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Photometry

Photometry

The science of measurement of visible light in terms of its perceived brightness to human vision

It is the measurement of light's brightness, or luminous intensity.

Photometry frequently focuses on the perceived brightness to the human eye. As such, it takes into account the eye's sensitivity to varying degrees of light and focuses primarily on the visible light spectrum.
### Definitions

#### 1. Candela (cd)

The SI unit of luminous intensity, or power emitted by a light source in a particular dimension.

A common candle emits light of approximately one (1) candela.

A source of one candela emits one lumen per steradian.

#### 2. Luminous Flux (F or Φ) or Luminous Power

All the radiated power emitted by a light source and is perceived by the eye is called luminous flux.

It is the light energy radiated out per second from the body in the form of luminous light waves.
Definitions

2. Luminous Flux (F or Φ) or Luminous Power

Since it is a rate of flow of energy, we can consider it to be a sort of power unit.

The unit of luminous flux is *lumen* (lm). Which is defined as the flux contained per unit solid angle of a source of one candela.

1 lumen is approximately 0.0016 watts.

Definitions

3. Luminous Intensity (I) or Candle Power

The luminous intensity or candle power of a point source in any particular direction is given by the luminous flux radiated out per unit solid angle in that direction.

It is the solid angular flux density of a source in a specified direction.

\[ I = \frac{d\Phi}{d\omega} \]

Where: \( d\Phi \) is the luminous flux radiated out by a source within a solid angle of \( d\omega \) steradian in any direction.
Definitions

3. Luminous Intensity (I) or Candle Power
With the flux measure in lumens and the solid angle in steradians, the unit of Luminous intensity is lumen/steradian (lm/sr) or candela (cd)

Luminous Intensity
“Total Power / Solid angle”
“candle power”

4. Illuminance or Illumination (E)
Total luminous flux incident on a surface, per unit area.

\[ E = \frac{\Phi}{A} \]

When luminous flux falls on a surface, that surface is said to be illuminated.

The unit of illuminance is lumens / unit area (lm / m²) or Lux. An alternative name is meter-candle (m-cd)
5. Luminance (L)

It is the brightness of an illuminated or luminous surface as perceived by the human eye.

The unit of measurement is in candelas per square meter (cd/m²)

6. Lamp Efficacy

The efficacy or efficiency of the lamp refers to the number of lumens leaving the lamp compared to the amount of power (in watts) required by the lamp (with ballast).

It is expressed in lumens per watt.

This is significant because sources with higher efficacy require less energy to light a space or area.
Definitions

7. Luminous Exitance (M) of a surface

The luminous exitance at a point on a surface is defined as luminous flux emitted per unit area in all directions. If an element of an illuminated area $\Delta A$ emits a total flux of $\Delta \Phi$ in all directions (over a solid angle of $2\pi$ steradian), then

$$M = \frac{\Delta \Phi}{\Delta A}$$

Definitions

8. Mean Spherical Candle Power (MSCP)

This is the average candle power of a point source.

Generally, the luminous intensity of a source is different from one direction to another. This is the average value of its candle power in all directions

$$MSCP = \frac{\text{Total Flux (lumens)}}{4\pi}$$
Definitions

9. Mean hemispherical Candle Power (MHCP)

For the average taken over a hemisphere

It is taken by the total flux emitted in a hemisphere (usually the lower side) divided by the solid angle subtended at the point source by the hemisphere.

\[ \text{MHCP} = \frac{\text{Total Flux in a hemisphere (lumens)}}{2\pi} \]

Definitions

**Lighting Terminologies and Basic Units**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Symbol</th>
<th>Unit (SI)</th>
<th>Definition of unit</th>
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<tbody>
<tr>
<td>Luminous Intensity</td>
<td>Ability of the source to produce light in a given direction</td>
<td>( I )</td>
<td>Candela (cd)</td>
<td>Approx equal to the luminous intensity produced a by standard candle</td>
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<tr>
<td>Luminous Flux</td>
<td>Total amount of light</td>
<td>( \Phi )</td>
<td>Lumen (lm)</td>
<td>Luminous flux emitted in a solid angle of 1 steradian by a 1 candela uniform point source</td>
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<tr>
<td>Illuminance (Illumination)</td>
<td>Amount of light received on a unit of surface (density)</td>
<td>( E )</td>
<td>Lux (lx)</td>
<td>One lumen equally distributed over one unit area of surface</td>
</tr>
<tr>
<td>Luminous Exitance</td>
<td>Density of light reflected or transmitted from a surface</td>
<td>( M )</td>
<td>Lm/m²</td>
<td>A surface reflecting or emitting 1 lumen per unit area</td>
</tr>
<tr>
<td>Luminance (brightness)</td>
<td>Intensity of light per unit area reflected or transmitted from a surface</td>
<td>( L )</td>
<td>Cd/m²</td>
<td>A surface reflecting or emitting light at the rate of 1 candela per unit of projected area</td>
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Definitions

