Chapter 7

ILLUMINATION

Engineering Practices

ENPRA101A

Topic 7-1

BASIC CONCEPTS

LIGHT

Light is Electromagnetic energy and as such obeys all the laws relating to this energy: Some of the properties of light include:

- Light travels in straight lines from the source to the object
- Light travels at the speed of light within the transmitting medium (3 x 10^5 km/sec through a vacuum)
- Light may be deflected and bent/distorted by another magnetic field
- Light may be reflected, refracted or absorbed by various transmission mediums and surfaces

LIGHT

- Light may be defined as Electromagnetic Radiation that stimulates the eye to sight.
- It forms a very narrow band of frequencies within the Electromagnetic Spectrum, bordered by Infra-red and Ultra-violet radiation (See **Fig PF-7-1-1**).
- Visible light covers a frequency range from around 5 x 10^{14} Hz for red light to 7.5 x 10^{14} Hz for violet light.
- In general, visible light colours are described in terms of the wavelength of a particular colour or hue.

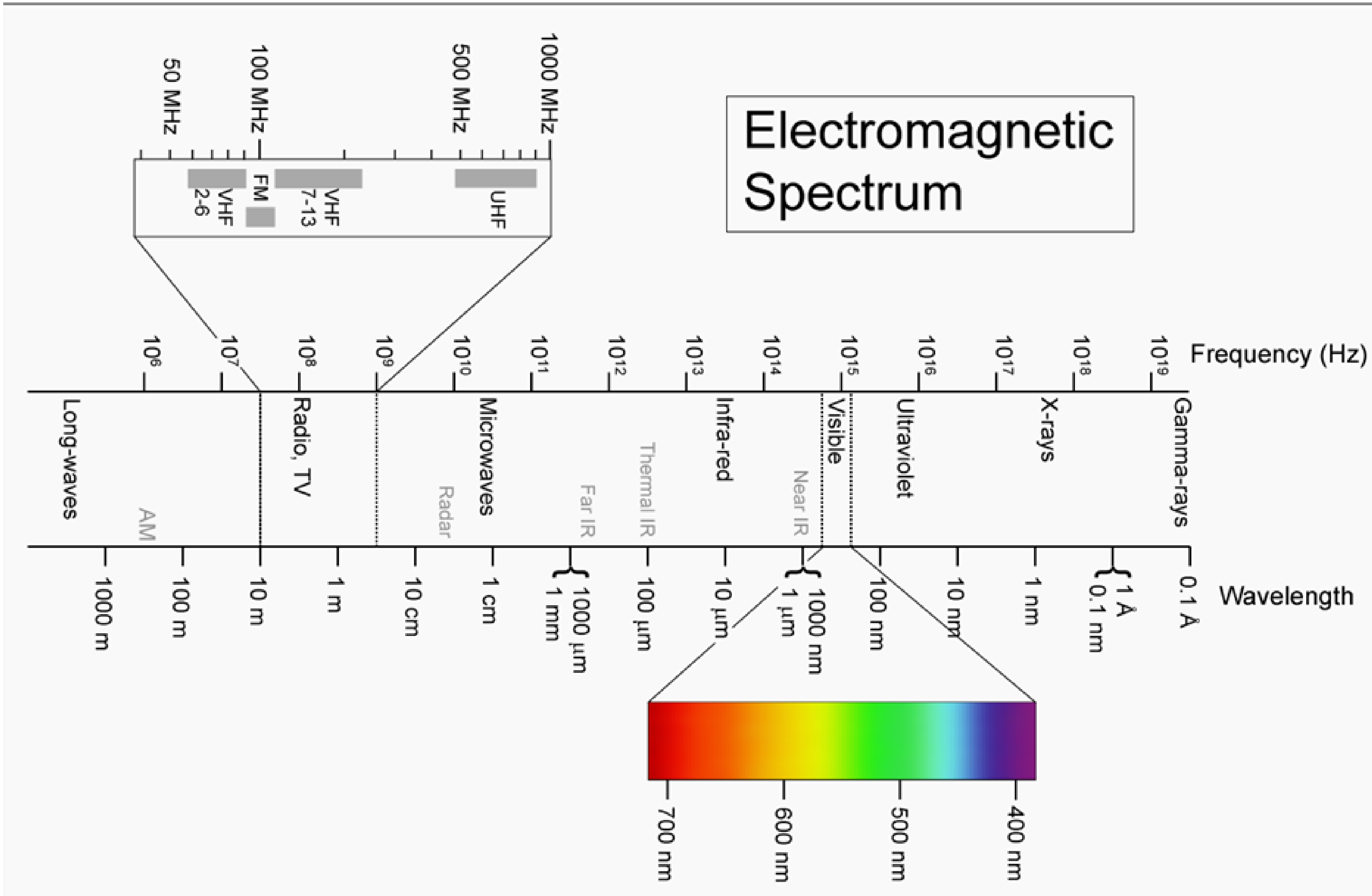

Fig. PF-7-1-1 Electromagnetic Spectrum

LIGHT

- Wavelength is measured in metres and is the length of one complete cycle and is found by dividing the speed of light by the frequency of that particular colour.

$$f = \frac{c}{\lambda}$$

PE-7-1-1

Where:
Speed of Light $c = 3 \times 10^8$ m/s
f = frequency Hz
λ = wavelength m

LIGHT

- The visible light spectrum consists of seven basic colours:
  - Violet – wavelength about 400 nm
  - Indigo – wavelength about 445 nm
  - Blue – wavelength about 475 nm
  - Green – wavelength about 510 nm
  - Yellow – wavelength about 570 nm
  - Orange – wavelength about 590 nm
  - Red – wavelength about 650 nm

LIGHT

- The eye has 3 types of receptors for colour, one each for blue, green and red – the primary colours
- All other colors are a result of a mixture of these colors.
- Photopic vision is vision under well-lit conditions, which provides for colour perception, and which functions primarily due to cone cells in the eye.
- Scotopic vision is monochromatic vision in very low light, which functions primarily due to rod cells in the eye.

LIGHTING TERMS AND UNITS

Term	Unit	Abbreviation	Usual Symbol
Luminous Flux	lumen	lm	F
Illuminance	lux	lx	E
Luminous Intensity	candella	cd	I
Luminance	candela per square metre	Cd/m^2	L

LUMINOUS FLUX (Φ or F)

- Luminous Flux is a measurement of the total quantity of light produced by the source.
- It is the quantity of the energy of the light emitted per second in all directions.
- The unit of luminous flux is the **lumen (lm)**.
- The lumen is defined as the luminous flux of a uniform point light source that has a luminous intensity of 1 candela and is contained in one unit of spatial angle (1 steradian).

LUMINOUS FLUX (Φ or F)

- **Steradian:** the spatial angle that limits the surface area of the sphere equal to the square of the radius.
- This concept is shown in **Fig. PF-7-1-2** for a 1 m radius of the sphere. Since the area of the sphere is $4\pi r^2$ then the luminous flux of the point light source is 4π lumens.

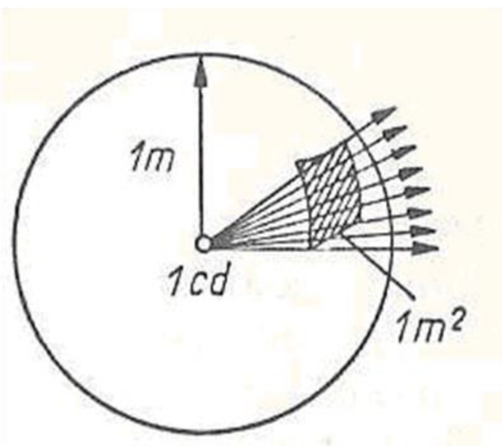

Fig. PF-7-1-2 Definition of the Steradian

LUMINOUS FLUX (Φ or F)

- The value of luminous flux is quoted by all lamp manufacturers for all of their lamps for initial use and after 100 hours of operation. Some examples of typical lumen output of some common lamps are:
  - 75W incandescent lamp: 900 lm
  - 39W fluorescent lamp: 3,500 lm
  - 250W high pressure sodium lamp 30,000 lm
  - 2000W metal halide lamp: 200,000 lm

LUMINOUS INTENSITY (I)

- Luminous intensity is the quantity of visible light that is emitted in unit time per unit solid angle.
- The unit for the quantity of light flowing from a source in any one second (the luminous flux) is called the **lumen**.
- The unit of luminous intensity is one lumen per Steradian, or one **candela,** i.e. a point source of light having a luminous intensity of 1cd will produce a total luminous flux of 1 lumen on a surface of $1m^2$ at a distance of 1m

LUMINOUS INTENSITY (I)

- **Fig PF-7-1-3** shows a point source of one lumen radiating into a solid angle of one Steradian defining a Luminous intensity of one candela

