PRINCIPLES OF ILLUMINATION

CHAPTER - 1

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1.1. INTRODUCTION

DEFINITION OF TERMS:

Illumination is defined as the intensity of light per unit area.

Electric Illumination is the production of light by means of electricity and its application to provide efficient, comfortable and safe vision.

FACTORS IN LIGHTING DESIGN

- **The quantity of light** – the amount of illumination or luminous flux per unit area. It deals with the number of light fixtures required for a certain area.
- **The quality of light** – pertains to the distribution of brightness in the lighting installation. It deals with the essential nature or characteristic of light.

ELEMENTS OF THE QUALITY OF LIGHT

- ✓ Brightness
- ✓ Brightness Ratio or Contrast
- ✓ Glare
- ✓ Diffuseness
- ✓ Color
- ✓ Psychological Reaction to Color and Fixtures
- ✓ Aesthetic
- ✓ Economics

FACTORS THAT AFFECT ILLUMINATION

- **Brightness** is the light that seems to radiate from an object being viewed.
- **Contrast** is the difference in brightness or the brightness ratio between an object and its background. The recommended ratio is 3:1
- **Glare** is a strong, steady, dazzling light or reflection.
- **Diffuseness** pertains to the control of shadows cast by light. **Perfect diffusion** is an equal intensity of light clashing from all directions producing no shadows.

TYPES OF GLARE

- **Direct Glare** is the annoying brightness of light in a person's normal field of vision.
- **Indirect or Reflected Glare** is much more serious and difficult to control. Technically, reflected glare is a glossy objects.

CHARACTERISTICS OF COLORATION

- **Hue** – is the quality attribute by which we recognize and describe colors as red, blue, yellow, green, violet and so on.
- **Brilliance or Value** – the difference between the resultant colors of the same hue, such as, white is the most brilliant of the neutral colors while black is the least.
- **Saturation or Chromate** – the difference from the purity of the colors. Colors of high saturation must be used in a well lit spaces.

1.2. ESTIMATING ILLUMINATION AND BRIGHTNESS

There are three types of luminance meters:

1. Comparator Type – requires the operator to make a brightness equivalence judgment between the target and the background.
2. Direct Reading Type – is basically an illumination meter equipped with a hooded cell arranged to block oblique light.
3. Accurate Laboratory Instrument – that is unsuitable for field work.

FOOTCANDLE – is the amount of light flux density. The unit of measure used when describing the amount of light in a room and is expressed in lumens per square foot.

$$\text{Footcandle } (f_c) = \frac{\text{Lumens}}{\text{Area}}$$

FOOTLAMBERT (f_l) is defined as the luminance of a surface reflecting, transmitting or emitting one lumen (lm) of illumination per square foot of area in the direction being viewed or the conventional unit of brightness or luminance.

LUMENS (lm) is the light output generated continuously by a standard wax candle.

Example 1: A 40-watt fluorescent lamp 120 centimeters (48 in.) long produces 3,200 lumens of light in a room having a general dimensions of 10 x 20 ft. Find the illumination on the floor.

Solution:

Footcandle (f_c) = lm / Area

= 3,200 / (10 x 20)

= 16 footcandle *answer*

The luminance or brightness of a diffusely reflecting surface is equal to the product of the illumination and the reflectance. Thus;

Luminance = Illumination x Reflectance Factor or

$$\text{Luminance} = \frac{(\text{Total Lumens} \times \text{Transmission Factor})}{\text{Area of Diffuser}}$$

Footlambert = Footcandle x Reflectance Factor

Example 2: From example 1, find the luminance if the reflectance factor of the wall is 40%.

Solution:

Footcandle (f_c) = 16 footcandle

Footlambert = footcandle x reflectance factor

= 16 x 40%

= 6.4

answer

Lighting Units in Metric Measures

DESCRIPTION	ENGLISH	METRIC (SI)
Length	Feet	Meter
Area	Square foot	Square meters
Luminance Flux	Lumens	Lumens
Illumination Flux Density	Footcandles	Lux
Luminance	Footlamberts	Lamberts

Illumination or light flux is expressed in Lux. Thus;

Lux = lumens / Area (sq. m)

Conversion factor:

one footcandle = 10.76 lux

one lux = 0.09294 f_c

millilambert = footlambert x 1.076

Example 3: Compute the brightness of a fixture with a 1' x 4' plastic diffuser having a transmittance of 0.6 and illuminated by 2 pieces 3,200-lumen lamp assuming 100% use of light flux.

