EXPERIMENT NO. 9

AIM: ***Measurement and testing of luminous flux and other parameters of electric bulbs/lamps using Photometric Integrating sphere.***

1. APPARATUS REQUIRED:

S.No	Name of Apparatus/Equipment	Specification	Quantity
1.	Photometric Integration sphere	1m diameter	1
2.	Photometric testing panel		1
3.	Lamp holder in the centre of the sphere	42 cm vertically long	1
4.	Lux meter	0 – 200000 lux	1
5.	Variac/Autotransformer	1ϕ, 2A, 0-270V, VA	1
7.	Photo sensor & Temperature Sensor in the sphere		One each
8.	Lamps	Incandescent lamp- 60W, CFL- 5W, LED-SW ,2ft Fluorescent tube, etc.	One each

1. THEORY:

1.1 Definitions

Radiometry

Radiometry is the study of entire optical radiation from light sources i.e. electromagnetic waves in the Ultra Violet (UV), visible and infra-r ed spectrum. It is concerned with the total energy content of the radiation. The most common unit of measurement in radiometry is the watt (W), which is the radiant flux (power). How much radiation energy is released from the light source(watt/m2/steradian) is known as radiance which is measured in watt-sec.

Photometry

It is a branch of radiometry and concerned with human's visual response to light. Photometry examines only the radiation that humans can see. The most common unit of measurement in photometry is the lumen (lm), which measure luminous flux. For monochromatic light of 555nm wavelength,

1 watt = 680 lumens.

Light that is visible to the human eyes is a part of electromagnetic spectrum ranging from 400nm (violet) to 700nm (red). Human eyes are most sensitive to radiations of wavelength 5550 A° (555nm) which corresponds to yellowish green color.

Luminous Efficacy

Luminous efficacy is a measure of how much of the electrical power supplied to the lamp is turned into luminous flux. It's unit is **lumens/watt.**

$$\text{Luminous Efficacy} = \frac{\text{Flux Out (Lumens)}}{\text{Power In (Watts)}}$$

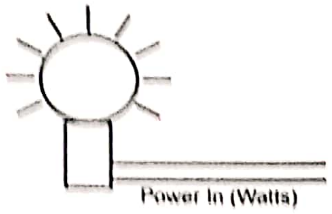

Fig.1 Luminous Efficacy of a light source

Luminous efficiency

Luminous efficiency is a measure of how much of the radiant energy is visible to the human eye. It is unitless and expressed in 'percentage'.

Co-efficient of Reflection

It is the ratio of the luminous flux leaving the surface to the flux incident on the surface.

Co-efficient of Absorption

The ratio of the light absorbed to the light entering is called the co-efficient of absorption.

CRI (Color Rendering Index)

CRI is a quantitative measure of a light source's ability to reproduce colors of various objects in comparison to an ideal or natural light source. It determines how "true" colors appear.Higher CRI lamps can better reproduce the visible light spectrum and can potentially reduce needed foot-candle levels. Ideally, all installations would have colour rendering indices of 100. There is no advantage in a lower colour rendering for general illumination. Product specifications for any lamp will list the CRI of that lamp in the range of (75-90) normally. It is recommended a CRI greater than 80.

CCT- Correlated Colour Temperature

The CCT of a light source is the temperature in Kelvin (K) at which the color of a heated black body radiator matches the colour of the light source. On heating, the black body glows deep red initially at low temperatures and eventually blue-white at very high temperatures. It is conventionally stated in terms of temperature, Kelvin (K). Colour temperatures over 5000K are called cool colours (bluish white), while temperatures in the range of 2700K-3000K are called warm colour.

2.2 WORKING PRINCIPLE OF THE PHOTOMETRIC INTEGRATING SPHERE:

The photometric Integrating sphere is a hollow sphere made up of a special type of fiber, coated from inside with a reflective coating of Barium Sulphate ($BaSO_4$) powder mixed with paint and water. The inside reflective walls provide reflection to light beams radiated by lamps and integrates them. The radiance of light considers the multiple surface reflections from the sphere-wall, and surface area of the sphere. The light received by the sphere by initial reflection is mostly diffused.

The sphere is made up of a special type of fiber which does not cause any variation in temperature of the outer surface with the inside temperature. The vertically long lamp holder placed inside the sphere for holding the lamp is coated with the same coating material as that of the integrating sphere wall. There is a rectangular opening of **13.5"x11.5"** size on the one side of the sphere to check and measure the illumination of intensive lightings.