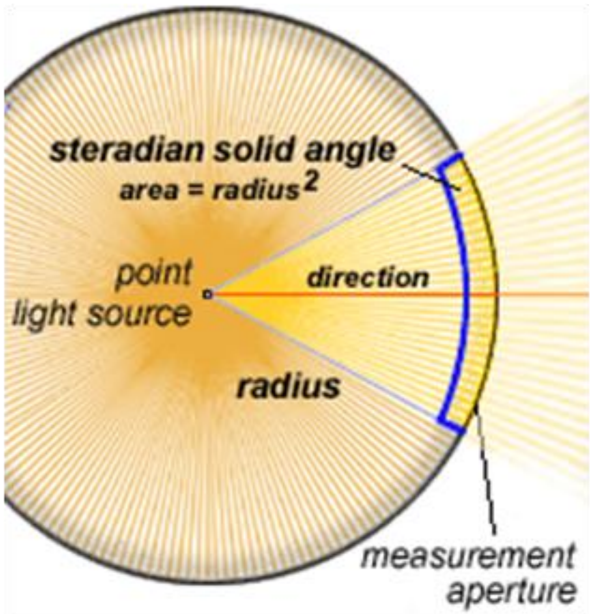

Fig. PF-7-1-3
Definition of Luminous Intensity

LUMINOUS INTENSITY (I)

- Some examples of Luminous intensity of light sources are:
  - 5W bicycle lamp without reflector: 2.5 cd
  - 5W bicycle lamp with reflector: 250 cd
  - 120W incandescent reflector lamp: 10 000 cd
  - Lighthouse: 2 000 000 cd

LUMINANCE (cd/m^2)

- Luminance is defined as the luminous intensity emitted per unit of area of a surface in a specific direction.
- The surface can itself be light-emitting (e.g. the surface of a lamp or the sun), or transmitting (e.g. reflecting surfaces like a road reflecting light from a streetlight and thus acting as a secondary light source).
- This is depicted diagrammatically in **Fig PF-7-1-4**

LUMINANCE (cd/m^2)

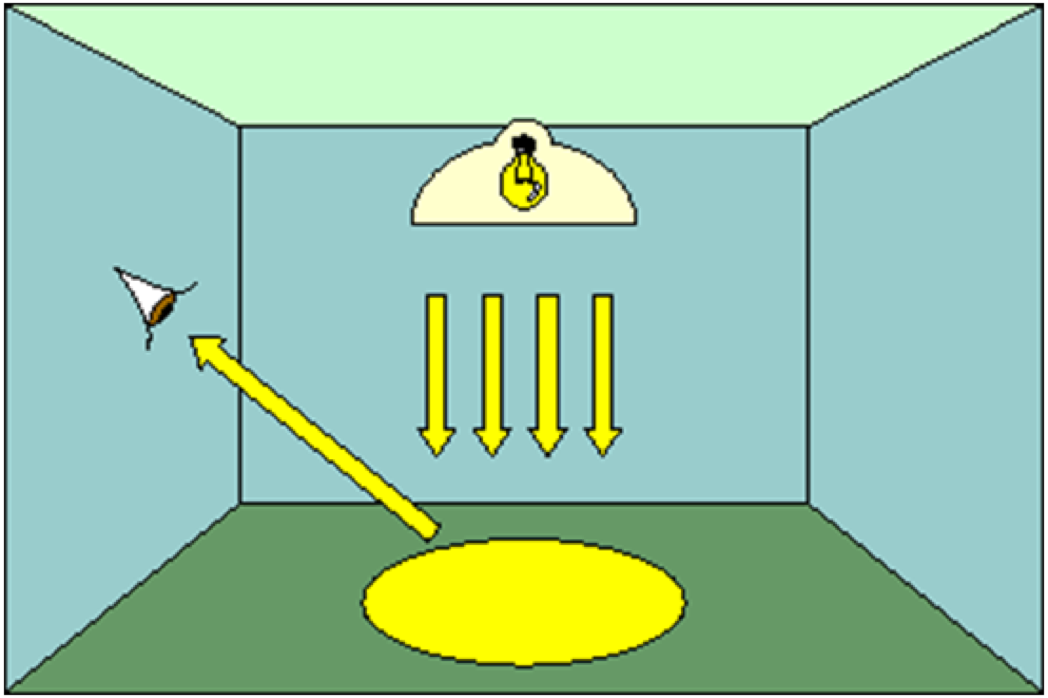

Fig. PF-7-1-4
Illustration of
Luminance

LUMINANCE (cd/m^2)

- Luminance is designated by the symbol L with units candela per square metre (cd/m^2).
- Some typical Luminance levels are:
  - Surface of the sun: 1,650,000,000 cd/m^2
  - Filament of a clear incandescent lamp: 7,000,000 cd/m^2
  - Fluorescent lamp: 5000-15,000 cd/m^2
  - Road surface under artificial lighting: 0.5-2 cd/m^2

ILLUMINANCE (Lx)

- This is a measure of the flux density on an illuminated surface.
- Illuminance is found by dividing the total luminous flux falling on a surface by the area of the surface being lit.
- The unit of illuminance unit is the Lux (lx). The symbol for illuminance is E.
- Some typical illuminance values are:
  - ➢ Summer, at noon, under a clear sky (equator): 100,000 lux
  - ➢ In the open under a heavily-overcast sky: 5,000 lux

ILLUMINANCE (Lx)

- Artificial light, in a well-lit office: 800 lux
- Full moon, on a clear night: 0.25 lux

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

PE-7-1-2

Where:

E - Illuminance in lux (lx)

F - Luminous Flux in lumens (lm)

- A - Area of surface being lit in square metres (m^2)

1680 part 2 for all applications.

OTHER ILLUMINATION DEFINITIONS

Illumination

- The term generally used in place of 'illuminance'.

Luminous Efficacy

- Luminous Efficacy is the ratio of the luminous flux to the electrical power input to the source.

$$\eta = \frac{F}{P}$$

PE-7-1-3

Where:

η - Luminous Efficacy in lm/W

F - Luminous Flux in lm

P - Input power in watts (W)

OTHER ILLUMINATION DEFINITIONS

Working (or Reference) Plane

- This is the horizontal (eg. Floor, bench/table height), vertical (e.g.. Wall) or inclined surface (e.g.. Ramp) which contains the visual task.

Task Area

- This is the specific area to be illuminated, e.g.. Floor/desk/wall. It may or may not be the same as the working plane.

OTHER ILLUMINATION DEFINITIONS

Visual Task

- This is the object/task/surface which is to be illuminated, eg paper/drawing, machine etc.

Reflection

- Light that strikes a surface is called **incident** light. The light that leaves the surface is called the **reflected** light . The **normal** is the line that is drawn at right angles to the surface at the point where the light ray is reflected.

OTHER ILLUMINATION DEFINITIONS

Reflection (Cont'd)

- Reflection, the most common form of controlling light, occurs when light rays impact and are then reflected from a surface. The types of reflection include:
  - Specular
  - Diffuse
  - Spread

OTHER ILLUMINATION DEFINITIONS

Reflection (Cont'd)

- **Specular** reflection is when light is reflected from a highly polished surface producing a consistent angle.
- **Diffuse** reflection is when light is reflected from a rough surface, producing a variety of angles, typically used to minimize glare, hot spots and shadows.
- **Spread** reflection is when light is reflected into a cone of light rays from surfaces such as corrugated or etched metal, plastic or glass.

OTHER ILLUMINATION DEFINITIONS

Reflection (Cont'd)

- The concept of reflection is shown in **Fig. PF-7-1-5** and the different types of reflection are illustrated below in **Fig. PF-7-1-6**

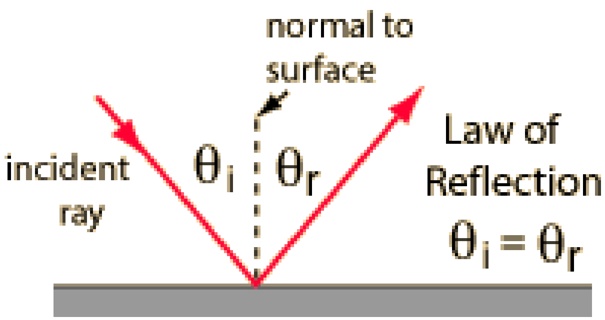

Fig. PF-7-1-5 Reflection

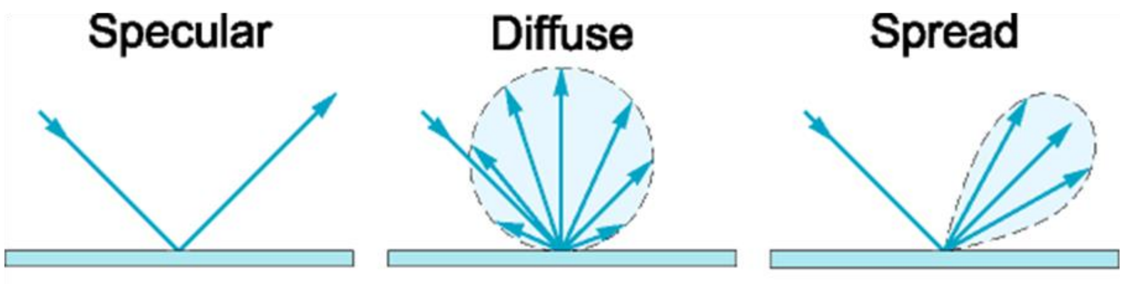

Fig. PF-7-1-6 Specular, Diffuse, and Spread Reflection from a Surface.