Solution:

$$\text{Luminance} = \frac{(\text{Total Lumens} \times \text{Transmission Factor})}{\text{Area of Diffuser}}$$

$$= \frac{2 \times 3{,}200 \times 0.6}{1' \times 4'}$$

$$= 960 \text{ footcandle}$$ *answer*

or $= 960\ f_c \times 1.076$

$= 1{,}032.96$ millilambert *answer*

The Watts Per Square Meter

Another method used in determining the illumination, is the **Watts per Square Meter.**

The floor area is computed from the outside dimensions of the building excluding open porches.

$1\ W/m^2 = 50 – 100\ lux \cong 5 – 10\ f_c$

- Industrial: $20\ W/m^2 = 100 – 150\ lux \cong 10 – 15\ f_c$
- Commercial: $22\ W/m^2 = 80 – 120\ lux$
- Greater Illumination: $40\ W/m^2 = 200\ lux \cong 20\ f_c$
- Conventional Requirements: $60\ W/m^2 = 300\ lux \cong 30\ f_c$
- $80\ W/m^2 = 300 – 350\ lux$

1.3. COEFFICIENT OF UTILIZATION & MAINTENANCE FACTOR

- Initial Footcandle or Lux = to the footcandle produced by the Coefficient of Utilization (cu)
- Lamp output normally drops and it is termed as Maintenance Factor (mf).
- The efficiency of a light fixture is equal the ratio of fixture output lumens to lamp output lumens. It is called coefficient of utilization (cu).

$$\text{Initial Illumination} = \frac{\text{Produced (lamp) Lumens x c.u.}}{\text{Area}}$$

$$\text{Maintenance Illumination} = \frac{\text{Lamp lumens x cu x mf}}{\text{Area}}$$

Coefficient of Utilization

FIXTURE DESCRIPTION	c.u.
Efficient Fixture, Large Unit Colored Room	0.45
Average Fixture, Medium Size Room	0.35
Inefficient Fixture, Small or Dark Room	0.25

Maintenance Factor

FIXTURE DESCRIPTION	m.f.
Enclosed Fixture, Clean Room	0.80
Average Conditions	0.70
Open Fixture or Dirty Room	0.60

Example 4: A school classroom with general dimensions of 24 x 30 feet is lighted with 10 fluorescent fixtures each containing 4F 40W T12 WW rapid start lamp. Calculate the initial and maintained illumination in footcandle and lux, assuming that the coefficient of utilization is 0.35 and the maintenance factor is 0.70

Solution:

Lumens/lamp = 3,200 lm

Lamp Lumens = # of fixture x lamps/fixture x lumens/lamp

= 10 x 4 x 3,200

Lamp Lumens = 128,000 lm

$$\text{Initial Illumination} = \frac{\text{Produced (lamp) Lumens x c.u.}}{\text{Area}}$$

$$= \frac{128,000 \times 0.35}{24 \times 30}$$

$$= 62.2\ f_c$$

answer

Example 4: A school classroom with general dimensions of 24 x 30 feet is lighted with 10 fluorescent fixtures each containing 40W T12 WW rapid start lamp. Calculate the initial and maintained illumination in footcandle and lux, assuming that the coefficient of utilization is 0.35 and the maintenance factor is 0.70

Solution:

Lumens/lamp = 3,200 lm

Lamp Lumens = # of fixture x lamps/fixture x lumens/lamp

= 10 x 4 x 3,200

Lamp Lumens = 128,000 lm

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$$\text{Maintained Illumination} = \frac{\text{Lamp Lumens x c.u. x m.f.}}{\text{Area}}$$

$$= \frac{128{,}000 \text{ x } 0.35 \text{ x } 0.70}{24 \text{ x } 30}$$

$$= \frac{31{,}360}{720}$$

Maintained Illumination = 43.55 f_c *answer*

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Initial Illumination = $(\text{Initial Illumination})_{\text{footcandle}}$ x 10.76 lux/footcandle

= 62.22 x 10.76

Initial Illumination = 669.49 lux *answer*

Maintained Illumination = $(\text{Illumination})_{\text{footcandle}}$ x 10.76 lux/f_c

= 468.49 lux *answer*

Example 5: An office room with general dimensions of 8 x 20 meters is to be lighted at an average maintained lux of 50. How many 3-lamp fixtures of 120 centimeters long F40 T12 WW rapid start fluorescent lamps are required assuming 0.38 cu and 0.75 mf?

