:

- It has an average life of 12000 working hours.
- Lamp efficacy of 38 – 104 lumens per watt.
- Wide range of colour options available.
- Low operating temperature.
- Wide range of applications in domestic, commercial and industrial premises.

GE OSRAM SYLVANIA PHILIPS

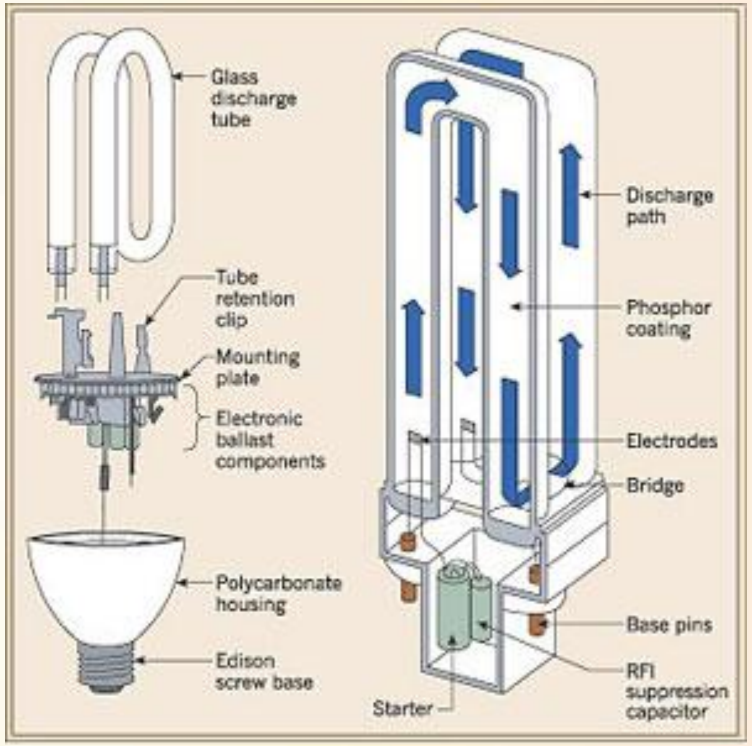


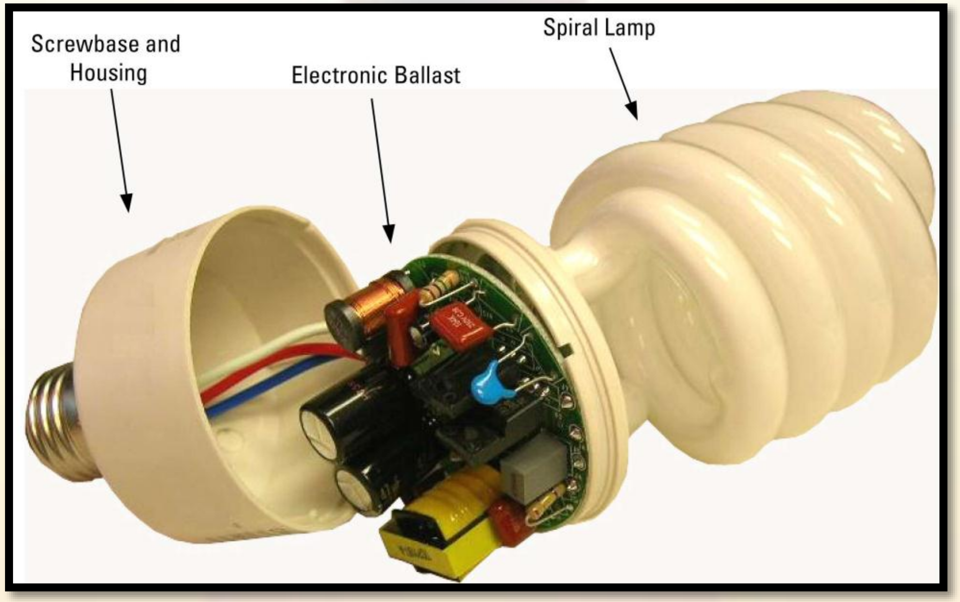
Watts	Length
10W	470mm / 18.5″
14W	360mm / 15″
15W	438mm / 18″
16W	720mm / 29″
18W	609mm / 2 ft
30W	914mm / 3 ft
36W	1219mm / 4 ft
38W	1066mm / 3½ ft
58W	1524mm / 5 ft
70W	1828mm / 6 ft



COMPACT FLUORESCENT LAMP (CFL)

The compact fluorescent lamps (CFL) are becoming more and more popular nowadays because of their low-power consumption, low running cost, longer life, attractive look, soothing light, and low maintenance





- **A CFL uses vacuum pipe which is principle wise same to the strip lamps (commonly known as Tube light) . Tube has two electrodes on both ends which is treated with Barium. Cathode is having a temperature of about 900° C and generates a beam of electrons which is further accelerated by potential difference between electrodes.**
- These accelerated electrons strike Mercury and Argon atoms which in turn results in the arise of a low temperature plasma. This process initiates the radiation of Mercury in Ultraviolet form.
- **The Ultraviolet light that excites a fluorescent coating (called phosphor) on the inside of the tube, which then emits visible light.**

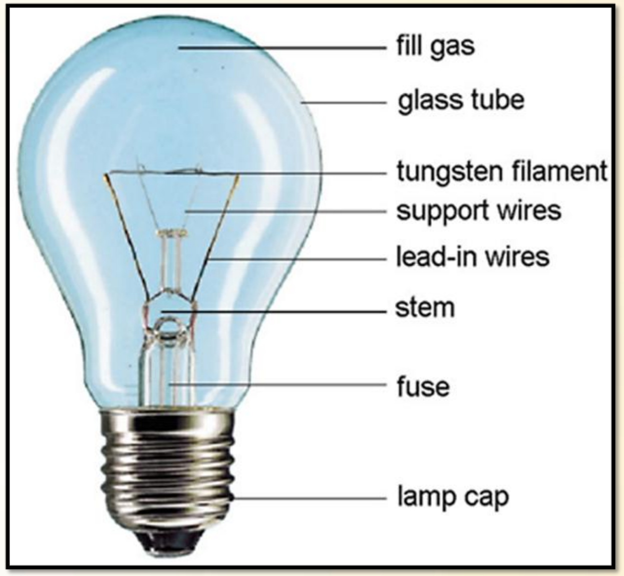
Advantages:

- **Low-energy consumption.**
- **Low maintenance costs.**
- **It provides instant glow.**
- **It provides light without heating the surroundings.**
- **Excellent colour rendering properties. Hence, all colours look natural and desired ambience can be created in various interiors.**
- **Low operational costs: The power consumption of CFL is 80 per cent less than incandescent lamps.**
- **The compact size opened up possibilities for exciting and aesthetically appealing new luminaries.**
- **Average life of compact fluorescent lamp is 8,000 working hour.**

COMPARISON BETWEEN TUNGSTEN FILAMENT LAMPS AND FLUORESCENT TUBES

Comparison between Tungsten Filament Lamps and Fluorescent Tubes

S.No.	Particulars	Tungsten Filament Lamp	Fluorescent Tubes
1.	Effect of voltage fluctuation	Voltage fluctuation has comparatively more effect on the light output.	Voltage fluctuation has comparatively more effect on the light output.
2.	Effect of voltage on luminous efficiency	Luminous efficiency per watt increases with the increase in applied voltage.	The luminous efficiency increases with the increase in applied voltage and length of the tube.
3.	Effect of coloured light on luminous efficiency	Luminous efficiency of coloured filament lamps is low because coloured glass absorbs light.	Their efficiency is high because coloured light is produced due to fluorescence.
4.	Colour distortion	It does not give light close to natural light, so colour rendering is defective.	It gives light close to neutral light and hence coloured objects can be properly seen.
5.	Heat Radiant	Heat radiations are also present due to higher working temperature.	Heat radiations are negligible due to low operating temperature.
6.	Brightness	It brightness is more.	Its brightness is less.
7.	Working life	The average life of filament lamp is about 1,000 working hours, but it varies with the working voltage. A slight increase in voltage may damage the lamp.	Its average life is about 6,000 working hours. Life of fluorescent tube is not affected so much by variation in operating voltage but it depends upon the frequency of starting.
8.	Initial cost	Initial cost per lamp is quite low.	Initial cost per tube is more.
9.	Wiring cost	For the same light output, a large number of lamps are required which results in a higher wiring cost.	For the same light output, smaller number of tubes is required and hence wiring cost is low.
10.	Effect of age on the output of the lamp	The output of the lamp reduces with the passage of time.	The output reduces more rapidly as compared to filament lamp.
11.	Maintenance cost	Overall maintenance cost is low.	Overall maintenance cost is low.

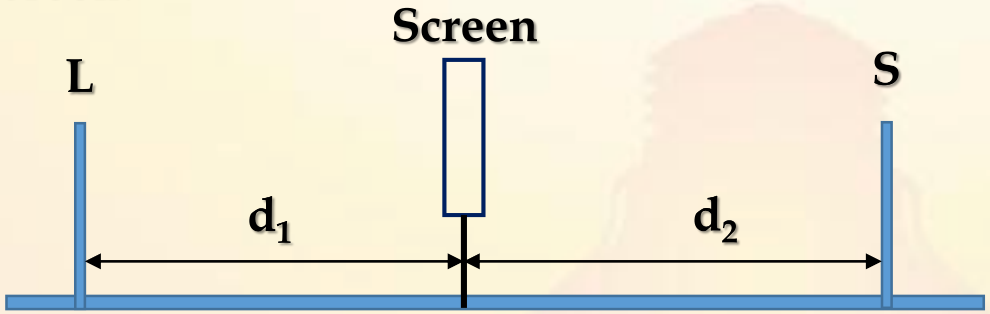


Ques: Describe the construction, operating principle, characteristic and advantages of LEDs.

PHOTOMETRY

- **Illumination at a point depends upon the luminous intensity or candela of the light source in that direction.**
- **The function of photometers is to measure the candela of a light source. Photometers are of two types:**
  - **Bench Photometers**
  - **Radial or Polar Curve Photometers**

- **In bench photometers, C.P. of a lamp is compared with that of a lamp whose C.P. is known by producing illumination levels. Two lamps are mounted on the bench with a screen in between them. One lamp S may be of known candle power and the other lamp L whose candle power is to be determined. The screen is moved in between the two lamps and its position adjusted. The illumination is the same on both sides of the screen.**



