Chapter 4.10: Lighting Systems

Short type questions

1.	Define Installed Load Efficacy? **Ans.** Installed Load Efficacy is the average maintained illuminance provided on a horizontal working plane per circuit watt with general lighting of an interior. Unit: lux per watt per square metre (lux/W/m²)
2.	Define Lamp Circuit Efficacy? **Ans.** Lamp Circuit Efficacy is the amount of light (lumens) emitted by a lamp for each watt of *power consumed by the lamp circuit, i.e. including control gear losses.* This is a more meaningful measure for those lamps that require control gear. Unit: lumens per circuit watt (lm/W)
3.	Define Installed Power Density? **Ans.** The installed power density per 100 lux is the power needed per square metre of floor area to achieve 100 lux of average maintained illuminance on a horizontal working plane with general lighting of an interior. Unit: watts per square metre per 100 lux (W/m²/100 lux) N.B. Installed power density (W/m²/100 lux) = $\frac{100}{\text{Installed load efficacy (lux / W / m}^2\text{)}}$
4.	What do you understand by Colour Rendering Index? **Ans.** Colour Rendering Index (CRI) is a measure of the effect of light on the perceived colour of objects. To determine the CRI of a lamp, the colour appearances of a set of standard colour chips are measured with special equipment under a reference light source with the same correlated colour temperature as the lamp being evaluated. If the lamp renders the colour of the chips identical to the reference light source, its CRI is 100. If the colour rendering differs from the reference light source, the CRI is less than 100. A low CRI indicates that some colours may appear unnatural when illuminated by the lamp.
5.	Define Room Index and minimum number of measurement points? **Ans.** Room Index is defined as follows: Room Index: RI = $\frac{L \times W}{Hm\,(L + W)}$ Where L = length of interior; W = width of interior; Hm = the mounting height, which is the height of the lighting fittings above the horizontal working plane. The working plane is usually assumed to be 0.75m above the floor in offices and at 0.85m above floor level in manufacturing areas. It does not matter whether these dimensions are in metres, yards or feet as long as the same unit is used throughout. The minimum number of measurement points can be ascertained from the table below:

Room Index	Minimum number of measurement points
Below 1	9
1 and below 2	16
2 and below 3	25
3 and above	36

6\. What is installed load efficacy ratio?

Ans.

$$\text{Installed load efficacy ratio (ILER)} = \frac{\text{Actual Lux / W / m}^2}{\text{Target Lux / W / m}^2}$$

Or

$$\text{Installed load efficacy ratio (ILER)} = \frac{\text{Target W / m}^2\text{ / 100 lux}}{\text{Actual W / m}^2\text{ / 100 lux}}$$

7\. Write the CRI values for excellent, good, moderate, poor and none performance sources?

Ans.

Condition	**CRI Value**
Excellent	> = 90
Good	80 – 89
Moderate	60 – 79
Poor	40 – 59
None	20 - 39

8\. What is meant by circuit Watts?.

Ans.

Circuit Watts is the total power drawn by lamps and ballasts in a lighting circuit under assessment.

9\. How is the lighting performance assessed from Installed load efficacy ratio (ILER)??

Ans.

ILER ratios of 0.75 or more may be considered to be satisfactory to good. Existing installations with ratios of 0.51 – 0.74 certainly merit investigation to see if improvements are possible. Of course there can be good reasons for low ratio, such as having to use lower efficacy lamps or less efficient luminaries in order to achieve the required lighting result but it is essential to check whether there is scope for a more efficient alternative. Existing installations with an ILER of 0.5 or less certainly justify close inspection to identify options for converting the installation to use more efficient lighting equipment.

10\. The ILER of a room is 0.7. If the lighting load is 990 W, calculate the annual energy wastage? Assume the room is ON for 8hours/day for 300 days

Ans.

Annual Energy Wastage = (1 – ILER) x Watts x no. of operating hours
= (1 – 0.7) x 990 x 8 hours/ day x 300 days

= 712 kWh/ annum

Long type questions

1. What are the differentiating characteristics of incandescent, compact fluorescent lamp, and high-intensity discharge (HID) lamps?