OTHER ILLUMINATION DEFINITIONS

Refraction

- Refraction is the "bending" of light at the interface of two materials of different refractive indices.
- Refraction of light is accompanied by a change of speed and wavelength.
- The denser the medium the slower the light travels.
- If the light enters the medium at an angle to the normal, it appears to bend.
- Light entering from a less dense medium to a denser medium will be refracted toward the normal.

OTHER ILLUMINATION DEFINITIONS

Refraction (Cont'd)

- Principle is used extensively in optics, e.g., lenses, lighting e.g., diffusers and fibre-optic cables. See **Fig. PF-7-1-7** for concept of refraction.

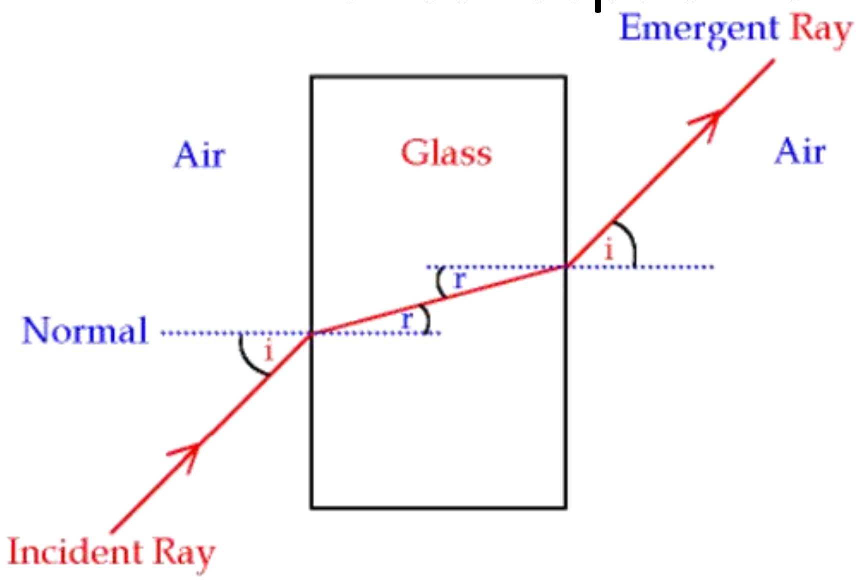

Fig. PF-7-1-7
Refraction of Light

OTHER ILLUMINATION DEFINITIONS

Factors Affecting the Visual Task

- There are a number of factors that have an effect on the visual comfort of a person performing/working to complete a task. These are:
  - Task illuminance
  - Task contrast
  - Glare

OTHER ILLUMINATION DEFINITIONS

Task Illuminance

- There must be sufficient light so that the required work can be carried out correctly and efficiently.
- Low lighting levels causes eye strain and fatigue and may even compromise workplace safety
- Too high a lighting level causes eye strain and unsafe working conditions.
- AS 1680 details the correct Illuminance values for the task, e.g. classroom 400 lux, fine detail (watch making) up to 3000 lux.

OTHER ILLUMINATION DEFINITIONS

Task Contrast

- Contrast is the difference in luminance and/or colour that makes an object (or its representation in an image or display) distinguishable

Glare

- Glare is caused by the brightness of a background or object in the person's field of vision, which distracts that person from the visual task.

OTHER ILLUMINATION DEFINITIONS

Glare (Cont'd)

- Glare is categorised as:
  - Discomfort glare - actual discomfort of the person but may not impair the visibility of the task.
  - Disability glare - may not cause discomfort to the person but impairs the visibility of the task.
  - Direct glare - the light source is in the field of vision of the person
  - Indirect glare - this is the reflection of a light source from a surface or object in the field of vision of the person

OTHER ILLUMINATION DEFINITIONS

Inverse Square Law

- The illumination at a surface can be calculated using the equation:

$$E = \frac{I}{d^2} \qquad \text{PE-7-1-4}$$

Where:
E = Illuminance in lux (lx)
I = Luminous Intensity in Candela (Cd)
d = distance (m)

- The inverse square law is illustrated in **Fig. PF-7-1-8.**

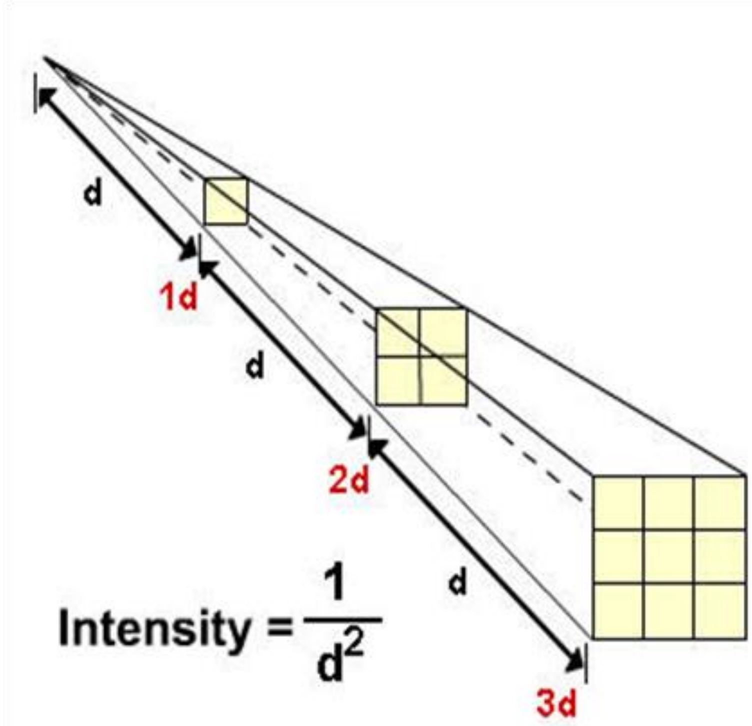

Fig. F-7-1-8 Inverse Square Law
A light source of 1 cd is positioned a distance d from a surface giving an illuminance of $1/d^2$ lux at that surface. If the surface is moved to a distance of 2d from the source, the illuminance will be $1/4d^2$ lux and for a distance of 3d it will be $l/9d^2$ lux.

OTHER ILLUMINATION DEFINITIONS

Inverse Square Law for Inclined Surfaces

- The value of illumination at any point on a surface will be reduced by the cosine of the angle of incidence and may be calculated from the following Equation. See **Fig. PF-7-1-9** for illustration

$$E = \frac{I \cos \phi}{d^2}$$ PE-7-1-5

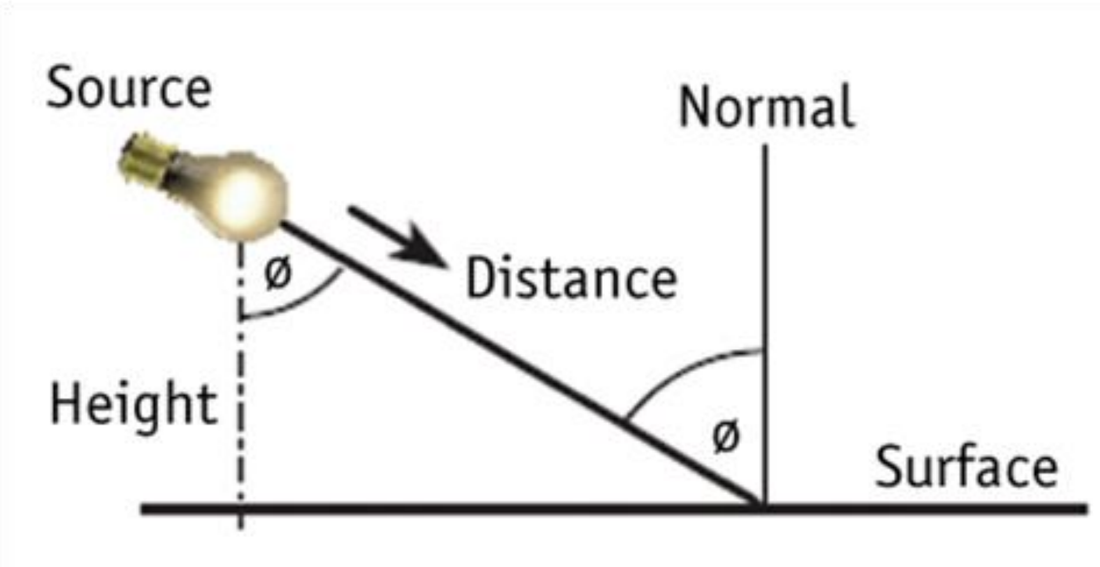

Fig. PF-7-1-9 Inverse Square Law for Inclined Surfaces

Topic 7-2

LAMPS

BASIC PRINCIPLES

- Four basic commonly used methods:
  - **Incandescence**. Current passing through a conductor makes it glow white hot producing light.
  - **Electroluminescence**. Current is passed through a conducting gas, ionising the gas producing UV radiation which bombards phosphors producing visible light.
  - **Gas Discharge.** Same as electroluminescence except that there is no use made of phosphors to give the visible light.
  - **LED.** Semiconductor p-n junctions under forward bias emit radiation by electroluminescence

INCANDESCENT LIGHTING

- This type of lighting is virtually obsolete for general purpose lighting and exists as special lamps which are impractical to manufacture as ‘energy saving’ lamps and Halogen lamps.