Applying Inverse Square Law

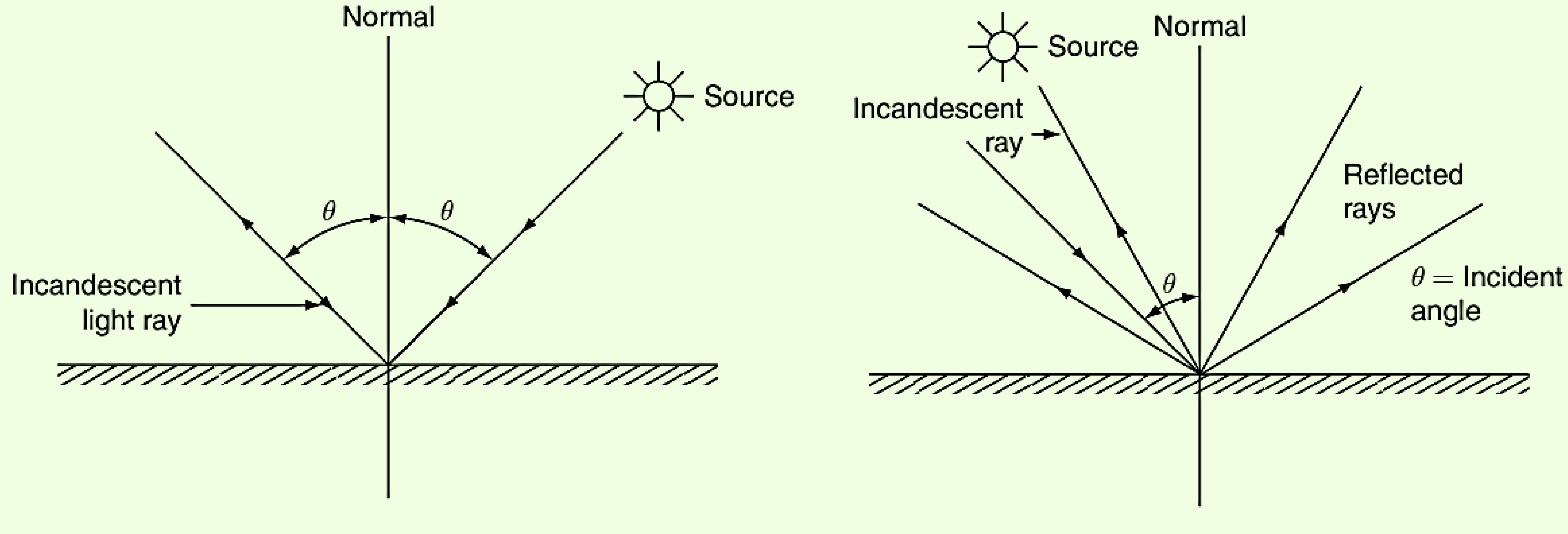
$$\frac{\text{candle power of L}}{\text{candle power of S}} = \frac{d_2^2}{d_1^2}$$

The screen is called the photometer head. The photometer bench is graduated so that distances d_1 and d_2 may be measured

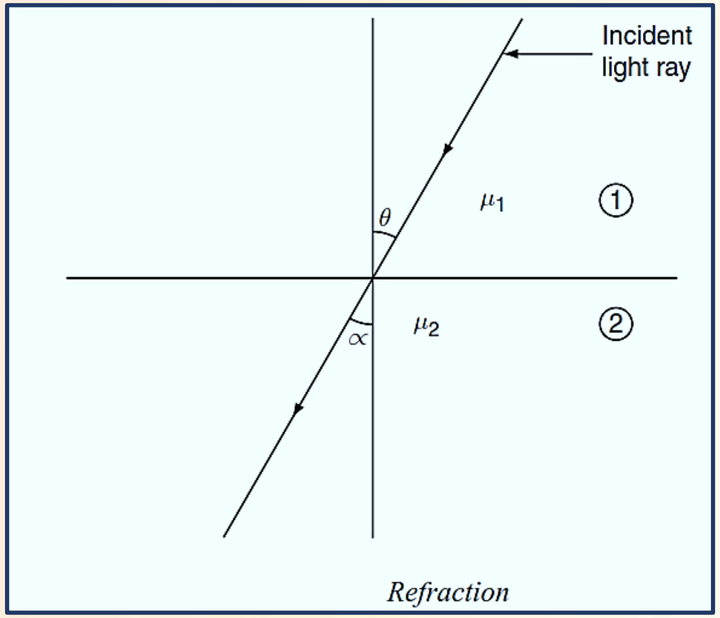
BASIC PRINCIPLES OF LIGHT CONTROL

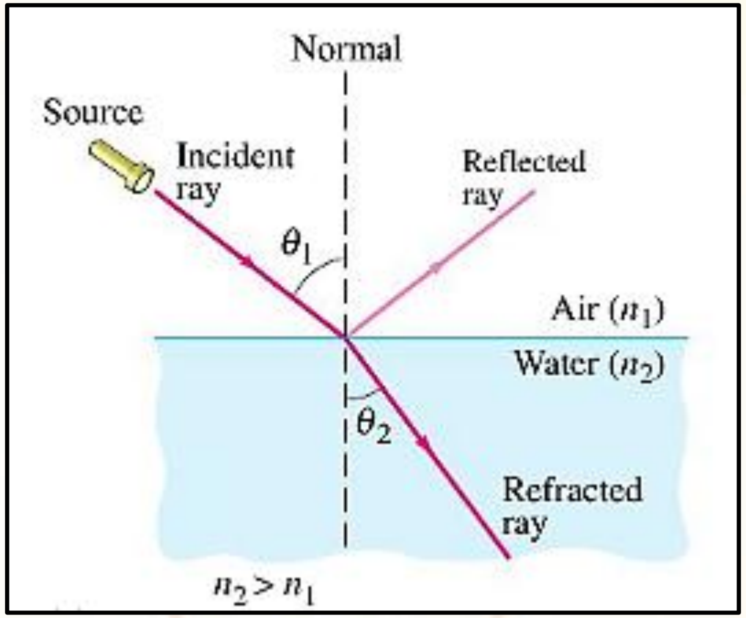
- When light strikes the surface of an object, based on the properties of that surface, some portion of the light is reflected, some portion is transmitted through the medium of the surface, and the remaining is absorbed. ***The ratio of reflected light energy to the incident light energy is known as Reflection Factor.***
- The method of light control is used to change the direction of light through large angle. There are four light control methods. They are:

