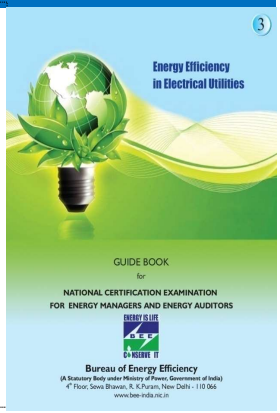
OPTC TRAINING COURSE

BOOK 3 – ENERGY EFFICIENCY IN ELECTRICAL UTILITIES
Brief Contents

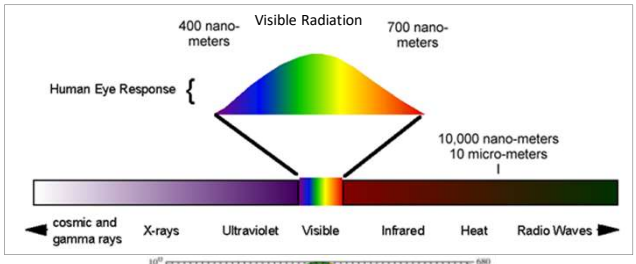


Chapter-8 Lighting System
Contents

1 Introduction

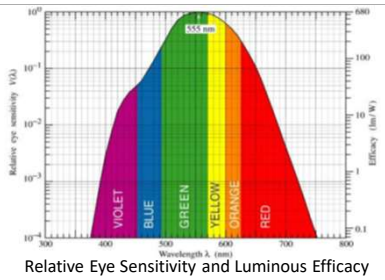
Light is an electromagnetic radiation that is visible to the human eye(400 to 700 nanometers wavelengths).

Visible light represents a narrow band between ultraviolet light (UV) and infrared energy (heat).



Three major factors to ensure energy efficiency

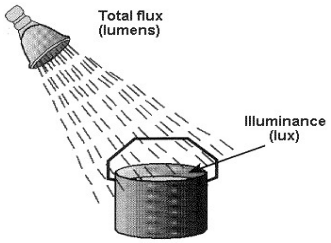
1. Select the most efficient light source
2. Match the proper lamp type to the intended work task (aesthetic ,color, brightness control)
3. Provide adequate light levels without compromising productivity security/safety.



Relative Eye Sensitivity and Luminous Efficacy

2 Basic Parameters and Terms in Lighting System

- **Luminous flux:** The luminous flux describes the quantity of light emitted by a light source.
- It is a measure of the total light output of the lamp. Lights are labeled with an output rating in lumens.
- **Illuminance** is measured in **lux (lumens/square meter)**. Density of luminous flux incident upon a surface.
- **Lux (lx) is** illuminance produced by a luminous flux of one lumens uniformly distributed over a surface area of one square metre



Illuminance decreases by the square of the distance (inverse square law).

The inverse square law states that the intensity of light per unit area is inversely proportional to the square of the distance from the source (essentially the radius).

Example: The illuminance is 10 lm/m² from a lamp at 1 meter distance. What will be the illuminance at half the distance?

Solution: $E_{(1m)} = (d_2 / d_1)^2 * E_2$

$= (1.0 / 0.5)^2 * 10.0$

$= 40\ lm/m^2$

3.Lighting Terms

Circuit Watts: is the total power drawn by lamps and ballasts in a lighting circuit

Luminous Efficacy (lm/W): is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. Unit: lumens per lamp Watt (lm/W).

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.
Unit: lumens per circuit Watt **(lm/W).**

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).**

Installed Power Density: 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 . Unit: Watts per square metre per 100 lux (**W/m²/100 lux**)

Other Lighting Terms

Color rendering index (CRI) is a measure of the degree of color shift that objects undergo when illuminated by the light source as compared reference source. In general, a lower CRI indicates that some colors may appear unnatural when illuminated by a lamp. Color rendering is measured on an index from 0-100, with natural daylight equal to 100.