2.2.1 Photo Sensors

A photo sensor, well shielded, is placed on one side of the Photometric Integrating sphere(Figs.2a-2c) and is used as a transducer, which converts the light, after multiple reflections of light from the inside coated surface of the photometric sphere, into the electrical signals output. The signal indicates the radiant light energy which ranges from infrared to visible to ultraviolet. It is connected at the back of the sphere at an exit port to sense the integrated light and fitted in such a manner that the light from the source should not fall on it directly. It receives only the integrated light after reflection. The optical fiber cable coming out of the lamp holder output is connected to Photometric Testing Panel. A thermal sensor is used to sense the temperature rise or fall inside the sphere.

Fig.2a Photometric integrating sphere

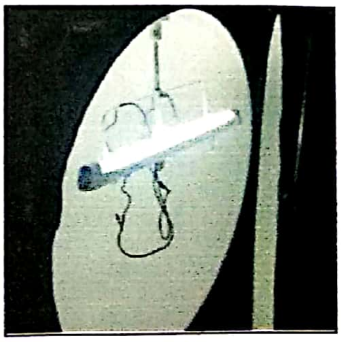

Fig.2b FT in the Photometric integrating sphere

Fig.2c Bulb in the Photometric integrating sphere

2.2.2 Expression of the radiance, L (radiometric considerations):

For an integrating sphere, the resulting radiance (L) of a diffuse surface for an input flux (F)must consider both multiple surface reflections and losses through the port openings needed to admit the input flux. The total flux incident on the sphere surface is higher than the input flux due to multiple reflections inside the cavity. The radiance, the flux density per unit solid angle is given by the following expression,

$$L = \frac{F}{\pi * A_s} * \frac{\rho}{1-\rho(1-f_r)} W/m^2/Sr$$

where, ρ is the reflectance, A_s is the surface area of the entire sphere illuminated and f_r is the port fraction.

2.2.3 Performance Characteristics of incandescent bulb and FT:

The variation in power consumption, lumens output, luminous efficacy/efficiency and life of incandescent bulb with the variation of input ac voltage is shown in Fig.3 and Fig.4 respectively.

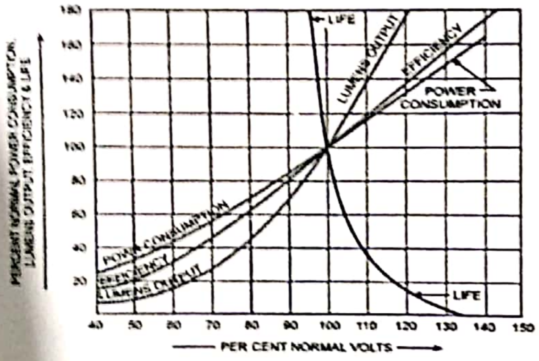

Fig.3 Performance curve of incandescent bulb

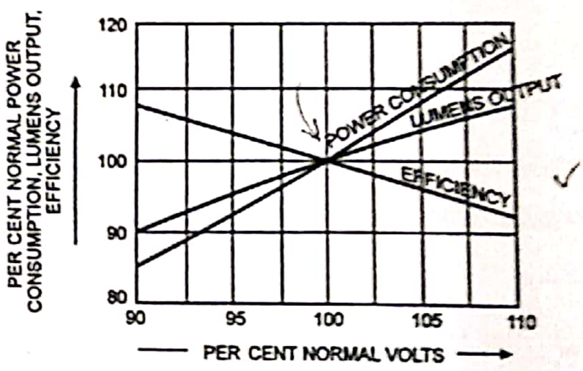

Fig.4 Performance curve of Fluorescent tube

2.3.4 Photometric testing panel

Photometric testing panel (Fig.5) having 5 different digital LCD displays for measurements of luminous flux (lumen), voltage(V), current(A), power, frequency(Hz), power factor, VA and power consumption (W).There is a knob beneath the lumen meter which either read zero or C (calibration) and R (reading). The observations should be taken when the knob is at C&R. The input to the panel is given through a Variac. The optical cable and the wire from the sensor are connected to the cable at the output and the sensor respectively on the back of the panel. There are two fuses, for the input and output, which are rated between 2A to 5A. The panel will give readings accurately when the sphere is closed, otherwise it will give erroneous reading of the lamp.