   1. ***Reflection,***
   2. ***Refraction, and***
   3. ***Absorption.***



Specular reflection *Diffuse reflection*





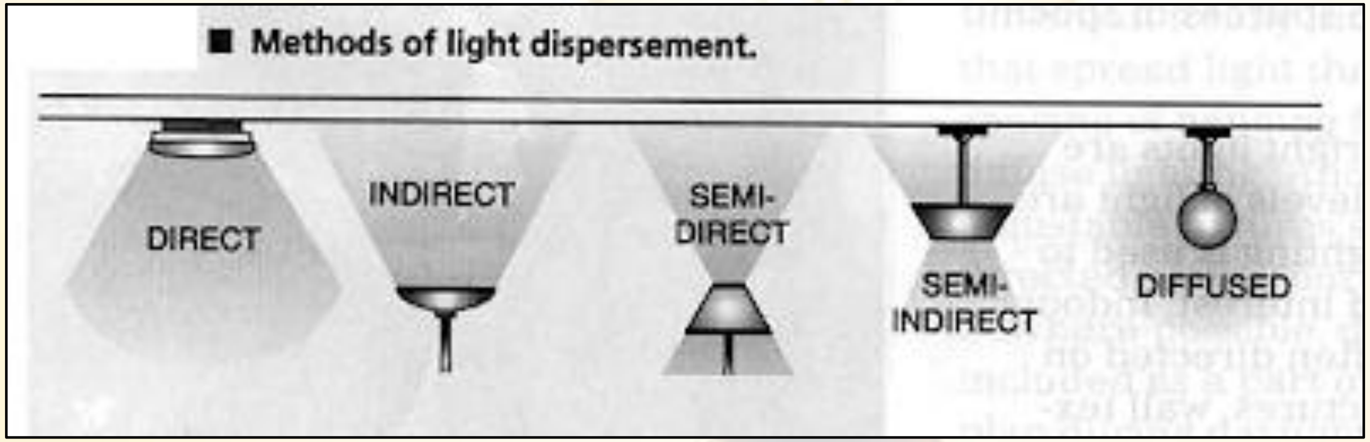
- When a light wave passes from a less refractive medium (such as air) to a more refractive medium (such as water), the velocity of the wave decreases. Conversely, when light passes from a more refractive medium (water) to a less refractive medium (air), the velocity of the wave increases.
- The normal is defined as a line perpendicular to the boundary, or interface, between two substances. If a light wave passes from a medium of lower refractive index to one of higher refractive index, it is bent toward the normal.
- If the wave travels from a medium of higher refractive index to a medium of lower refractive index, it is bent away from the normal. Snell's Law describes the relationship between the angles of the two light waves and the indices of refraction of the two materials

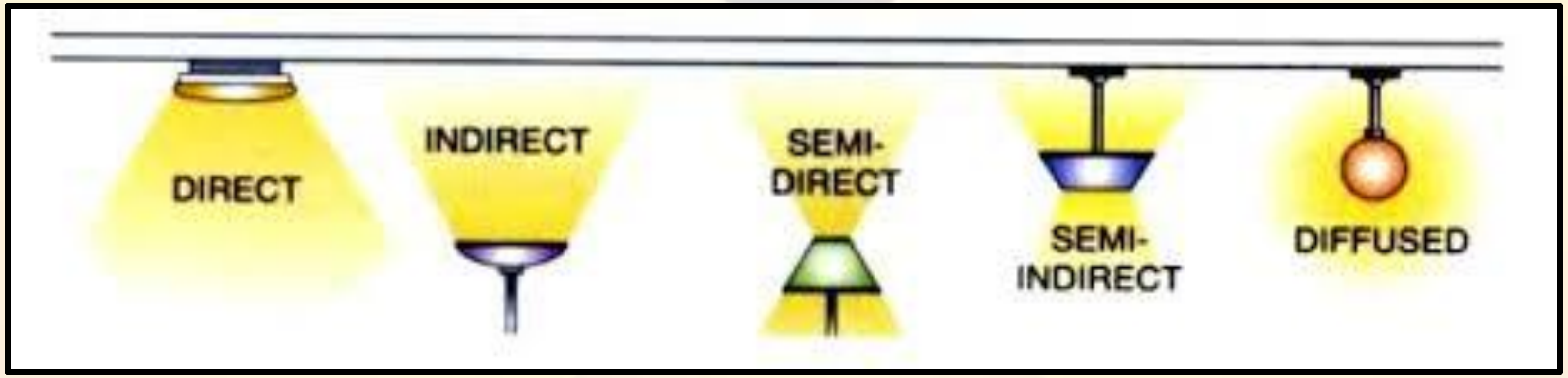
DESIGN OF LIGHTING SCHEME

- Lighting systems are conventionally divided into five categories according to how they control or distribute light:

  (1) Direct, (2) Indirect, (3) Semi-Direct (4) Semi- Indirect, and (5) General - Diffuse.

  They differ principally in the proportion of light directed upward or downward.

