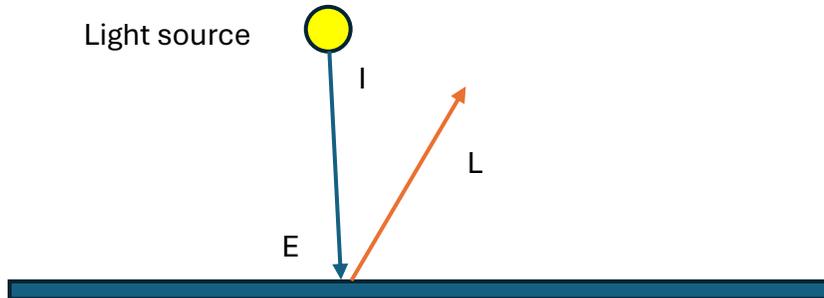


Making Sense of Photometry

Start with the definitions:



Luminous Flux (Φ): the rate of flow for light energy.

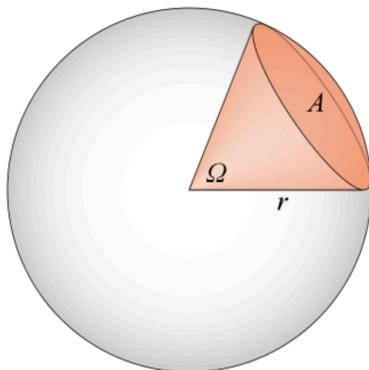
Luminous Intensity (I): the Luminous Flux (rate of flow of light energy) from a source.

Illuminance (E): the Luminous Flux incident on a surface.

Luminance (L): the light emitted (transmitted or reflected) in a given direction.

Measurement	Symbol	Units	Formula
Steradian	ω	steradian	A/d^2 , $A = \text{area}$
Luminous Flux	Φ	lumens	$\Phi = I\omega$
Intensity	I	Candela (cd)	$I = \Phi/\omega$
Illuminance	E	lux (lumens/area)	$E = \Phi/A$, $A = 4\pi r^2$
Luminance	L	(cd/m ²)	$L = I/A(\cos\theta)$

The Steradian



A = area
 R = radius
 Ω = solid angle (ω)

The total space around a point = 4π steradians

The Fundamental Laws of Photometry

Inverse Square Law

The inverse square law states that the illuminance on a surface is inversely proportional to the square of the distance between the point and the source.

$$E = \frac{I}{r^2}$$

Cosine Law

The cosine law states that if the normal to the illuminated surface is at an angle θ to the direction of the incident light, the illuminance is proportional to the cosine of θ .

$$E = \frac{I}{r^2} (\cos \theta)$$

Problem Types

Calculate Luminous Flux (lumens) when given Intensity (candela or foot-candles)

Calculate the Intensity of a light source.

When given luminous flux (lumens)

When given Illumination (lux) on a surface (lumens/area)

Calculate Illuminance on a surface from a light source.*

When given Intensity (cd) and distance (metric or imperial units) (inverse square law)

Calculate the Luminance of a surface.

Calculate the change in luminance with increase or decrease in distance.

*When calculating Illuminance on a surface the light source is usually be treated as a point source if Intensity is known (when intensity is provided in candela or foot-candles).

Examples

Intensity (find intensity given luminous flux)

A 400 lumen bulb emits a light in a half sphere. What is the intensity of the light: (Assume the bulb approximates a point source).

What is the question asking: find the intensity of the light source.

Intensity (luminous intensity (I)) is the rate of flow of light energy from the source.

The Luminance Flux (expressed in lumens) is provided: 400 lumens.

Intensity is measured in candelas (formerly foot-candles).

One candela is 1 lumen / steradian.

Steradians in a hemisphere is 2π steradians.

Intensity: $I = \Phi/\omega$

Intensity = 400 lumens / $2(3.14) = \mathbf{63.69 \text{ candela}}$

Luminous Flux (find luminous flux when given intensity and source type)

What is the rating (in lumens) of a light bulb that has an Intensity of 99.5 candela:

We are solving the problem for Luminous Flux (in lumens).