GLS LAMPS

Construction:

- See **Fig PF-7-2-1**

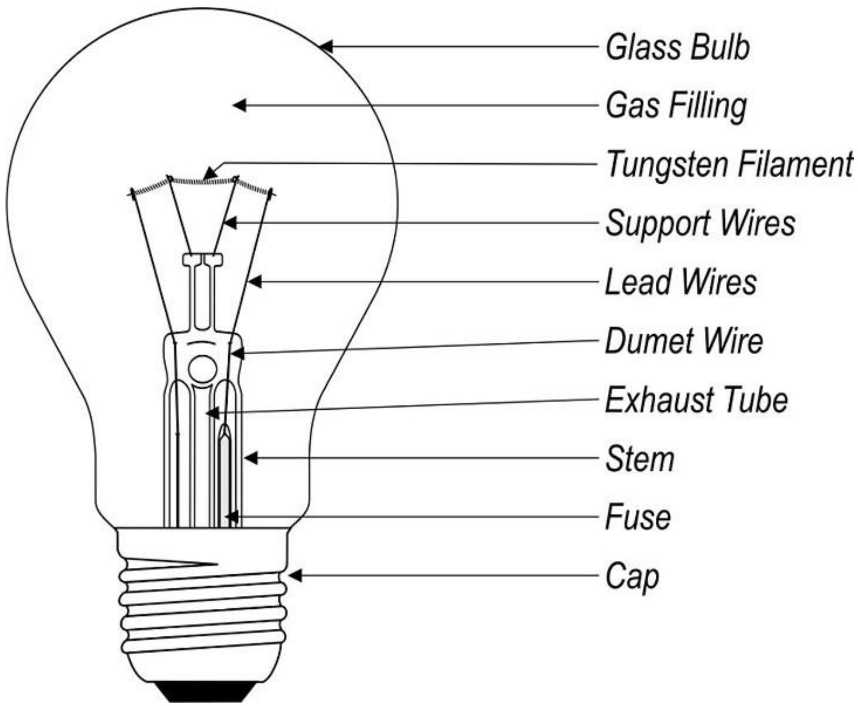

Fig PF-7-2-1
Standard GLS Bulb

GLS LAMPS

Electrical Connection (Cap type):

- **Bayonet Cap (BC)** - Has two electrical connection points on the base of the cap
- **Edison Screw (ES)** - Has a single electrical contact point on the base of the cap. The screw section of the cap gives the other electrical connection
- **Bi-pin** - Has two protruding pins from the cap/base of the lamp. Primarily used on ELV downlights.
- **Screw connect** - Has two screw connectors on the rear side of the lamp. (used for sealed beam lamps).

GLS LAMPS

Filling Gas:

- Approx. 7% nitrogen and the remainder inert argon.
- The inert gas serves three functions:
  - Displaces all oxygen from the bulb. Nitrogen is used to flush the air from the bulb during manufacture which eliminates oxidation of the element.
  - Reduces filament evaporation as the heated gas pressurises the filament
  - Improves colour rendition.

INCANDESCENT LIGHTING

GLS LAMPS

Operating Characteristics

- **Luminous Efficacy**: 10-15 lm/W (lowest luminous efficacy of all artificial electrical light sources). Most of the energy is dissipated as heat.
- **Light Colour**: Depends on the operating temperature of the lamp. The hotter the filament, the closer to white the light will be. Light output is broad spectrum (mainly red) giving a close representation of daylight. (See **Fig F-7-2-2** for comparison with natural daylight)

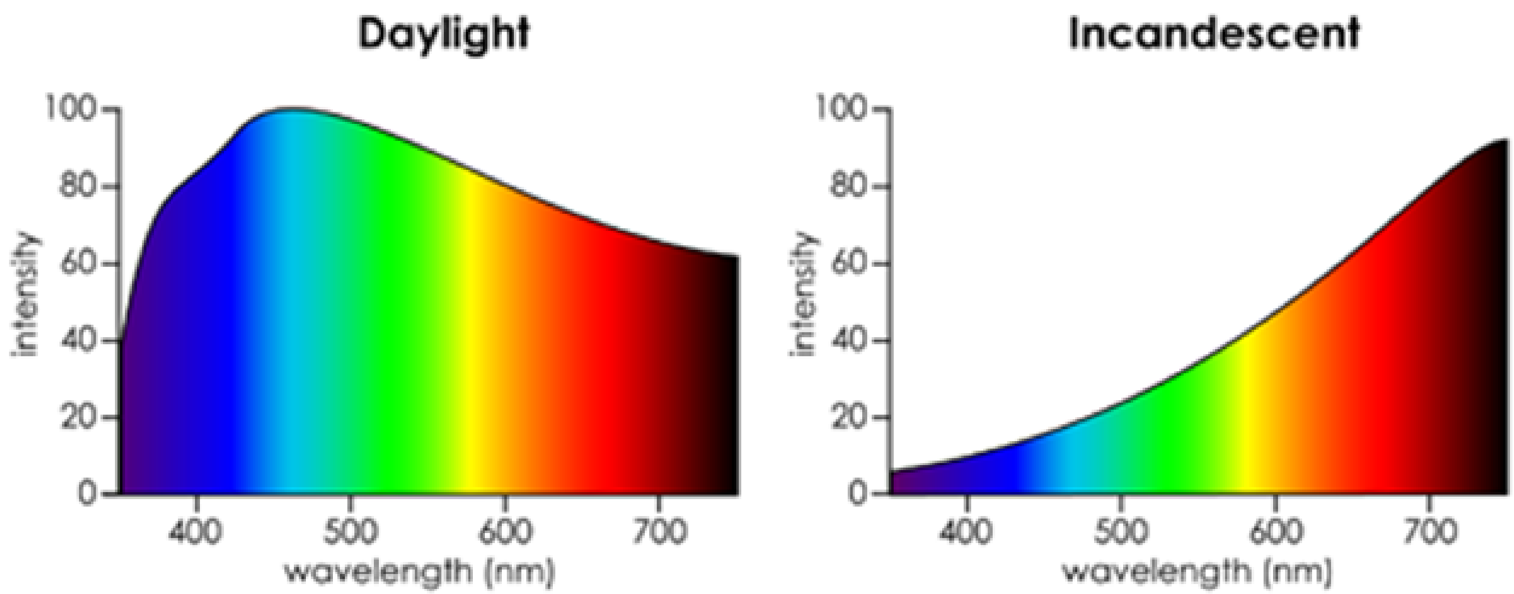

Fig. F-7-2-2
Comparison of Incandescent Lamp Light against Daylight

INCANDESCENT LIGHTING

GLS LAMPS

Operating Characteristics

- **Life:** Average 1000 hours, but affected by:
  - Voltage - 5% variation in voltage can either double or halve the life of GLS lamps
  - Vibration .
  - Switching (on/off) - filament receives a thermal shock when it turns on/off.

HALOGEN LAMPS

Introduction

- The reason for the development of this lamp was a requirement for high output coupled with small size (See Fig PF-7-2-3)
- Lamps are filled with halogen gas inside the bulb instead of other inert gases.

Construction

- **Filament** - Thoriated tungsten.
- **Bulb** - quartz (because of higher temperatures)

Fig. F-7-2-3(a)
300W 240V Quartz-Halogen Lamp

Fig. F-7-2-3(b)
12V Automotive Quartz-Halogen Lamp

HALOGEN LAMPS

<u>Construction</u> (Cont'd)

- **Cap** - Three common types:
  - ➢ **Bi-pin** - As per the GLS lamp. Commonly used with ELV downlights
  - ➢ **Press sleeve** - Used on high power linear lamps (horizontal mount). Each end of the bulb has a connector which slides into position in the lampholder.
  - ➢ **Quick connect** - Lugs are attached to the base of the bulb. Commonly used in automotive headlights.

HALOGEN LAMPS

Construction (Cont'd)

- **Filling Gas** - Halogen eg iodine, bromine.
  - By including a Halogen gas into the bulb a regenerative cycle for the filament is set up.
  - As the filament evaporates, the tungsten combines with the halogen gas to form a Halide.
  - Due to the heat, the gas will circulate inside the bulb.
  - When the Halide nears the filament, the intense heat breaks the bond between the tungsten and the gas and the tungsten is deposited back onto the filament.
  - This increases the lamp life.

HALOGEN LAMPS

Operating Characteristics

- **Luminous Efficacy** - 16 to 22 lm/W.
- **Colour** - Lamp burns hotter, therefore colour of the light is closer to white (daylight) when compared to the GLS lamp. Because of this, it has become the standard light source for general display lighting.
- **Life** – in excess of 2000 hours

FLUORESCENT LIGHTING

- There are two basic types of basic fluorescent lighting, standard tube (called hot cathode) and the cold cathode tube (often called the neon tube).