Solution:

Lumens/lamp = 3,200 lm

$$\text{Lamp Lumens} = \frac{\text{maintained illumination x area}}{\text{cu x mf}}$$

$$= \frac{50 \text{ lux x } (8 \text{ x } 20)}{0.38 \text{ x } 0.75}$$

Lamp Lumens = 28,070 lm

Example 5: An office room with general dimensions of 8 x 20 meters is to be lighted at an average maintained lux of 50. How many 3-lamp fixtures of 120 centimeters long F40 T12 WW rapid start fluorescent lamps are required assuming 0.38 cu and 0.75 mf?

Solution:

Number of Lamps = Lamp lumens ÷ lumens per lamp

= 28,070 ÷ 3,200

Number of Lamps = 8.77 lamps

Number of fixtures = numbers of lamps ÷ number of lamps per fixture

= 8.77 ÷ 3

Number of fixtures = 2.92 say 3 fixtures *answer*

Formula of computing lamp fixtures per bay or row:

$$\text{Number of Fixtures} = \frac{\text{Illumination x Area}}{\text{Lamp/fixture x lumens x cu x mf}}$$

Formula of computing the area lighted by a single fixture:

$$\text{Area per Fixture} = \frac{\text{Lamp per fixture x lumens per lamp x cu x mf}}{\text{Illumination}}$$

1.4. MEASURING FOOTCANDLE

- The unit of the measure of illumination is footcandle or lux
- In measuring illumination level:
  - The meter will be held horizontally with its sensitive surface at least 30 cm from the body of the person holding the meter.
  - If the illumination check inside a room, the meter is held about 80 cm above the floor.
  - The reading should be undertaken throughout the room & the results will be recorded on the plan of each room.

1.5. UNIFORMITY OF LIGHT

The average illumination at the working level is directly related to the maximum spacing of the light to the mounting height ratio represented by:

$$\text{Mounting Height Ratio (MHR)} = \frac{\text{spacing of light fixture (s)}}{\text{mounting height (mh)}}$$

Spacing and Mounting Height Ratio

SYSTEM	RATIO
Direct Concentrating	0.40
Direct Spreading	1.20
Indirect Diffusing	1.30
Semi-indirect Diffusing	1.50

Example 6: A room with a ceiling height of 3 meters is to be lighted with direct concentrating fluorescent light. What is the maximum fixture spacing

Solution:

From table above; MHR = 0.40 for direct concentrating

$$\text{Mounting Height Ratio (MHR)} = \frac{\text{spacing of light fixture (s)}}{\text{mounting height (mh)}}$$

Spacing (S) = 0.40 x 3m

S = 1.20 m (side-side of the fixture) *answer*

1.6. CLASSIFICATION OF LIGHTING SYSTEM

Lighting System is classified into four types:

- ✓ Direct Lighting – when the light on an illuminated area is focused downward coming directly from the lighting fixture.
- ✓ Semi-direct Lighting – when the dominant light on the illuminated area is fed directly from the lighting units wherein the greater amount of light is obtained from the ceiling through reflection.

1.6. CLASSIFICATION OF LIGHTING SYSTEM

Lighting System is classified into four types:

- ✓ Semi-indirect Lighting – A lighting arrangement wherein 5% to 25% of the light is directed downward with one more than half of the light focused upward and reflected from the ceiling.
- ✓ Indirect Lighting – when it is diffused and reflected from a wide ceiling area.

Light Distribution of Various Types of Lighting Systems

Type of Illumination	Percent of Distribution	
	Upward	Downward
Direct Lighting	1 – 10	90 – 100
Semi-direct Lighting	10 – 40	60 – 90
General Diffusing	40 – 60	40 – 60
Semi-indirect Lighting	60 – 90	10 – 40
Indirect Lighting	90 – 100	1 – 10

Thank You!