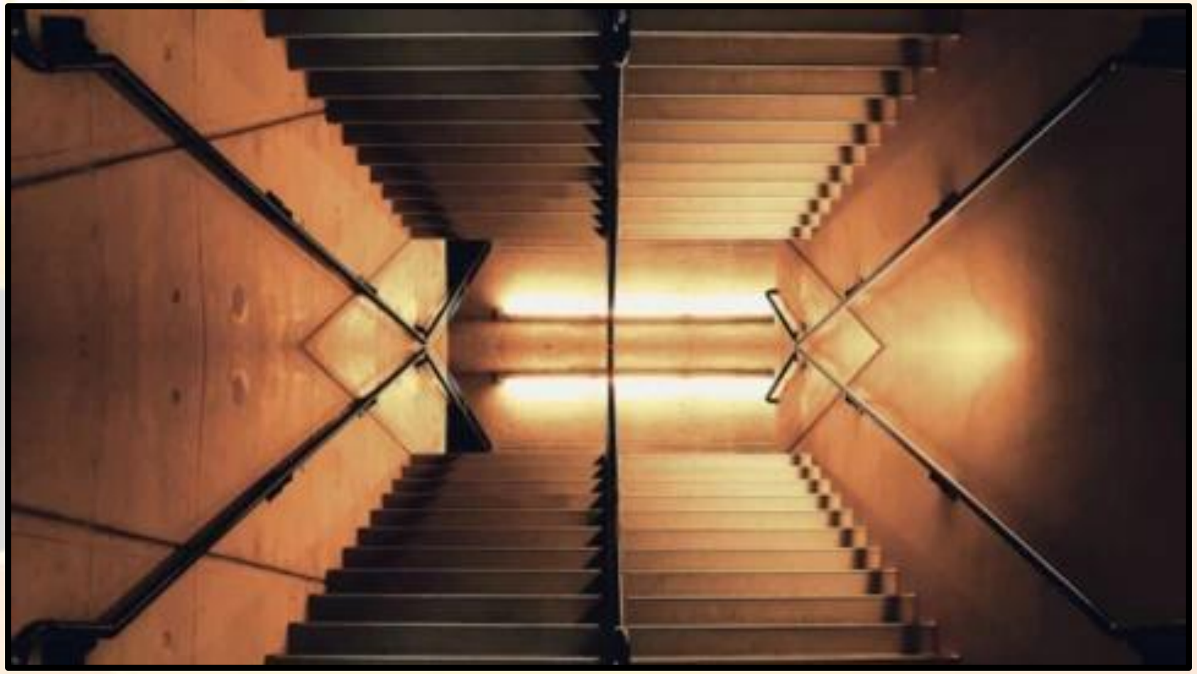




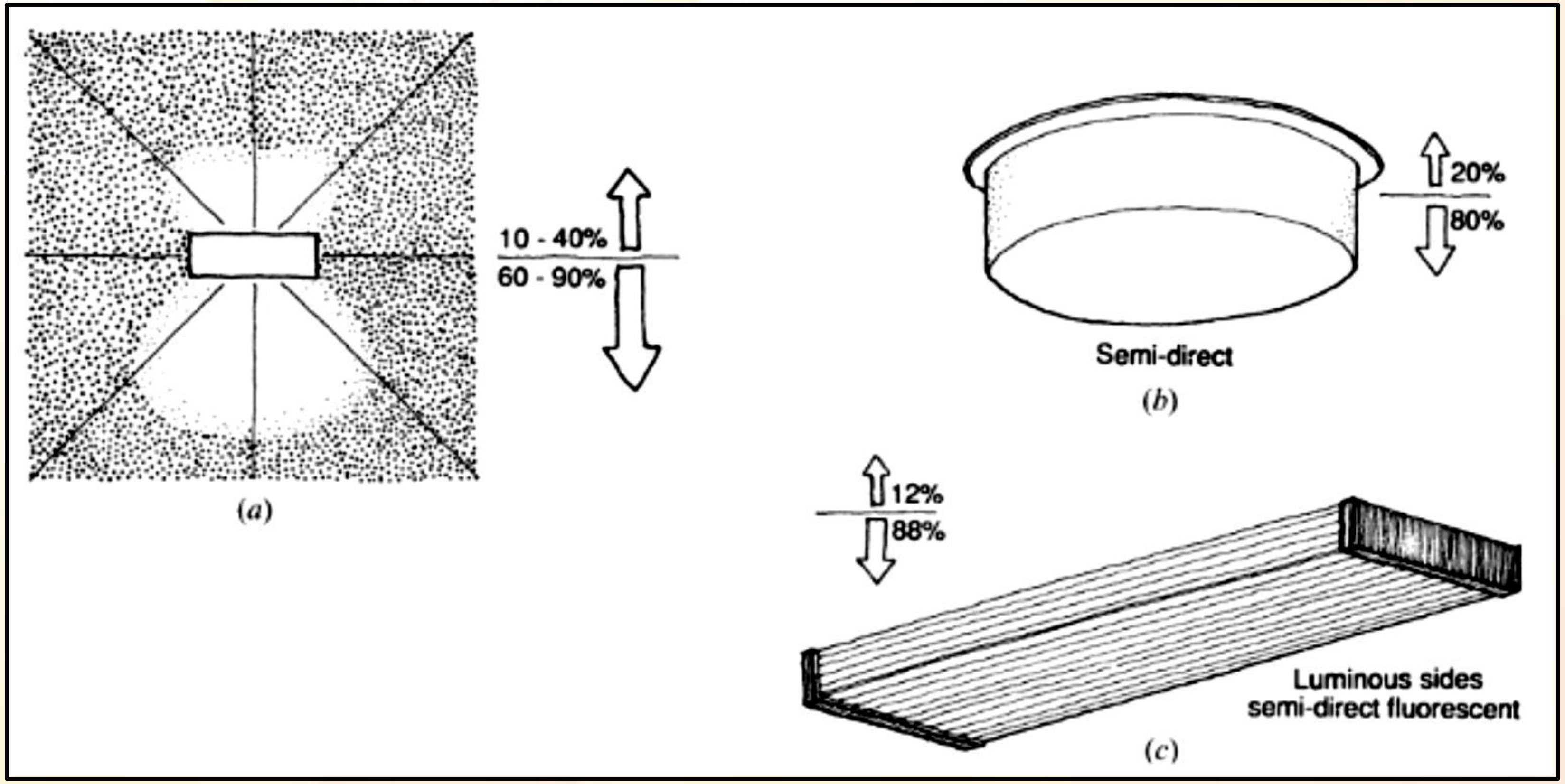
❑ DIRECT LIGHTING SYSTEM:

These systems are inherently efficient. Since basically all light is directed downward, illumination of the ceiling is entirely due to light reflected from the floor and room furnishings. Almost 90 to 95 per cent 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 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.