Construction

The basic standard tube fluorescent lamp consists of a number of parts: (See **Figs PF-7-2-4** and **PF-7-2-5**)

- **Filaments**
  - The standard Fluorescent lamp, contains two filaments, one at each end of the tube.

Fig. PF-7-2-4
Compact Fluorescent lamps (CFLs) and standard tubular types

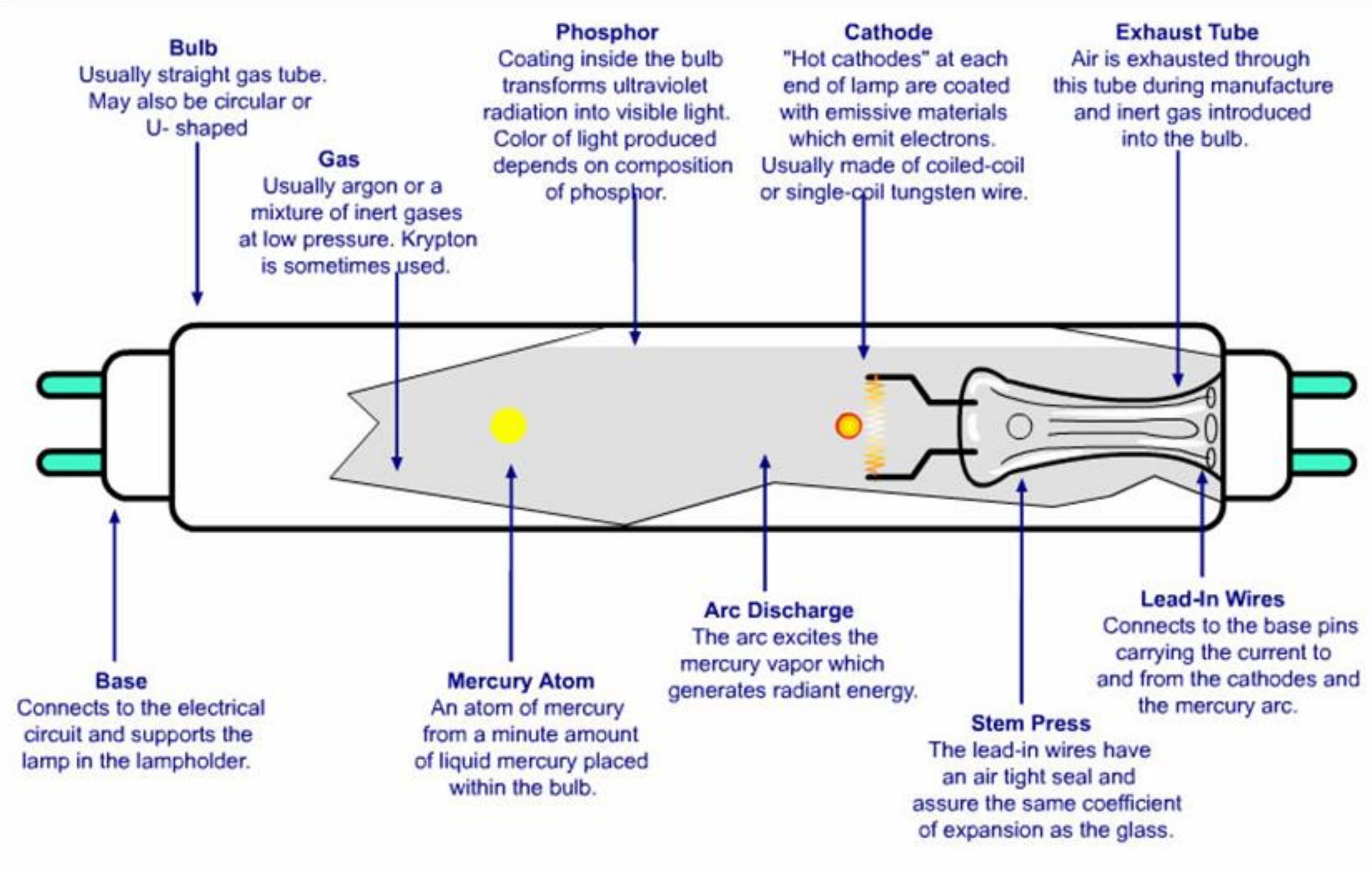

Fig. F-7-2-5

Illustration of the components of a fluorescent lamp and how they work

FLUORESCENT LIGHTING

- **Filaments** (Cont'd)
  - Filaments are made of thoriated tungsten coated with an emissive material and are referred to as cathodes.
  - These cathodes produce the electrons, which will flow though the ionised gas, between the cathodes, within the tube.
  - Cathodes are located on the end caps.
  - Fluorescent lamps are referred to as either "hot or cold cathode".

FLUORESCENT LIGHTING

- **Bulb**
  - The bulb is made of thin toughened glass in the form a tube.
  - The tube may be straight, doubled back onto itself or circular.
  - The inner surface is coated with a combination of phosphorescent powders dependent upon the desired light output colour of the lamp.
- **Cap**
  - The cap for standard fluorescent tubes is the bi-pin.
  - Cathode at each end is connected to each pin.

FLUORESCENT LIGHTING

- **Cap** (Cont'd)
  - The cap for the cold cathode has only one terminal/pin.
  - CFLs may be single bi-pin, or may incorporate an electronic controller in the base along with either an ES or BC cap
- **Filling Gas**
  - The fluorescent lamp contains an inert conducting gas, typically argon.
  - This allows conduction to start which in turn vaporises mercury inside the tube.
  - The mercury vaporising reduces the tube resistance which then allows full current to flow.

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FLUORESCENT LIGHTING

Operation

- The standard hot cathode fluorescent lamp takes time to function.
- When power is first applied, the cathodes heat up and produce electrons.
- The movement of electrons between cathodes through the argon ionises the gas.
- A high voltage is then applied between the cathodes and if the gas is sufficiently ionised, a large current will pass while the voltage is applied.

FLUORESCENT LIGHTING

Operation (Cont'd)

- This creates heat, vaporising the mercury within the tube and allowing sustained conduction within the tube without applying a high voltage.
- The above process can take up to 60 seconds to attain nominal lamp output
- The operation of the cold cathode fluorescent lamp is different in that the cathodes are not pre-heated before the tube is struck (conducting)

FLUORESCENT LIGHTING

Characteristics

- **Luminous Efficacy:**
  - 40-85 lm/W for standard fluorescent
  - can be increased to approx. 100 lm/W if it is operated at frequency (e.g. 25kHz) using electronic control.
- **Size**
  - The fluorescent lamp has a number of standard sizes, ranging from the 6W/225mm tube used in exit lights etc, to 85W/2400mm tube used in outdoor lighting

FLUORESCENT LIGHTING

- **Size** (Cont'd)
  - CFLs are specified by their wattage being typically 7W, 11W, 15W and 20W.
  - Cold cathode tubes have a length dependent upon their application.
  - As the tube lengthens, the starting voltage increases, but does have a maximum value of 15,000 volts, as per AS/NZS 3000:2007.
- **Colour**
  - Depends on the phosphor(s) used to coat the inner surface of the tube.

FLUORESCENT LIGHTING

- **Colour** (Cont'd)
  - Blended phosphors produce the "Warm White", "Cool White" and "Daylight" colours of modern fluorescent tubes.
- **Life**
  - 7500-8000 hours for the standard tube. ("Life" here means up to the point where the light output falls below 80% of the nominal)

HIGH-INTENSITY DISCHARGE (HID) LAMPS

- HID lamps are similar to fluorescents in that an arc is generated between two electrodes.
- The arc tube is made of:
  - ➢ quartz for Mercury and Metal Halide lamps, or
  - ➢ ceramic sintered aluminium oxide for high pressure sodium lamps.
- **Fig. PF-7-2-6** shows the arc tube of a HID lamp.
- Originally developed for outdoor and industrial applications, HID lamps are also used in office, retail, and other indoor applications.

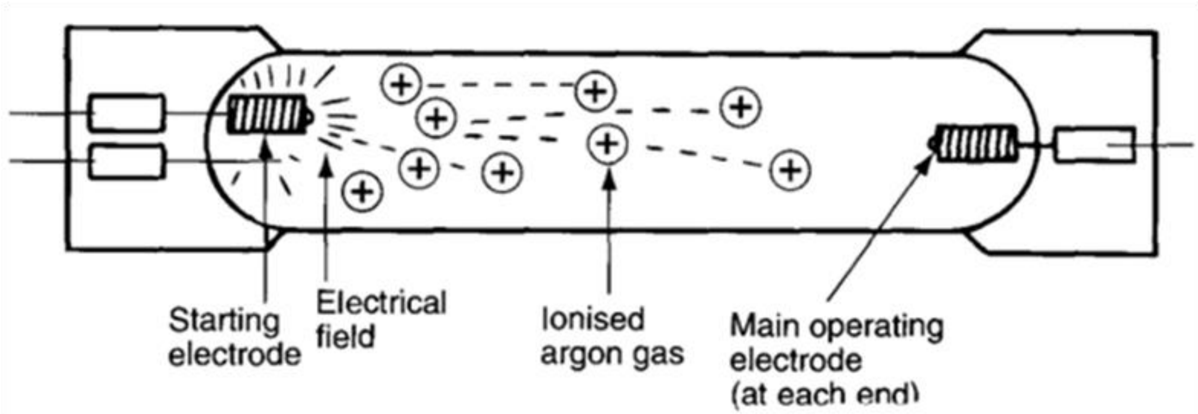

Fig. PF-7-2-6 Arc tube of a HID lamp

HIGH-INTENSITY DISCHARGE (HID) LAMPS

- There are several advantages to HID sources:
  - relatively long life (5,000 to 24,000 hrs)
  - relatively high lumen output per watt
  - relatively small in physical size
- HID sources have the following operating limitations:
  - Require time to warm up. It varies from lamp to lamp, but the average warm-up time is 2 to 6 minutes.
  - HID lamps have a "restrike” time, meaning a momentary interruption of current or a voltage drop too low to maintain the arc will extinguish the lamp.