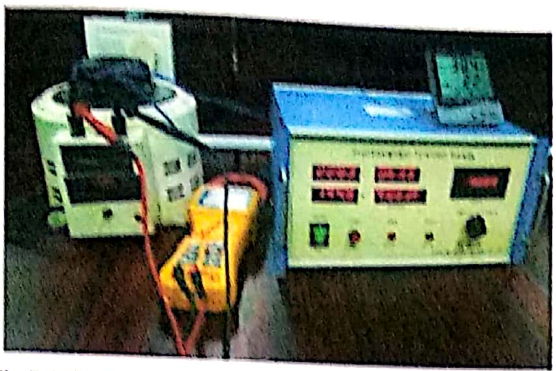

Fig.5 Calibration of Lumen meter in the Photometric panel

2.3.5 Photometric measurements

The photometric measurements are made to determine the total luminous flux (lumens), luminous efficacy (lm/W), and luminous intensity (candelas) in one or more directions at various input AC voltages and temperature. The total flux data is to be obtained from the photometric testing panel.

The electrical connection between the AC power supply, AC powered bulb/FT under test, and digital photometric testing panel (V,A,f,W,pf,Hz) enables to measure the electrical parameters viz. input RMS AC voltage, input RMS AC current, input power(wattage) of the AC powered bulbs/FT, input frequency, and power factor.

When the specific lamp is switched ON, the panel will give the reading of the electrical parameters i.e., voltage, current, power, power factor, lumens and frequency, voltage and current waveforms, active and reactive power drawn by the lamp, and the luminous flux (lumen).
The effect of input voltage variation on lumens output and luminous efficacy of lamps, and variation in lumens due to difference in temperatures are to be studied.

The effect of temperature variation caused by heating of the lamps and corresponding effect on lumens output and luminous efficacy of lamps are to be studied. A comparison between incandescent lamp, CFL, Fluorescent tube and LED bulbs is to be studied.

2. PROCEDURE:

(i) Keep the working table clean.

(ii) Check the testing panel switches and digital displays of various parameters in the photometric testing panel.

(iii) Make and check the circuit connections by patch cords between the photometric sphere, photometric testing panel and Variac.

(iv) Check supply voltage (V) and frequency (Hz) of the supply.

(v) The Variac is adjusted to supply the potential coil at voltages between 190V and 240V with a step of increment of 10V.

(vi) Start the experiment and keep records of times (minutes)and various

(vii) The window of the photometric sphere should be properly closed to avoid flux leakage from the photometric sphere.

(viii) Note the various readings as tabulated on a time scale and Draw the performance characteristics of incandescent bulb, and Fluorescent tube.

(ix) Make a comparative assessment on luminous efficiency for the light sources used.

(x) Calibration of the Lumen Meter in the Photometric Panel **(Fig.5)** - An NPL tested LED bulb is used for calibration of the Lumen Meter present in the Photometric Panel.

3. **Nameplate readings of the Bulb and Calibration:**

Nameplate Readings of the tested Bulb		***Readings after Calibration***	***Percentage error***
Voltage (V)			
Current(A)			
Watt (W)			
pf			
Luminous flux (lumen)			

Case-II CFLS (Bajaj5 W CFL, 220-240V,50Hz, 210 Lumens, 0.85pf and 6500 °K (to operate at 240V-190V supply voltages)

Time (mins)	Volt(V)	I(A)	Lumens	PF	watt(w)	VA	Temp (°C)	Freq (Hz)	Efficacy (lm/w)
t+30	240								
t+35	220								
t+40	200								
t+45	180								
t+50	160								
t+55	140								

Case-III LED (Philips 8W LED bulb, 0.5 pf,720 lumens(to operate at 240V - 190V supply voltages)

Time (mins)	Volt(V)	I(A)	Lumens	PF	watt(w)	VA	Temp (°C)	Freq (Hz)	Efficacy (lm/w)
t+60	240							50.0	
t+65	220								
t+70	200								
t+75	180								
t+80	160								
t+85	140								

4. PRECAUTIONS

(i) Good electrical contacts are necessary to make total luminous flux and electrical operating parameter measurements meaningful. Good quality and clean lamp socket can be used.

(ii) An interior coating reflectance should be of **90% to 98 %** for the sphere wall, depending on the sphere size and usage of the sphere.

(iii) In total luminous flux measurements, the most obvious systematic error is the calibration uncertainty and it is to be minimized by taking appropriate measures.

(iv) Flux losses through the Sphere's port openings should be minimized.

(v) Regulated power supply for operating the lamps during photometric testings is to checked.

5. CONCLUSION

The performance characteristics of the light sources (viz. bulbs/FT) including variation of luminous flux at variable voltage, and luminous efficacy are studied meticulously and the results of the experimental observations are captured as depicted here briefly.