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

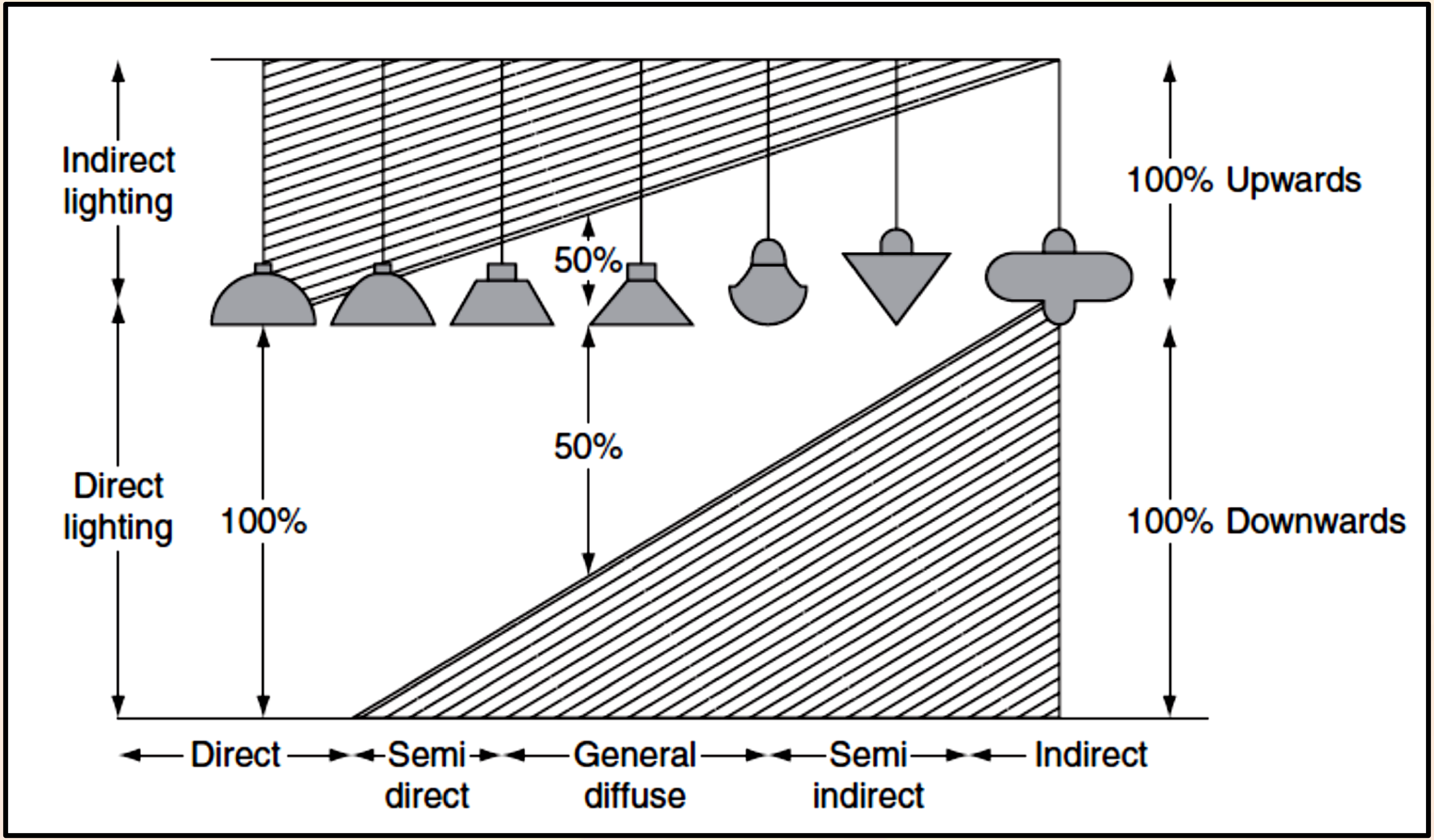


SEMI - DIRECT LIGHTING: This is also an efficient system of lighting and chances of glare are also reduced. With this type of lighting system, 60 to 90% of the luminaire output is directed downward, and the remaining upward component serves to illuminate the ceiling. This also provides a uniform distribution of light and is best suited for rooms with high ceilings.



SEMI - INDIRECT LIGHTING: In this system, about 60 to 90 per cent 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.

GENERAL DIFFUSE LIGHTING: This system employs such type of luminaries, shades, and reflectors which give equal illumination in all directions. / Lighting from luminaires that emit an equal distribution of light upward and downward.


Indirect lighting
Direct lighting
100%
50%
50%
100% Upwards
100% Downwards
Direct
Semi direct
General diffuse
Semi indirect
Indirect

REQUIREMENTS OF A GOOD LIGHTING SCHEME

1. **It should provide adequate illumination.**
2. **It should provide uniformly distributed light all over the working plane.**
3. **It should avoid glare and hard shadows as far as possible.**
4. **It should provide light of suitable colour.**
5. **It should provide luminaries suspended at suitable height so that these may not come in line with the vision.**

- ***Transmittance, luminous transmittance, transmission factor, or coefficient of transmission:*** **The ratio of the light transmitted through a material to the total incident light falling on it**. Some materials selectively absorb certain colors more than others. Like reflection, light transmission may be either direct, diffuse, or a combination of the two.

METHODS OF LIGHTING CALCULATIONS

Lighting calculations means to find out a suitable number of lamps to be installed a particular place for proper illumination. There are three common methods employed for lighting calculations:

- **Watts per square metre method:** This is an approximate method and **generally employed for rough estimates**. Here, an allowance of watts per square metre of an area to be illuminated is made on the assumption of overall efficiency of the system and degree of illumination.
- **Light flux method:** This method is applicable to those sources of light which produce an approximately uniform illumination over the working plane. In this case, first, the size of lamps is selected and their lumen output is calculated. Then, lumens reaching at the working plane are determined by taking into account the depreciation and utilization factor, considering the following relations:

Lumens received on the working plane = (No. of lamps × wattage of each lamp × efficiency of each lamp in Lumens/watt × coefficient of utilization)/depreciation factor.

This method is usually employed for determining the lighting schemes of domestic and commercial buildings.

- **Point to point or inverse square law method:** This is applied where illumination at a particular point is required and the candle power of the source is known. If the polar curve of a source or a lamp is known, the candle power in any particular direction can be calculated. Then, by applying inverse square law, the illumination at any point can be found out. If two or more lamps illuminate the same working plane, the illumination due to each can be added to get total illumination. This system is employed in street lighting and yard lighting.