HIGH-INTENSITY DISCHARGE (HID) LAMPS

- HID operating limitations: (Cont'd)
  - re-striking takes between 2 and 10 minutes, depending on which HID source is being used.
- The following HID sources are listed in increasing order of efficacy:
  - mercury vapour
  - metal halide
  - high pressure sodium
  - low pressure sodium

MERCURY VAPOUR LAMPS

- Consist of an mercury-vapour arc tube with tungsten electrodes at both ends
- The arc tube is filled with high purity mercury and argon gas and is enclosed within the outer bulb which is filled with nitrogen.
- See **Figs. PF-7-2-7** and **PF-7-2-8** for details.
- Lamp produce a blue-green light
- Has the lowest efficacy of the HID family, rapid lumen depreciation, and a low colour rendering index.

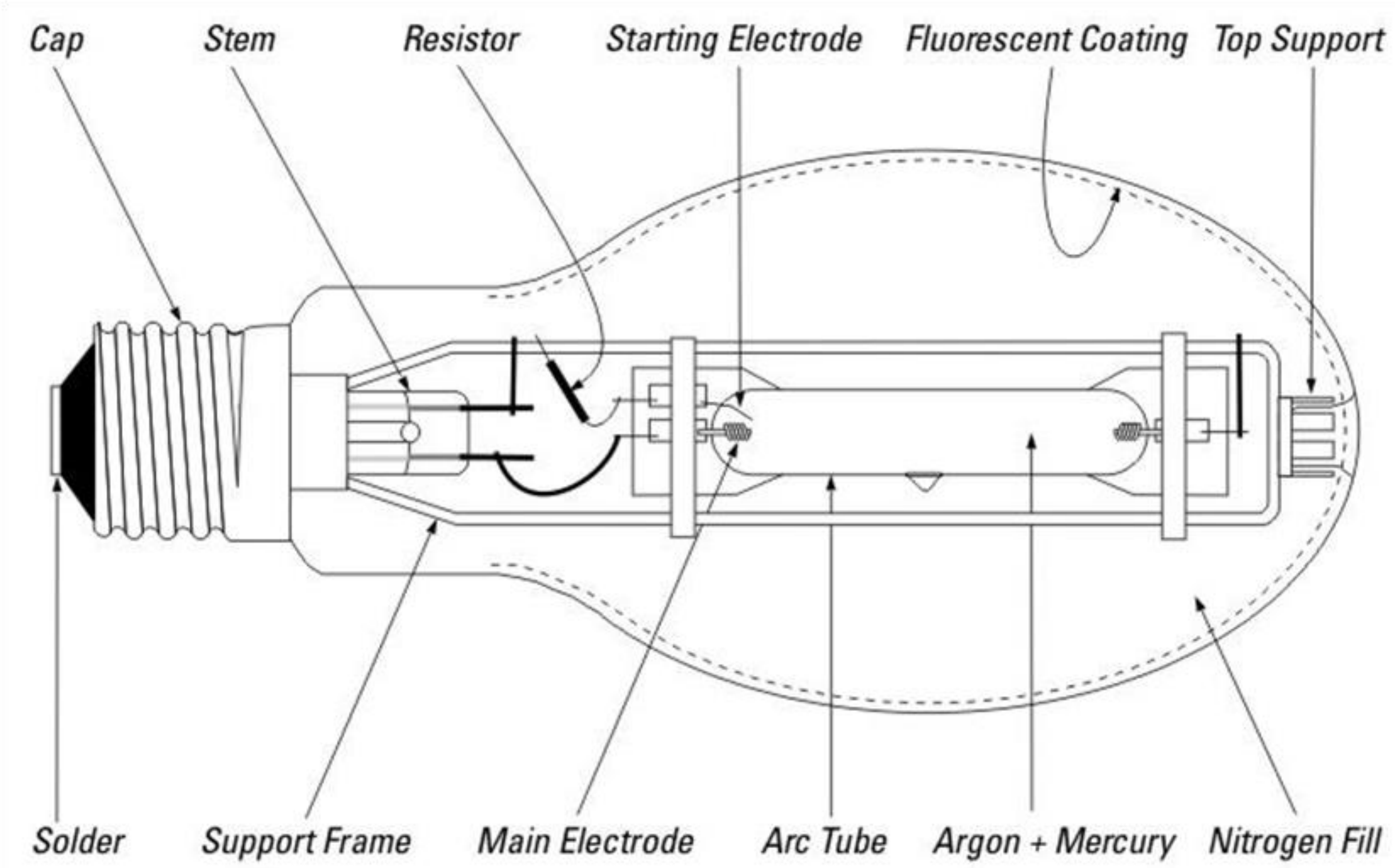

Fig. PF-7-2-7 Mercury Vapour Lamp Components

Fig. PF-7-2-8
Mercury Vapour Lamp

MERCURY VAPOUR LAMPS

- Redeeming Features:
  - Long lamp life (24,000 hours)
  - Popular sources for landscape illumination because of their vivid portrayal of green landscapes.
- Lamp emits a large volume of UV radiation
- Colour-improved mercury lamps use a phosphor coating on the inner wall of the bulb to improve the color rendering index.
- Typical efficacy is approx. 65-75 lm/W

HID LAMPS

METAL HALIDE LAMP

- These lamps are similar to mercury vapor lamps but use metal halide additives inside the arc tube along with the mercury and argon (See **Figs PF-7-2-9** and **PF-7-2-10**).
- These additives enable the lamp to produce more visible light per watt with improved color rendition.
- Wattages range from 32W to 3500W
- Efficacy ranges from 50 to 115 lm/W
- Life – 7500 hours for lower wattage lamps while high wattage lamps average 15,000-20,000 hours.

HID LAMPS

METAL HALIDE LAMP

- Because of good colour rendition and high lumen output, these lamps are used in sports arenas and stadiums.
- Indoor uses include large auditoriums and convention halls.