The Intensity of the source is 99.5 candela.

A bulb has 4π steradians.

Luminous Flux (Φ) = $I\omega$

Luminous Flux = 99.5 cd x 4π

Luminous Flux = **1250 lumens**

Intensity (find intensity when given illuminance and distance)

The illuminance of the earth's surface during a full moon is 0.02 lm/ft^2 and the distance between the earth and moon is 235,000 miles. What is the intensity of the moon light.

Question: what is Intensity (I)?

Illumination E (using inverse square law) = I/d^2

$$I = E \times d^2$$

$$d = 235,000 \times 5,280 = 1,240,800,000 \text{ft}$$

$$d^2 = (1.24 \times 10^9)^2 = 1.54 \times 10^{18}$$

$$I = 0.02 \text{lm/ft}^2 \times (1.54 \times 10^{18})$$

$$\text{Intensity} = \mathbf{3.08 \times 10^{16} \text{ candela}}$$

Illuminance (find using Inverse Square Law / Cosine Law)

A lamp with an intensity of 100candela is 4m directly above a point P on the floor of a room.

- A. What is the illuminance at point P.
- B. What is the illuminance produced at another point on the floor 6m from P.

A. What is the Illuminance at P:

Inverse Square Law: $E = I/d^2$

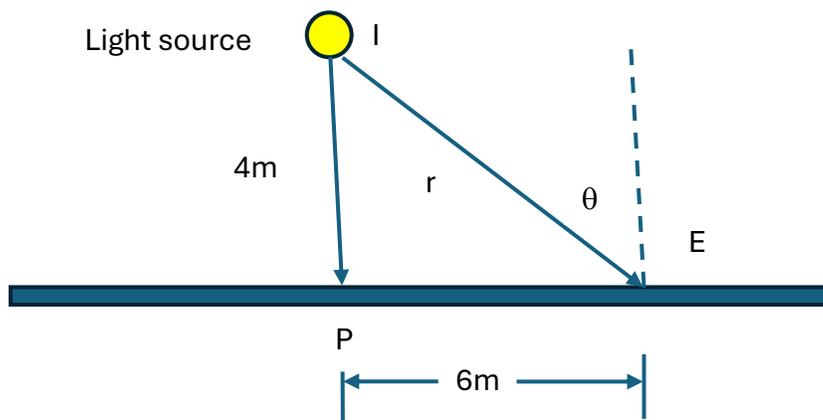
$$\text{Illuminance} = (100\text{cd}) / (4)^2$$

$$\text{Illuminance} = 100 / 16$$

$$\text{Illuminance} = \mathbf{6.25 \text{ lux}}$$

B. What is the Illuminance 6m from P:

Use Cosine Law



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

I is Intensity (100cd)

