Daylighting

Light Sources

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Daylighting

Daylighting characteristics

Light sources and luminaires

Daylighting characteristics

1. Light sources
2. Luminaires
3. Design
4. Illumination characteristics
5. Energy sources
6. Luminaire location
7. Daylighting and artificial lighting co-existence
Artificial Lighting

**Light sources:**
- incandescent light sources
- fluorescent tubes
- LEDs, OLEDs

Daylighting

**Light sources**
- direct sunlight
- diffused light of the sky
- reflected light by the exterior surfaces (such as: neighbor building)

Artificial Light

**Light sources:**
- incandescent light sources
- fluorescent tubes
- LEDs, OLEDs

**Luminaires**
- direct,
- semi-direct,
- diffused,
- semi-indirect,
- indirect characteristics
Daylighting

**Light sources**
- direct sunlight
- diffused light of the sky
- reflected light

**Luminaires**
- **Openings:**
  - side-lights (such as windows)
  - skylights
- **Special daylighting systems**

Daylighting: light sources

**Sun radiation**

**The source of daylighting**
- determines it basic characteristics of daylight
- parallel radiation arrives from the sun
- the atmosphere scatters and transforms the radiation provided by the sun
Daylighting: light sources

*Projected to a definite point of the interior*

**Sun:** direct sun radiation through the atmosphere

**Sky:** diffused light of the sky

**Environment:** artificial and natural environment that reflects daylight
Daylighting: light sources

Direct Sunlight  Diffused sky-light  Exterior surfaces

Direct	 Sunlight Diffused	 sky-light Exterior	 surfaces

Daylighting: light sources

Direct Sunlight

1. **Variable sunlight direction**
   (Sun path diagram)
2. **Illuminance** ($E_{\text{sun}}$):
   
   0 - 50,000 lx
3. **Color temperature** ($T$):
   
   2500 – 5800 K
4. **Color rendering** ($R_a$):
   
   excellent
5. **Frequency**: 50% probability

C.I.E.

color diagram

(1931)

CIE:
Commission internationale
de l'éclairage

International Commission
on Illumination

www.cie.co.at
Color Rendering: $R_a [-]$

The color rendering of daylight is always excellent, regardless the part of the year of the time of the day.
Color Rendering

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Direct Sunlight

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Direct Sunlight

**Variable direction of sunlight**  
(Sun path diagram)
Sun path diagram: inSOLation

50% Probability of Direct Sunlight
Direct Sunlight

Expected duration of direct Sunlight in the function of orientation in Hungary (considering 14 hours daylight)

- **North**: 2 hours,
- **South**: 12 hours,
- **East-West**: 7 hours,
- **Horizontal plane**: 14 hours

Direct Sunlight

Illuminance: $E_{sun} = 0 - 50.000 \text{ lx}$

Considering the hours of the year, having at 50% probability of direct Sunlight

- The probability of direct Sunlight in Hungary is about **35-45%** during the daylight hours

- Direct Sunlight causes **uneven illumination** and high probability of **glare** (visual discomfort) in the interior
Direct Sunlight

- The probability of direct Sunlight in Hungary is about 35-45% during the daylight hours
- Direct Sunlight causes uneven illumination and high probability of glare (visual discomfort) in the interior

Direct Sunlight

When considering direct Sunlight for the daylighting of the interior the caused glare and related visual discomfort effects must always be considered!

Daylighting: light sources

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The diffused light of the Sky

Characteristics:
1. Luminance distribution proportions (Sky models)
2. Illuminance caused on the unobstructed horizontal plane \(E_{\text{exterior}}\)
3. Duration of daylight
4. Color temperature
5. Color rendering

The Sky model:

more or less transparent hemisphere where the transparency constantly varies

the sky hemisphere is much greater than the interior space therefore the interior space model is always at the center of the sky model

Diffused Sky light

Luminance distribution proportions of the sky models

- overcast sky
- foggy sky
- clear sky
Luminance distribution-proportions of the foggy sky model

$L_\theta = \text{constant}$
Luminance distribution-proportions of the overcast sky model

\[ L_0 = \frac{1 + 2 \sin \theta}{3} \]

Luminance distribution-proportions of the clear sky model

\[ L = L_2 \left( 1 - e^{-\sin \theta} \left( 0.91 + 10e^{-3z} + 0.45 \cos^2 \varphi \right) \right) \]

\[ 0.274 \left( 0.91 + 10e^{-3z} + 0.45 \cos^2 \varphi \right) \]
**D_f : The Daylight factor**

The illuminance caused on the unobstructed horizontal external plane ($E_{\text{external}}$) is proportional to the illuminance caused at a defined point of the interior ($E_{\text{internal}}$)

$$D_f = \frac{E_{\text{in}}}{E_{\text{ex}}} [%]$$

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**The diffused light of the Sky**

Duration of daylight provided by the diffused sky light:
- $E_{\text{ex}}$ characteristics
- 50% probability
- Diagrams describing annual and daily illumination changes

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**Diffused light of the sky**

Illuminance: $E_{\text{ex}} = 0 – 40.000$ lx

Considering the hours of the year, having at 50% probability
Diffused light of the sky

Diffused skylight is available about 4400 hours per year (Hungary).

A = 1 m²

Luminance caused by the diffused sky ≈ (40,000 lx × 4400 h/year)/2 = 8.8 × 10⁷ lm/h luminance annually

Considering artificial light sources:
- Incandescent ≈ 15 lm/W = 5867 kWh/yr.
- Fluorescent t. = 80 lm/W = 1100 kWh/yr.

energy consumption

Considering 47 Ft/kWh energy costs:
- Inc. = 5867 × 47 = 275,000 Ft/yr.
- Fluorescent t. = 1100 × 47 = 51,000 Ft/yr.
Diffused light of the sky

**Color temperature**
- Overcast sky: 4,500-7,000K
- Clear sky: 10,000 – 50,000K

**Color rendering:** excellent

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Diffused light of the sky

The diffused sky light causes more uniform **illuminance distribution** in the interior than the direct sunlight!

**Available** all through the day over the entire year (4400 hours per year in Hungary)

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Diffused light of the sky

The diffused sky light is the **primary light source** of daylighting!
Daylighting: light sources

Direct Sunlight  Diffused sky-light  Exterior surfaces

Reflected light from the exterior surfaces

**Exterior** surfaces

**Reflect** the light of the sun and of the sky towards the interior space

**Modify** the amount and characteristics of the reflected daylight
Reflected light from the exterior surfaces

The role of obstructions

- obstruct part of the sky hemisphere
- reflect light from the other parts of the sky hemisphere into the interior

The role of obstructions

The amount and characteristics of the reflected light is determined by the
- geometry
- surface properties (reflectance)
  of the obstructions
Obstructions: geometry

Obstructions: surface properties

Reflected light from the exterior surfaces

The reflected light from the exterior considered as a secondary light source of daylighting
Daylighting

1. Comparing daylighting to artificial lighting
2. Light sources: sun, sky, external surfaces
3. Sky models, Daylight factor