Fig. **PF-7-2-9**
Metal Halide Lamp

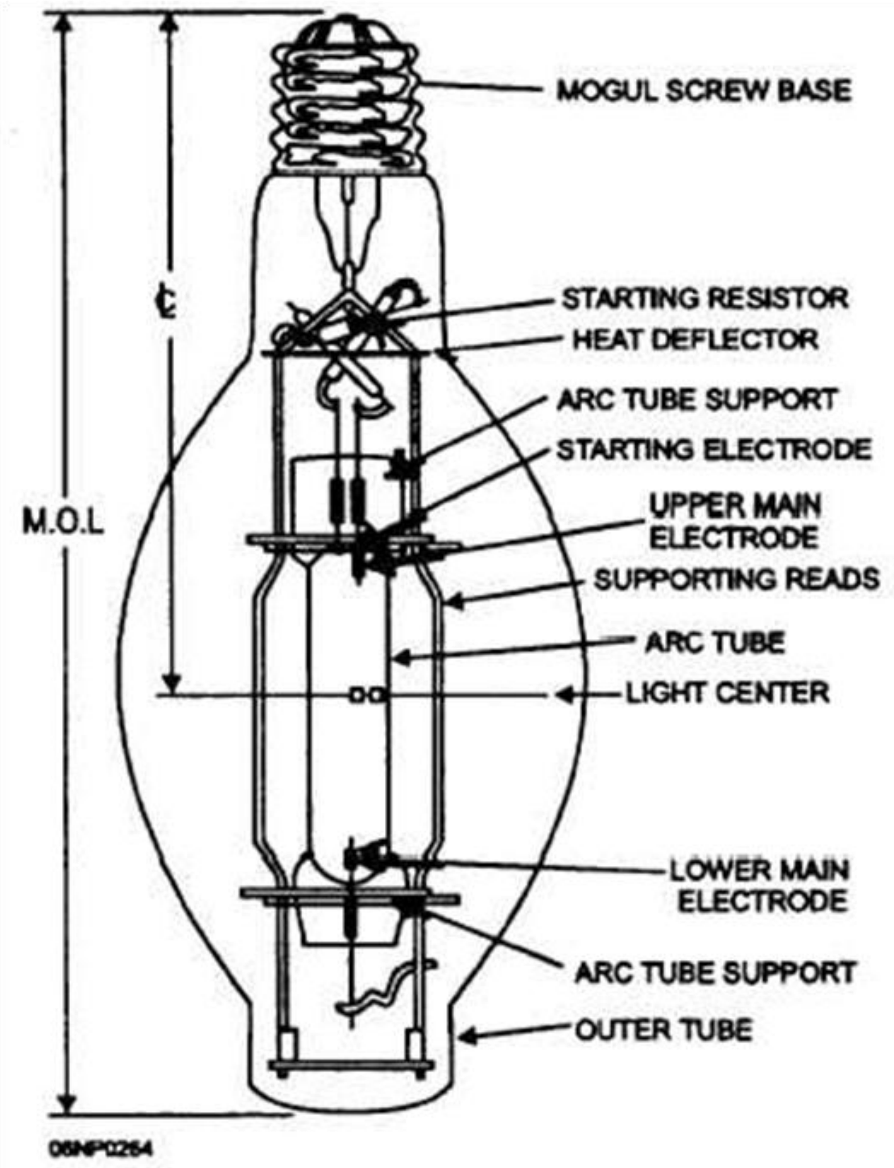

Fig. **PF-7-2-10**
Metal Halide Lamp Components

HID LAMPS

HIGH PRESSURE SODIUM (HPS) LAMP

- The HPS lamp (See Fig **PF-7-2-11**) is widely used for outdoor and industrial applications.
- Poor color rendering
- Do not contain starting electrodes; the ballast circuit includes a high-voltage electronic starter (igniter).
- The arc tube is made of a ceramic material which can withstand temperatures up to 1300°C.
- Filled with xenon to help start the arc, as well as a sodium-mercury gas mixture.

HIGH PRESSURE SODIUM (HPS) LAMP

- Efficacy: up to 140 lumens per watt.
- Colour: HPS lamp produces a “golden white” color that is characteristic of HPS lamps.

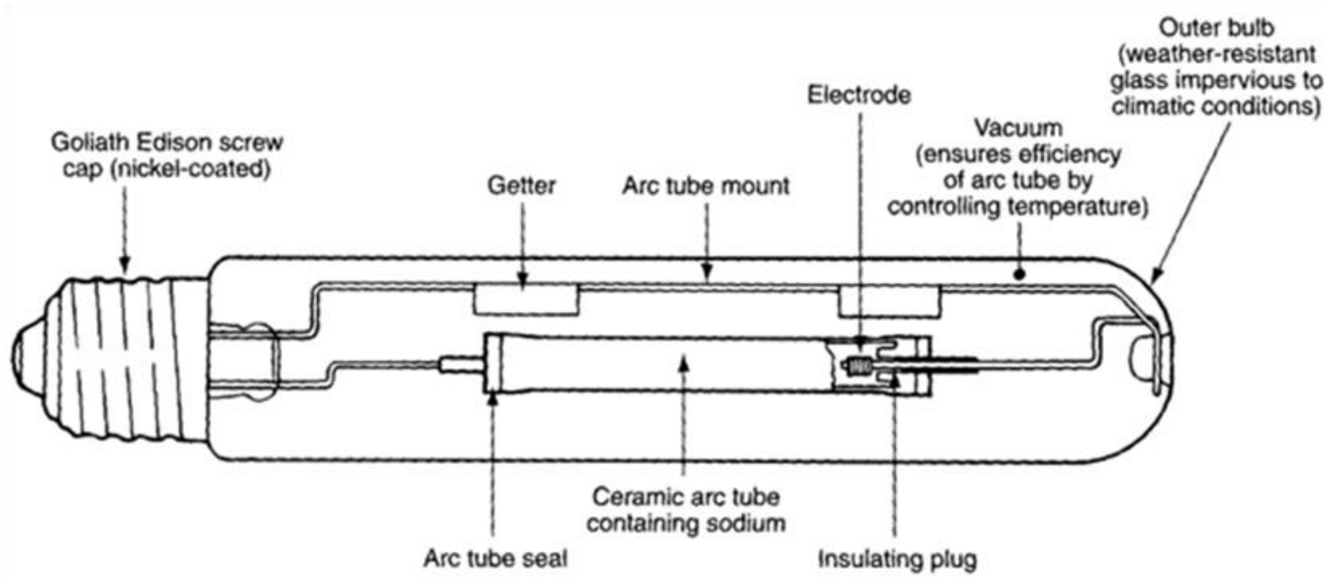

Fig. **F-7-2-11** High Pressure Sodium Lamp Components

LOW PRESSURE SODIUM (LPS) LAMP

- See Figs **PF-7-2-12** and **PF-7-2-13**
- LPS lamps are the most efficacious light sources, ranging up to approx. 200 lm/W
- Produce a monochromatic yellow light (under an LPS source all colours appear either black, white, or shades of gray)
- LPS lamps are available in wattages ranging from 18-180W.
- LPS lamp use has been generally limited to outdoor applications such as security or street lighting

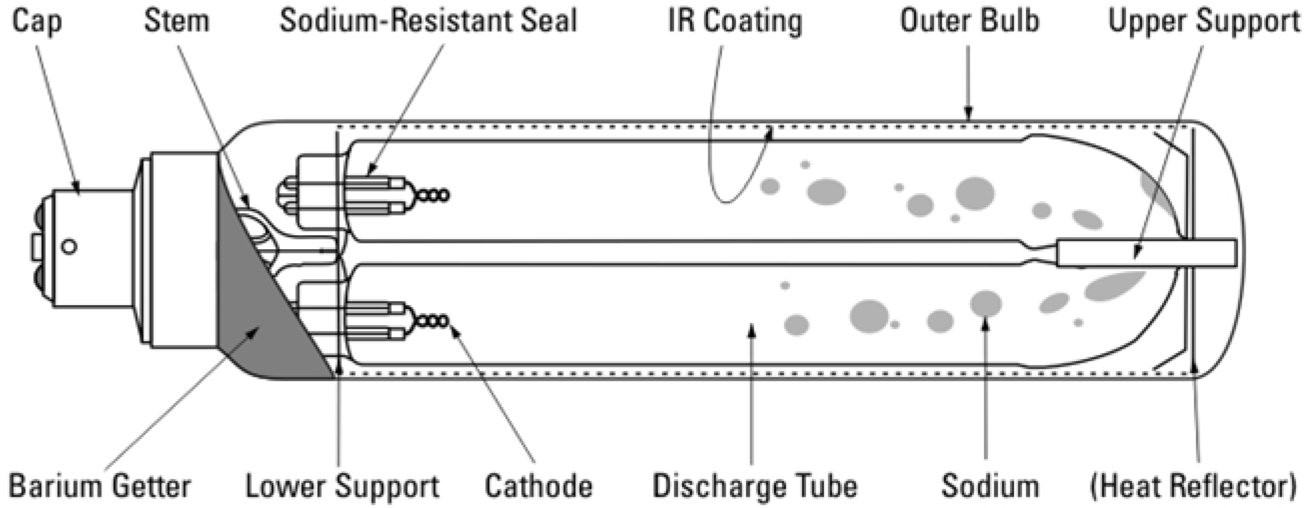

Fig. PF-7-2-12 Low Pressure Sodium Vapour Lamp Components

Fig. PF-7-2-13 Low Pressure Sodium Vapour Lamp

High Pressure Sodium Xenon Lamps (white SON)

- High intensity sodium lamp with no mercury and additional xenon gas
- Operating at a very high pressure and temperature.
- Produces much whiter light than the standard HP sodium lamp
- Lamp power ratings range from 35-100W
- Luminous efficacy of about 50 lm/W.
- Used for display and down lighting applications.
- Control is by a ballast and an igniter.

XENON METAL HALIDE LAMPS

- Similar to sodium xenon lamps
- use similar control gear
- more efficient (75 lm/W)
- Fused silica ceramic arc tube (like HP sodium lamp).
- Arc tube contains a mixture of xenon gas and metal halides
- Operates at a higher pressure and temperature than standard metal halide lamps.
- Excellent colour rendering

OTHER LAMPS – NEWER TECHNOLOGY

PULSED HP SODIUM XENON LAMPS

- Arc discharge is controlled by microprocessor driven solid state switching producing current pulses
- By varying pulse duration and magnitude the colour temperature and colour rendering can be controlled.
- The lamp has a pleasant warm colour temperature of 2300K with a luminous efficacy of about 70 lm/W.
- Lamp produces no UV radiation
- Lamp has a very short run up time of 70 seconds
- Life is about 12,000 hours.

LIGHT EMITTING DIODE (LED)

Colour

- The material used in the semiconducting element of an LED determines its color.
- The two main types of LEDs presently used for lighting systems are:
  - aluminum gallium indium phosphide alloys for red, orange and yellow LEDs; and
  - indium gallium nitride alloys for green, blue and white LEDs.

LIGHT EMITTING DIODE (LED)

Colour (Cont'd)

- Slight changes in the composition of these alloys changes the color of the emitted light.