FLOOD LIGHTING

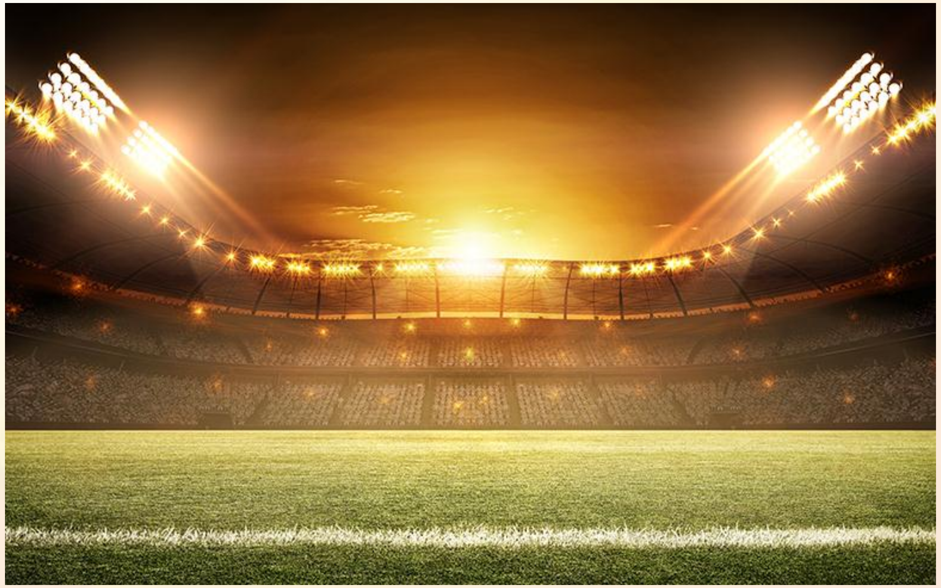
- Floodlighting means flooding of large surface areas with light from powerful projectors.
- A special reflector and housing is employed in floodlighting in order to concentrate the light emitted from the lamp into a relatively narrow beam, which is known as floodlight projector.
- This projector consists of a reflecting surface that may be a silvered glass or chromium plate or stainless steel. The efficiency of silvered glass and polished metal are 85–90% and 70%, respectively.
- Usually metal reflectors are robust; therefore, they can be preferred. An important application of illumination engineering is the floodlighting of large and open areas.
- It is necessary to employ floodlighting to serve one or more of the following purposes:
  - **Esthetic [pleasant or artistic appearance of something] Floodlighting:**

    They are used for enhancing the beauty of monuments, ancient buildings, and churches by floodlighting.
  - **Industrial and Commercial Floodlighting:**

    They are used for illuminating sports arenas, railway yards, quarries, car parks, etc.
  - **Advertising:**

    They are used for illuminating showcases and advertisement boards and for the decoration of houses, etc.



FACTORY LIGHTING

- Industry or factory lighting must satisfy the following aspects:
  1. The quality of work is to be improved.
  2. Accidents must be reduced.
  3. The productivity of labor should be increased.
- The above requirements can be met by the factory lighting only when the lighting scheme provides:
  a. Adequate illumination on the working plane.
  b. Minimum glare.
  c. Clean and effective source fitting.
  d. Uniform distribution of light over the working plane.
- The lamps used for factory lighting are fitted with specially designed reflectors and they can be easily cleaned.

STREET LIGHTING

- Street lighting not only requires for shopping centers, promenades, etc. but also necessary for the following.
  1. In order to make the street more attractive, so that obstructions on the road clearly visible to the drivers of vehicles.
  2. To increase the community value of the street.
  3. To clear the traffic easily in order to promote safety and convenience.
- The basic principles employed for the street lighting are given below.
  a. Diffusion principle.
  b. The specular reflection principle.

QUES: **A workshop measures 10 m × 20 m and is lighted by 15 lamps which are each rated at 200 watts and have an efficiency of 15 lumen/watt. Assuming a depreciation factor of 1.5 and coefficient of utilization as 0.5. Find the illumination on the working plane.**

SOLUTION:

Area of the workshop 'A' = $10 \times 20 = 200$ m^2.

No. of lamps = 15

Efficiency = 15 lumens/watt

Depreciation factor = 1.5

Utilization factor = 0.5

Using the relation,

$$\text{Lumens reaching the working plane} = \frac{\text{No. of lamps} \times \text{wattage} \times \text{eff.} \times \text{UF}}{\text{DF}}$$

$$\therefore \quad \phi = \frac{15 \times 200 \times 15 \times 0.5}{1.5} = 15{,}000 \text{ lumens}$$

$$\therefore \quad \text{Illumination, } E = \frac{\phi}{A} = \frac{15{,}000}{200} = 75 \text{ lux}$$

QUES: **Find the total saving in electrical load and percentage increases in illumination if instead of using twelve 150 *W tungsten filament lamps, we use twelve 80 W fluorescent tubes. It may be assumed* that (i) there is a choke loss of 25% of rated lamp wattage, (ii) average luminous efficiency throughout life for each lamp is 15 lumens/watt and for each tube 40 lm/W, and (iii) coefficient of utilization remains the same in both cases.**

SOLUTION:

Total power consumption of filament lamps $= 12 \times 150 = 1{,}800$ W

$$\text{Total power consumption of fluorescent tubes} = 12 \times \left[80 + \frac{25}{100} \times 80\right] = 1{,}200 \text{ W}$$

Saving in electrical load $= 1{,}800 - 1{,}200 = 600$ W

Lumen output of filament lamps $= 12 \times 150 \times 15 = 27{,}000$

Lumen output of fluorescent tubes $= 12 \times 80 \times 40 = 38{,}400$

Increase in lumen output $= 38{,}400 - 27{,}000 = 11{,}400$

$$\%\text{ increase in illumination} = \frac{11{,}400}{27{,}000} \times 100 = 42.22\%$$

QUES: A drawing hall in an engineering college is to be provided with a lighting installation. The hall is 30 m × 20 m × 8 m (height). The mounting height is 5 m and required level of illumination is 144 lux. Using metal filament lamps, estimate the size and number of single lamp luminaries and also draw their spacing layout. Assume the following:

- Utilization coefficient = 0.6
- Maintenance factor = 0.75
- Space–height ratio = 1.0
- Lumens/watt for 300 W lamp = 13
- Lumens/watt for 500 W lamp = 16

SOLUTION:

Area to be illuminated = $30 \times 20 = 600\ \text{m}^2$

Total lumens required = $600 \times 144 = 86{,}400$

$$\text{Gross lumens required} = \frac{86{,}400}{\text{Utilization factor} \times \text{Maintenance factor}}$$

$$= \frac{86{,}400}{0.6 \times 0.75} = 1{,}92{,}000$$

Lumen output of 500 W lamp = $500 \times 16 = 8{,}000$

$$\text{No. of lamps required} = \frac{1{,}92{,}000}{8{,}000} = 24$$

Space–height ratio = 1

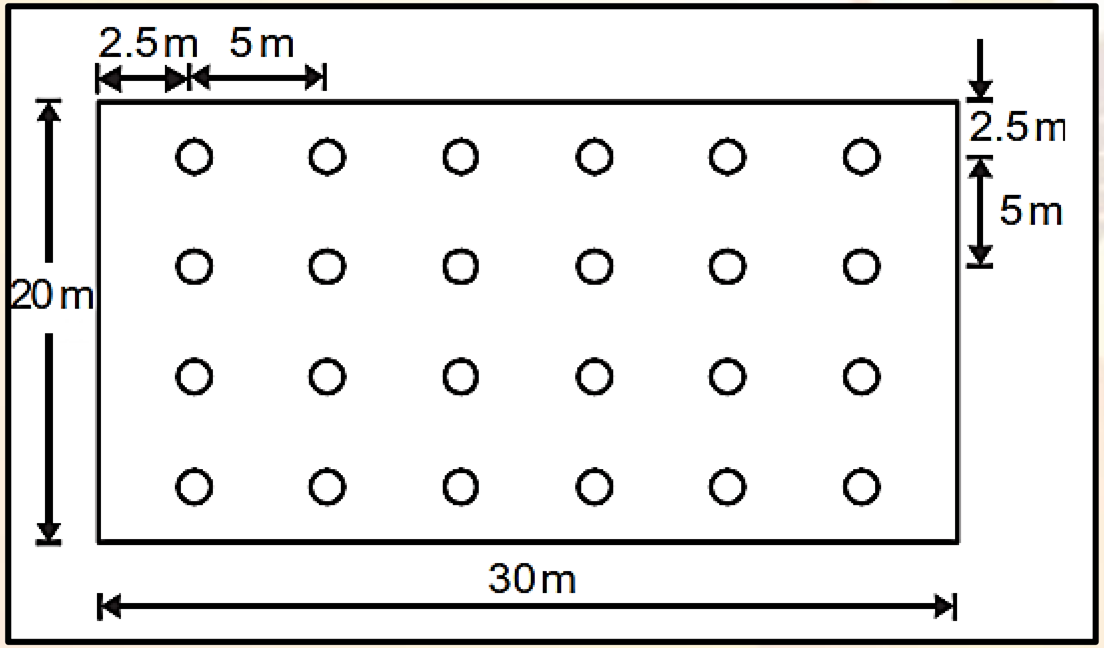
Mounting height = 5 m

Space between the lamps = Space–height ratio × height

$$= 1 \times 5 = 5 \text{ m}$$

$$\text{No. of lamps placed lengthwise} = \frac{30}{5} = 6$$

$$\text{No. of lamps placed breadthwise} = \frac{20}{5} = 4$$



QUES: **The front of a building 50 m × 16 m is illuminated by sixteen 1,000 watt lamps arranged so that uniform illumination on the surface is obtained. Assuming a luminous efficiency of 17.4 lumens/ watt, depreciation factor 1.3, utilization factor 0.4, and waste light factor 1.2, determine the illumination on the surface.**

SOLUTION:

Surface area to be illuminated by flood lights = $50 \times 16 = 800$ m^2

Total lumens output of 16 lamps = $1{,}000 \times 16 \times 17.4$

that is, Gross lumens = 2,78,400 lumens

$$\text{Total lumens reaching the surface} = \frac{\text{Gross lumens} \times \text{UF}}{\text{DF} \times \text{Waste light factor}}$$

$$= \frac{2,78,400 \times 0.4}{1.3 \times 1.2} = 71,400 \text{ lumens}$$

$$\text{Illumination on the surface, } E = \frac{71,400}{800} = 89 \text{ lux}$$

QUES: The illumination in a drawing office 30 m × 10 m is the have a value of 250 lux and is to be provided by a number of 300 watts filament lamps. If the coefficient of utilization is 0.4 and the depreciation factor 0.9, determine the number of lamps required. The luminous efficiency of each lamp is 14 lumen per watt. (Ans. 50)

QUES: The illumination in a drawing hall measuring 30 m × 10 m is to have an average lighting of 300 lux and is to be provided by filament lamps. If the coefficient of utilization is 0.4 and depreciation factor 0.9, calculate the number of lamps required. Design a suitable lighting scheme and draw a sketch showing the relative position of lamps. Given luminous efficiency for 100-W lamp = 13.4; 200-W lamp = 14.4; 300-W lamp = 16.0

(Ans. 52 lamps of 300 W each)

QUES: A foundry shop 80 m × 20 m with a ceiling height of eight metre is to be illuminated by mercury vapour lamps, the desired illumination being 100 lux. Design the lighting installation giving the number, size, location, and mounting height. The lamp sizes available are 80 W, 125 W , and 400W, and the efficiency being 40 lumens/watt. Take coefficient of utilization as 0.5 and depreciation factor as 1.43. Show the arrangement on plan.

(Ans. 100 lamps of 125 watt in 5 rows of 20 lamps each; mounting height 4 m)