Luminaire- A complete lighting unit consisting of lamps and the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply

Gear

Ballast is a current limiting device. In case of fluorescent lamps, it aids the initial voltage build-up, required for starting. In an electric circuit the ballast acts as a stabilizer

Igniters -Used for starting high intensity discharge lamps -Metal Halide and Sodium vapour lamps

Types of Lighting Source

1. Incandescent lamps
2. Tungsten Halogen Lamps
3. Fluorescent lamps
4. Compact fluorescent lamps
5. High pressure sodium lamps
6. Low pressure sodium lamps
7. Mercury vapour
8. Metal halide
9. Induction
10. LED lamps

4.Types and performance

Luminous Performance Characteristics of Commonly Used Luminaries

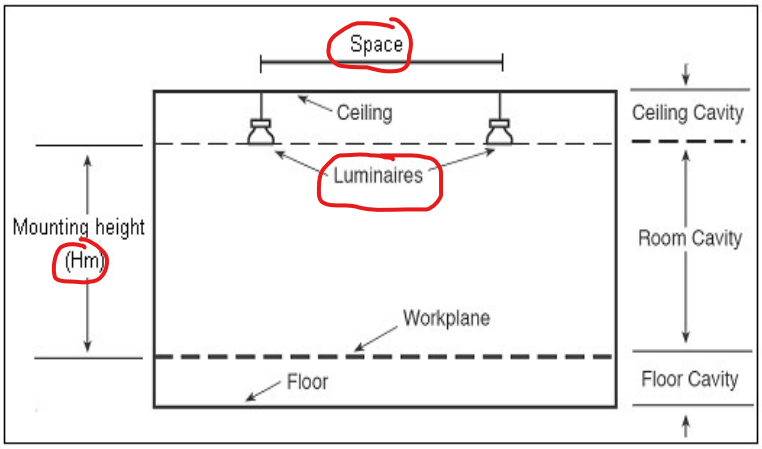
Type of Lamp	Lumens / Watt		Colour Rendering Index	Typical Application	Typical Life (hours)
	Range	Avg.			
Incandescent	8-18	14	Excellent (100)	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent lamps	46-60	50	Good w.r.t. coating (67-77)	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good (85)	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair (45)	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent (100)	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair (22)	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor (10)	Roadways, tunnels, canals, street lighting	6000-12000
Metal halide lamps	75-125	100	Good (70)	Industrial bays, spot lighting, flood lighting, retail stores	8000
LED lamps	50-130	90	Very good (80)	Office, industry, outdoor, retail, hospitality, etc	30,000-60,000
Induction Lamps	65-90	75	Very good (80)	General lighting, factories, warehouse, street lighting, flood lighting, etc	60,000-1,00,000

5 Recommended Illuminance Levels for Various Tasks / Activities / Location

Scale of Illuminance:	The minimum illuminance for all non-working interiors, has been mentioned as 20 Lux (as per IS 3646). A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance.

Petroleum, Chemical and Petrochemical works	
Exterior walkways, platforms, stairs and ladders	30-50-100
Exterior pump and valve areas	50-100-150
Pump and compressor houses	100-150-200
Process plant with remote control	30-50-100
Process plant requiring occasional manual intervention	50-100-150
Permanently occupied work stations in process plant	150-200-300
Control rooms for process plant	200-300-500

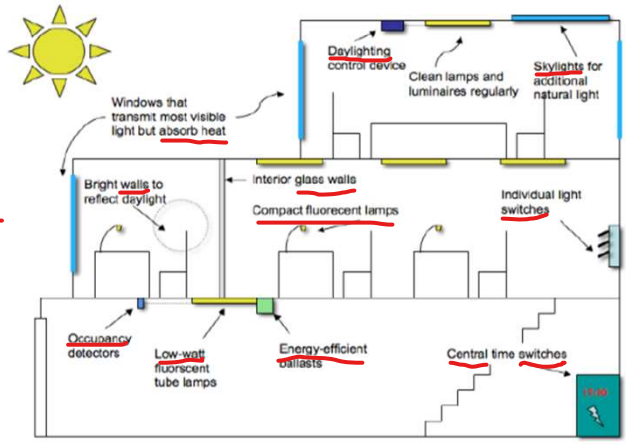
6 Methods of Calculating Illuminance - Lighting Design for Interiors