How white light is made with LEDs

- Presently, there are two methods of creating white light.
  - **Mixed-colour white light**:

    One approach is to mix the light from several colored LEDs to create a spectral power distribution that appears white.

LIGHT EMITTING DIODE (LED)

- **Mixed-colour white light**: (Cont'd)

  Advantages: higher overall luminous efficacy, good color rendering properties, complete flexibility for achieving any desired color property

  Disadvantages: difficult to completely mix light, difficult to maintain color stability over life and at different operating conditions, including dimming

- **Phosphor-converted white light**:

  Use of different phosphors together with a short-wavelength LED (similar to fluorescent lamps where by changing phosphors the colour of light is changed)

LIGHT EMITTING DIODE (LED)

- **Phosphor-converted white light**: (Cont'd)

  Advantages: results in a single, compact, white light source

  Disadvantages: lower overall luminous efficacy, limited range of available color properties based on phosphor availability

Electrical characteristics of LEDs

- A typical voltage-current relationship for an illumination-grade LED is shown in Figure **PF-7-2-14**.
- A slight change in voltage can result in very large changes in current and thus light output.

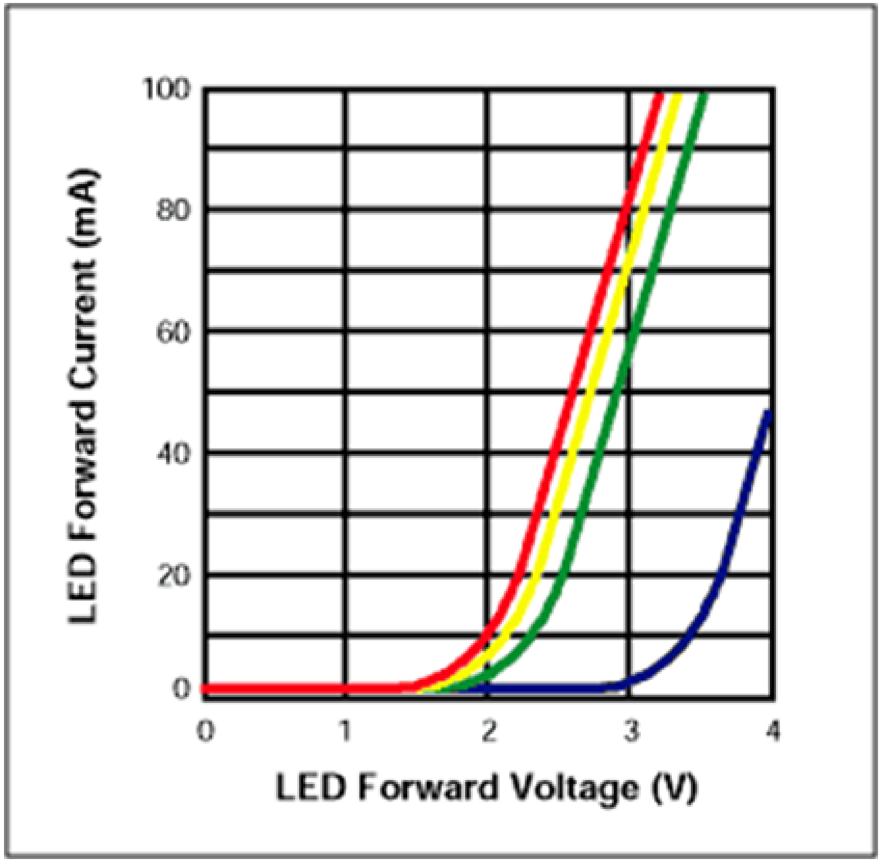

Fig. **PF-7-2-14**
LED forward voltage vanes with color and current.

LIGHT EMITTING DIODE (LED)

Ambient Temperature

- Higher temperatures generally reduce light output.
- The light output of an LED for a constant current varies as a function of its junction temperature (See **Fig. PF-7-2-15**).
- Junction temperature is a function of:
  - ambient temperature
  - current through the LED
  - amount of heat sinking material in and around the LED

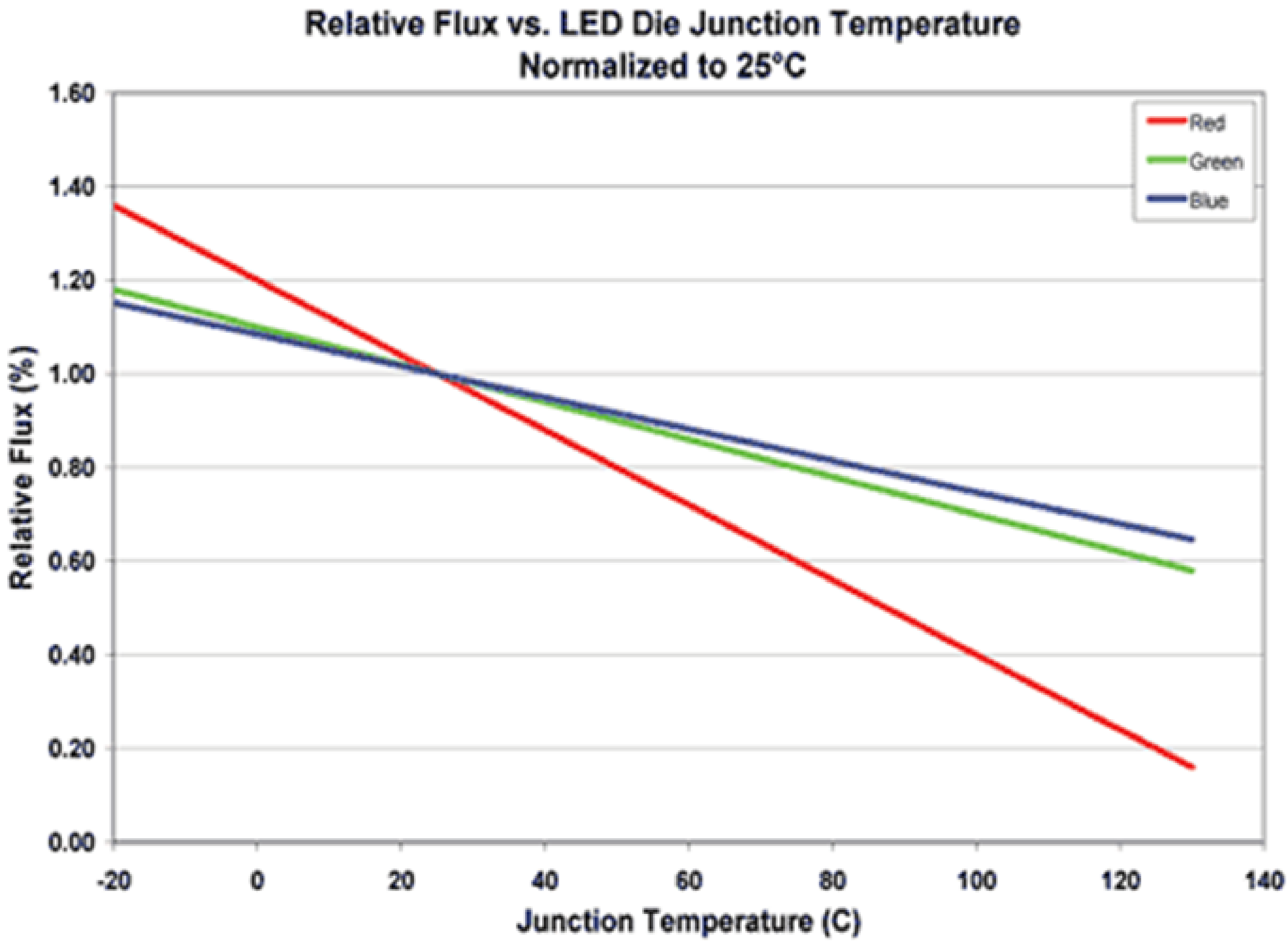

Fig. **PF-7-2-15** LED Junction Temperature versus Light Output

OTHER LAMPS – NEWER TECHNOLOGY

LIGHT EMITTING DIODE (LED)

Heat sinking

- LEDs are referred to as "cool" sources because the spectral output of LEDs for lighting does not contain infrared radiation.
- Although LED lighting systems do not produce significant amounts of radiated heat, LEDs still generate heat within the junction, which must be dissipated by convection and conduction.

LIGHT EMITTING DIODE (LED)

Heat sinking (Cont'd)

- Extracting heat from the device using heat sinks enables higher light output and longer life.
- It is important to install LED lighting in such a manner that heat is able to be removed from its surface.

Fig. **PF-7-2-16** 5W & 8W LED GLS style Lamps showing the heat dissipating arrangement Structure

LIGHT EMITTING DIODE (LED)

Light Output

- Compared to most light sources, LEDs have relatively low light output, therefore, will continue to be packaged into arrays to be useful as light sources
- At present, single white LED packages have reached nearly 100 lumens.
- LED packages are available in a range of beam angles from very narrow (near 6°) to quite wide (more than 100°).

LIGHT EMITTING DIODE (LED)

Life

- No standard definition of life

Colour

- Typical phosphor-based white LEDs have color rendering index (CRI) values comparable to discharge lamps

END