Ans.

Incandescent lamps:

- Appear "warm" in colour and have excellent colour rendering.
- Are the least efficient of general lamp types due to the amount of energy consumed heating the filament in order for the lamp to turn incandescent
- Have a short lamp life of between 500 and 1,000 hours.
- Are easy to install because no ballast is required.

Compact Fluorescent lamps:

- Are available in a complete range of colour combinations.
- Produce low heat.
- Require a more extensive installation because ballasts are a necessary part of the fixture.
- Have an extremely long life of up to 24,000 hours.
- Due to smaller sizes and screw base/pin type base features, compact fluorescent lamps can replace incandescent lamps.

High-intensity discharge (HID) lamps:

- Are ideal for large stores, warehouses, auditoriums, outdoor parking areas, and applications where efficiency is a priority.
- Have a warm-up period, which results in slower start-up.
- Deliver a large amount of light over a wide area.
- Have a long life of between 5,000 and 24,000 hours.
- Require ballasts.

2. Describe in short on the following common lighting control tools?

a) Programmable timers
b) Occupancy sensors
c) Photo switches

Ans.

a) Programmable Timers: Programmable timers are used to implement time-based control of electric lights. The usual method of implementation is a system of low-voltage controlled relays that are controlled by a programmable time clock. These systems are primarily used to efficiently schedule the operation of a lighting system in areas where the occupant schedule is relatively predictable. To accommodate lighting needs during off-hours, these systems are typically equipped with overrides so that building occupants can control the lights using a low-voltage switch or a telephone override system.

b) Occupancy Sensors: Occupancy sensors are switches that are activated by detecting the presence or absence of people in the sensor's field of view. There are two basic types of occupant sensor: passive infrared sensing and ultrasonic (some sensors combine these two methods). These sensors are most effective in locations where occupancy is not easily predicted (e.g., conference rooms, restrooms, and storerooms).

c) Photo-Switches: Photo-switches are photo-electrically controlled switches that can be used to switch off lights in building zones receiving daylight from adjacent windows. These devices are usually installed in one of three ways: on each fixture; on groups of fixtures using intermediate relays; or as inputs to low-voltage programmable relay systems.

Numerical type questions

1. Two main areas of an industrial plant have the following lighting systems:

Area A: 50 x 400W High Pressure Sodium (HPSV) single lamp luminaires.

Area B: 35 x 400W Mercury Vapour (HPMV) single lamp luminaires.

In *Area A* and *Area B*, the measured illuminance during daylight hours (12 hours) without artificial light was found to be adequate.

In *Area B* it was noted that 8 of the MV fixtures are redundant.

Plant Operating Hours: 24 hours per day, 365 days per year.

Electricity

Energy costs: Rs 3.00/kWh

Calculate the annual potential energy cost savings from switching off unnecessary lights and from disconnecting redundant luminaires?

Note: Ignore the ballast energy consumption.

Area A Energy Savings:

The annual energy saved by switching 50 x 400W HPSV lights off for the 12 hours of daylight time each day is:

$$= \frac{50 \text{ x } 400\text{W} \text{ x } 12 \text{ h/d} \text{ x } 365 \text{ d/y}}{1000} = 87{,}600 \text{ kWh}$$

The cost of the annual saved energy is: 87,600 x Rs. 3.00 /kWh

= Rs. 262,800/-

Area B Energy Savings

The annual energy saved by removing 8 redundant 400W HPMV luminaires is:

$$= \frac{8 \text{ x } 400\text{W} \text{ x } 12 \text{ h/d} \text{ x } 365 \text{ d/y}}{1000} = 28{,}032 \text{ kWh}$$

The annual energy saved by switching the remaining 27 x 400W HPMV lights off for the 12 hours of daylight time each day is:

	$= \frac{27 \text{ x } 400\text{W x } 12 \text{ h/d x } 365 \text{ d/y}}{1000} = 47{,}304 \text{ kWh}$ The total annual energy saved is :(28,032 + 47,304) kWh = 75,336kWh The cost of the annual saved energy is: 75,336 x Rs. 3.00/kWh = Rs.226,008/- The overall cost of annual energy saved: = Rs.262,800/- +Rs. 226,008/- = Rs. 488,808/-

2. The exterior areas of a Compressor House are illuminated by twenty wall-mounted 1000W Tungsten Halogen, single lamp, luminaires. The lamps burn 12 hours a day, throughout the year. The energy and cost savings that could be realized by changing to a more efficient light source were investigated.