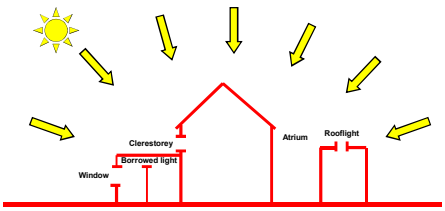
Typical Room Space

7 General Energy Saving Opportunities

1. Use natural day lighting
2. De-lamping to reduce excess lighting
3. Task lighting
4. Selection of high efficiency lamps and luminaries
5. Reduction of lighting feeder voltage
6. Electronic ballasts
7. Lighting controllers
8. Lighting maintenance
9. Clean light fixtures.
10. Consider lowering the fixtures



Case Study of day lighting



8 Energy Efficient Lighting Controls

1. Occupancy Sensors
2. Timed Based Control
3. Daylight Linked Control
4. Localized Switching

Street lighting Controls system are

1. **Timer control** (ON/OFF as per set timing)
2. **Day light control(Based** on illumination level)
3. **Selective switching/Alternate** switching of street lights low traffic density areas (after midnight).
4. Switching control **based on lux levels**.(after midnight)
5. Installations of **Voltage controllers** to be operated after midnight.
6. **Installation of PLC** controlled Lighting panels for effective control and monitoring.

9 Standards and Labeling Programs for FTL Lamps

	1 Star	2 Star	3 Star	4 Star	5 Star
Lumens per Watt at 1000 hrs of use	<61	>=61 & <67	>=67 & <86	>=86 & <92	>=92
Lumens per Watt at 2000 hrs of use	<52	>=52 & <57	>=57 & <77	>=77 & <83	>=83
Lumens per Watt at 3500 hrs of use	<49	>=49 & <54	>=54 & <73	>=73 & <78	>=78

Star Rating scheme for FTL (101 mm upto 40 w)

10 Lighting Case Study

Replacement of existing T12 Fluorescent lamps in street lighting system with LED lamps

Existing: Fluorescent lamp (T12) fixture of 40 numbers is connected to the entire campus for security purpose. All the lights remain in operation for around 12 hours at night (6 p.m. to 6 am) every day throughout the year. All the light fixtures are equipped with electromagnetic ballast which consumes around 12 to 14 watt of additional power while in operation. Hence the power consumption of a single fluorescent light fixture considering minimum ballast loss is 40+12=52 watts. The total light output of all the fluorescent light fixtures is around 2400 lumen.

Proposed: It was proposed to replace existing lamps with high efficient LED lamps of 18 W with a luminous efficacy of around 120-140 lm/w. The total luminous output of these lamps is around 2340 lumen.

Existing Fittings			
No of FTL-T12 lamps installed	=	40	No's
Wattage Consumed			
40 No's of (40W+12W (Ballast)=52 W)	=	2.1	kW
Average operating hours per day	=	12	hrs/day
Total energy consumed by operating lights	=	25	kWh/day
Annual energy consumption by operating the lights (365 days/year)	=	9125	kWh/year
Proposed option			
Replacement of all 40 no's of 40 Watts T12-FTL with 18 Watts LED lamps			
Total energy consumed by operating with LED	=	0.72	kW
Average operating hours per day	=	12	hrs/day
Total kWh/day consumed by operating lights	=	9	kWh/day
Annual energy consumption by operating the lights (365 days/year)	=	3285	kWh/year
Savings			
Total energy reduction per annum	=	5840	kWh/year
Annual monetary savings (@Rs. 5/unit)	**=**	***29,200***	***Rs./year***
Investment @ **Rs.2500/ Lamp**	=	1.0	Lakhs
Simple payback period	=	3.4	Years

QUESTIONS	
Objective Type Questions	
1.	The unit of one lux is a) 1000 lumen per square feet b) 10 lumen per square meter c) 1 lumen per square meter d) 1 lumen per square feet
2.	Luminous efficacy of a lamp is given by a) Lux/Watt b) lumens/Watt c) Watt/Lux d) Watt/lumens
3.	A fluorescent tube light fitted with an electronic choke will a) operate at 50 Hz b) not need a starter c) operate at 0.5 power factor d) none of the above
4.	A device that distributes and filters the light emitted from one or more lamps is a) control gear b) lamp c) luminaire d) starter
5.	The T2,T5,T8 and T12 fluorescent lamps are categorized based on a) diameter of the tube b) length of the tube c) both diameter and length d) none of the above

Thank You

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Save energy and water for Sustainable Life