r is hypotenuse of triangle

θ is angle of light source from normal to surface at point of interest

$$r^2 = 4^2 + 6^2 = 52$$

$$r = 7.2\text{m}$$

$$\cos \theta = 4/7.2$$

$$\cos \theta = 0.556$$

$$E = (100\text{cd} / 52)(0.556)$$

$$\text{Illuminance} = \mathbf{1.07 \text{ lux}}$$

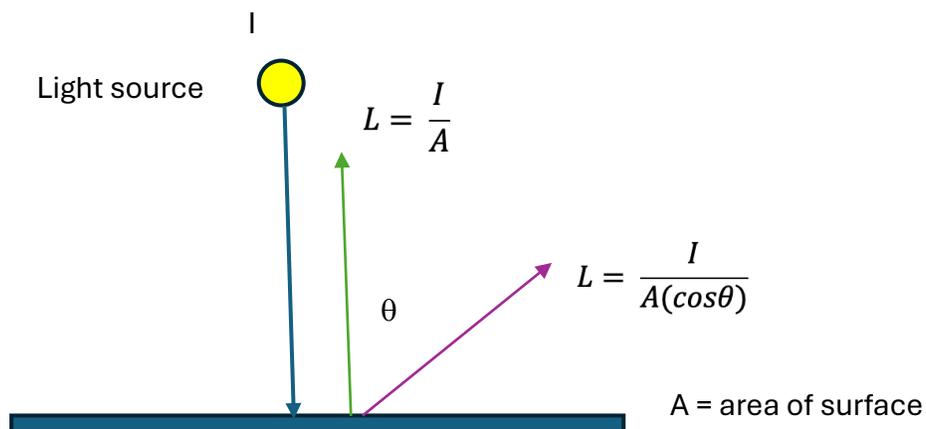
Luminance

Luminance is a measurement of the apparent brightness of a surface due to diffuse reflection.

Illuminance does not depend on the nature of the surface, but Luminance does.

Luminance normal to the surface is the Intensity of reflected light divided by the area of the surface: $L = I/A$.

If the Luminance is measured at an angle from normal (θ), the Luminance = $I / (A \times \cos\theta)$.



Luminance example

A barn has a luminance of 100 cd/m^2 at 30 meters. What is the luminance of the barn at 10 meters:

Step 1: assess information given: Luminance and distance.

Step 2: recall the formula for Luminance is $L = I/A(\cos\theta)$.

In this case $\theta = 0$ degrees, so $\cos\theta = 1$.

Need to find Intensity.

Step 3: Apply inverse square law to find Intensity (I).

At 30 meters:

$$L = I/d^2 \text{ so } I = d^2L$$

$$I = 30^2 \times 100\text{cd/m}^2$$

$$I = 90,000\text{cd}$$

At 10 meters:

$$L = I/d^2$$

$$L = 90,000/100$$

$$L = \mathbf{900\text{cd/m}^2}$$

Luminance example

An extended source has a luminance of 500cd/m^2 . If the source has a diameter of 0.5m, what is the intensity:

Given luminance find intensity.

$L = I/A$ so need to determine area(A) of source.

Area of circle is πr^2

$$\text{Area of source} = 3.14 \times (0.25)^2 \quad A = 0.196 \text{ square meters}$$

$$L = I/A$$

$$I = LA$$

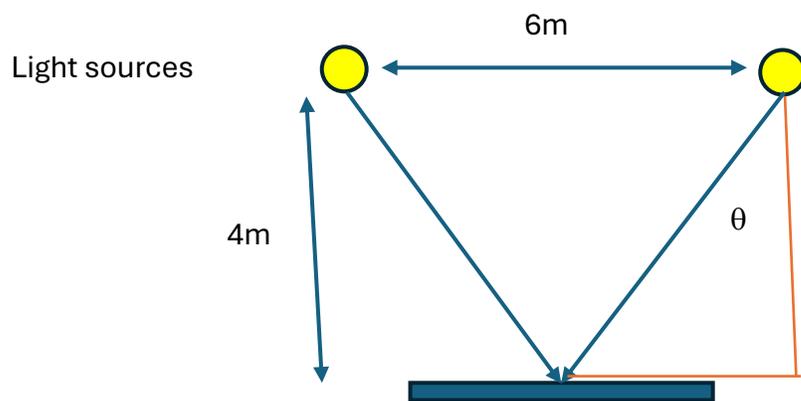
$$\text{Intensity} = 500\text{cd/m}^2 \times 0.196\text{m}^2$$

$$\text{Intensity} = \mathbf{98\text{cd}}$$

Illuminance with 2 sources

A picture is illuminated by 2 lamps of 50 cp each which are 6m apart and 4m from the plane of the picture. If the picture is placed centrally between the two lamps, find the illumination at the center of the picture:

Step 1: draw a diagram



Step 2: use cosine law to find illumination from each source

$$E = (I/r^2)\cos\theta$$

Use trig to find r : $r^2 = 3^2 + 4^2$, so $r^2 = 25$

$$\cos\theta = 4/5 = 0.8$$

$$E = (50/25) \times 0.8$$

$$E = 1.6\text{cd}$$

Total illuminance on picture is $2 \times 1.6\text{cd} = \mathbf{3.2\text{cd}}$