Summary

Laws of Illumination
Laws of Illumination or Illuminance

The illumination of a surface depends on the following factors. (the assumption that the source is a point source, or is otherwise sufficiently far away from the surface)

1. Illuminance (E) is directly proportional to the luminous intensity (I) of the source. E α I

2. Inverse Square Law. The illumination of a surface is inversely proportional to the square of the distance of the surface from the source.

\[ E = \frac{1}{r^2} \]

3. Lambert's Cosine Law. The illuminance is directly proportional to the cosine of the angle made by the normal to the illuminated surface with the direction if the incident flux

The luminous flux on the first surface is; \( E_1 = \frac{\Phi}{A} \)

The luminous flux on the second surface is; \( E_2 = \frac{\Phi}{A} \cos \theta \)
Laws of Illumination or Illuminance

Combining all the factors together.

with \( I = \frac{\Phi}{A} \)

We obtain:

\[
E = \frac{I \cos \theta}{r^2}
\]

The unit is lm/m²

Example 1
A lamp giving out 1200 lm in all directions is suspended 8m above the working plane. Calculate the illumination at a point on the working plane 6m away from the foot of the lamp.

Ans. 0.764 lm/m²

Example 2
A small light source with intensity uniform in all directions is mounted at a height 10m above a horizontal surface. Points A and B lie on the surface with point A directly beneath the source. How far is B from A if the illumination is only an tenth as great as A?

Ans. 19.1m
Laws of Illumination or Illuminance

Illumination at multiple points

\[ E_B = E_A \cos^3 \theta_1 \]
\[ E_C = E_A \cos^3 \theta_2 \]
\[ E_D = E_A \cos^3 \theta_3 \]

Example 3
A 2400 lumen lamp is suspended 10m above point A. find the illumination at points A, B and C if B and C is 5 and 10m away from point A respectively.

Ans. 1.91 lm/m², 1.367 lm/m², 0.675 lm/m²

Example 4
A corridor is lighted by 4 lamps spaced 10m apart and suspended at a height of 5m above the center line of the floor. If each lamp gives 200 lux in all directions below the horizontal, find the illumination at the point on the floor on the mid-way between the second and third lamps.

Ans. 6.16 lm/m²
Example 5
Two lamps A and B of 200cd and 40cd respectively are situated 100m apart. The height of A above the ground level is 10m and that of B is 20m. If a photometer is placed at the midpoint of the two lamps, what will be its reading?
Ans. 0.066 lm/m²

Example 6
The average luminous output of an 80W fluorescent lamp 1.5m in length and 3.5cm I diameter is 3300 lumens. Calculate the average brightness. If the auxiliary equipment associated with the lamp consumes a load equivalent to 25% of the lamp, calculate the cost of operating a twin unit for 2500hrs at Php 0.030.
Ans. 6,366 cd/m², Php15

Example 7
A lamp of 100cd is hung 1m below a plane mirror which reflects 90% of the light falling on it. The lamp is hung 4m above the ground. What is the illumination at a point on the ground 3m away from the point vertically below the lamp
Ans. ---
Laws of Illumination or Illuminance

Coefficient of Utilization or Utilization Factor ($\eta$)

It is the ratio of the lumens that actually received by a particular surface to the total lumens emitted by a light source.

$$\eta = \frac{\text{Lumens actually received on the work plane}}{\text{Lumens emitted by a light source}}$$

Laws of Illumination or Illuminance

Coefficient of Utilization or Utilization Factor ($\eta$)

The value of this factor varies widely and depends on the following factors:

1. Type of lighting system (direct or indirect)
2. Type and mounting height of the fittings
3. Color and surface of walls and ceilings
4. Shape and dimension of the room
Example 8

Determine the average illumination of a room measuring 9.15m by 12.2m illuminated by a dozen 150W lamps. The luminous efficiency of the lamps are 14 lm/w and the coefficient of utilization is 0.35.

Ans. 79 lux