With reference to data given below suggest the suitable retrofit for annual energy saving and the simple pay back period.

Luminaire	Lumens	Efficacy	Cost /lamp
1000 W Halogen lamp	22,700	22.70	Rs. 5000
250 W HPSV lamp	24,600	98.40	Rs. 5500
400 W Metal halide lamp	27,000	67.50	Rs. 6500

Plant Operating Hours: 12 hours per day, 365 days per year.

Electricity Costs: Rs 3.00/kWh

Ans.

From the given table the lumen output of 250 W HPSV is sufficient for retrofit and the efficacy is more than 4 times the efficacy of 1000 W Halogen lamps.

Annual energy consumed by 1000 W Halogen lamps

$$= \frac{20 \text{ x } 1000\text{W x } 12 \text{ h/d x } 365 \text{ d/y}}{1000}$$

= 87,600 kWh

Annual energy consumed by 250 W HPSV lamps on replacement

$$= \frac{20 \text{ x } 250\text{W x } 12 \text{ h/d x } 365 \text{ d/y}}{1000}$$

= 21,900 kWh

Annual energy savings by replacing with 250 W HPSV lamp

= 87,600 – 21,900 kWh

= 65,700 kWh

Annual cost of energy saved = 65,700 x Rs. 3.00/kWh

= Rs. 197,100/-

Cost of implementation of 20 Nos. 250 W HPSV lamp

= 20 x Rs. 5500

= Rs. 110,000/-

Simple payback period = Implementation cost ÷ Annual cost of energy saved

= 110,000 ÷ 197,100

= 0.6 year

3. Application = Industrial lighting

Room Dimensions = 10 x 7 x 3 m

Lighting load = 1000 W

Average maintained illuminance = 500 lux, target lux/W/m^2 (from table in the book for the room index) = 38

Calculate

(a) Room index

(b) Watts/m^2

(c) ILER

Ans.

(a) Room index = L x W / H_m (L+R) = 10 x 7 / 3 x (10+7) = 1.37

(b) Watts/m^2 = 1000 / (10 x 7) = 14.3

(c) Actual lux/watt/m^2 = 500 / 14.3 = 34.9

Target lux/W/m^2 (from table in the book for the above RI) = 38

ILER = 34.9 / 38 = 0.92 (satisfactory to good)

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4. An industrial plant has an incandescent lighting load of comprising 100 Nos. of 60 W and 140 Nos. of 100 W. Calculate the energy savings if each incandescent load is replaced by 1 X 40W fluorescent load. Lighting is required for 4000 hours/year and the cost of electricity is Rs. 4.0 per kWh. Replacement cost is Rs. 135 per unit consider ballast consumption as 15 W

Given data:

100 W incandescent lamp = 2200 lumens

60 W incandescent lamp = 1320 lumens

40 W Fluorescent lamp = 2400 lumens

Ans.

Power required by existing incandescent lamps = 100 x 60 + 140 x 100

= 6000 + 14000 = 20.0 kW

One 40 W fluorescent lamp each will be required to replace one 100 W incandescent and two of 60 W lamps (as observed from given data).

∴ we require 140 nos. of 40W fluorescent lamps and 50 Nos. of 100 watts fluorescent lamps.

Total number of Fluorescent lamps required = 50 + 140 = 190 Nos.

Power required for one of fluorescent lamp is 55 W (including conventional ballast power)

Power required for total fluorescent load = 190 x 55 W = 10.45 kW

Annual Energy Savings = (20 – 10.45) x 4000 = 38,200 kWh

Annual cost savings = 38,200 x 4 = Rs. 1.53 lakh

Replacement cost = 190 x Rs. 135/unit = Rs.0.26 lakh

Simple payback period = 0.26/1.53 = 2 months