

Optics 2

Module 5 Summary

Photometry & Radiometry

Photometry: measuring light in terms of its perceived brightness to the human eye

Radiometry: measuring electromagnetic radiation(EMR) including visible light

Light Bulbs (specification)

Watts: electrical consumption

Lumens: light output

Lumens: perceived amount of output or brightness of a source

Takes into account the color sensitivity of the human eye.

The more lumens the brighter the source.

Wattage: defines how much energy a light bulb uses to produce a certain brightness or luminous output (number of lumens).

Color Temperature

A way to describe the appearance of light.

Measured in Kelvin (K) from 1,000 to 10,000 K

Kelvin

Absolute zero (0K) is equivalent to -273.15°C (-459.67°F).

Conversion from Celsius to Kelvin $T(\text{K}) = T(^{\circ}\text{C}) + 273.15$.

Color Temperature

A heated metal object glows with various colors (orange, yellow, blue) depending on temperature.

Color temperature is meant to replicate Kelvin temperature of heated metal object.

Light Output

Based on Area

Point Source: zero area

Extended Source: finite area

Based on Wavelength

Monochromatic Source: Single Wavelength

Polychromatic Source: Multiple Wavelengths

Brightness: the visual system's sensitivity to color

Luminosity Curve or $V\lambda$ curve

Brightness depends on how the visual system detects light and color.

Photopic: Daylight or Cone vision

Scotopic: Night or Rod vision

Radiometry

Absolute measure of light.

Not compensated for eye's sensitivity to color.

Measures all types of EMR.

Photometry

Measure of light compensated for eye's sensitivity to color.

Wavelength dependent.

Measures visible EMR.

Measures of Quantity of Light Emitted

Energy (E)

Flux (Φ)

Intensity (I)

Luminance (L)

Measures of Quantity of Light Received

Illumination / Illuminance / Irradiance (E)

Amount of light falling on an object or surface

Must Distinguish Between:

1. The amount of light emitted by a point source
Luminous Flux and Luminous Intensity
2. The amount of light received on a surface
Illumination or Illuminance
3. The amount of light emitted or re-emitted by a surface
Luminance (brightness)

Quantum Concept: Wavelike photon

Light of given wavelength exists in packets

$$E = hf \text{ and } f = c/\lambda \text{ therefore: } E = hc / \lambda$$

Radiometric Unit: Radiant Energy: Joule

Photometric Unit: Luminous Energy: Talbot

Shorter wavelengths have more energy.

Higher frequencies have more energy.

Flux

Joules / sec = watts (Φ) (not the same as electrical watt)

Talbot / sec = Lumens (Φ)

Sensitivity is a function of wavelength.

Intensity (I)

Radiant Intensity: watts / steradian (I)

Luminous Intensity: lumens / steradian (I)

Angle vs Solid Angle (Radian vs Steradian)

Radian (rad)

$$1 \text{ radian}(\text{rad}) = \frac{\text{arc of same length as radius}}{\text{radius}}$$

Full circle has 2π radians (2π)

Semi-circle has π radians (π)

Steradian (ω) omega

3D geometry of a solid angle

$$\omega = \frac{\text{area}}{\text{distance}^2} = \frac{A}{d^2}$$

Sphere = 4π steradians

Hemisphere = 2π steradians

Flat Surface = π steradians

Example Problems

A source has an area of 3000 cm² and a solid angle of 0.30 steradians. What is the distance of the source?

$$\omega = \frac{\text{area}}{\text{distance}^2}$$

$$d^2 = A/\omega \quad d^2 = 3000 \text{ cm}^2 / 0.30 \quad d = (10,000)^{-1/2}$$

$$d = 100\text{cm}$$

If a point source emits 100 lumens in 2π steradian, what is the candle power of the source?

$$\text{Candle power} = \text{cd} = \text{lumens/steradian} = I$$

$$\text{candle power} = \frac{\text{flux}}{\text{solid angle}} = \frac{\phi \text{ (lumens)}}{\omega \text{ (steradians)}} = \frac{100}{2\pi} = 15.92 \text{ candela}$$

Illumination

Inverse Square Law

The illuminance onto a surface decreases exponentially with the square of the distance from a point source.

$$E = I/d^2$$

E = (lux): (illuminance)

I = candela (cd): intensity

d = (cm or m): distance from point source

Lambert's Cosine Law

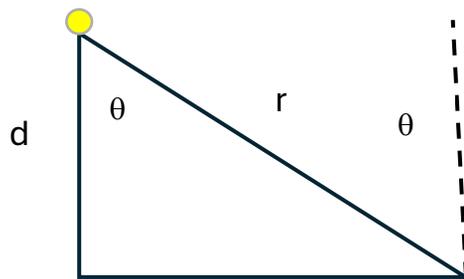
Lambertian Reflection

The property of a surface where light is scattered equally in all directions, regardless of the angle at which it hits the surface.

When the surface is not normal / perpendicular to the source, the perceived / apparent surface area is reduced, and the illuminance decreases linearly with the angle of the surface from the normal.

The projected area is reduced by the amount of the angle from normal.
Called the foreshorten area.

Area varies as the cosine of the normal area.



d: distance from source to normal

r: distance from source due to angle

$$A_{\theta} = A_0 \cos\theta$$

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

E = lux

I = candela

r = cm or m

θ = degrees