

# VISUAL PERFORMANCE (NATURAL & ARTIFICIAL LIGHTING)

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# Introduction

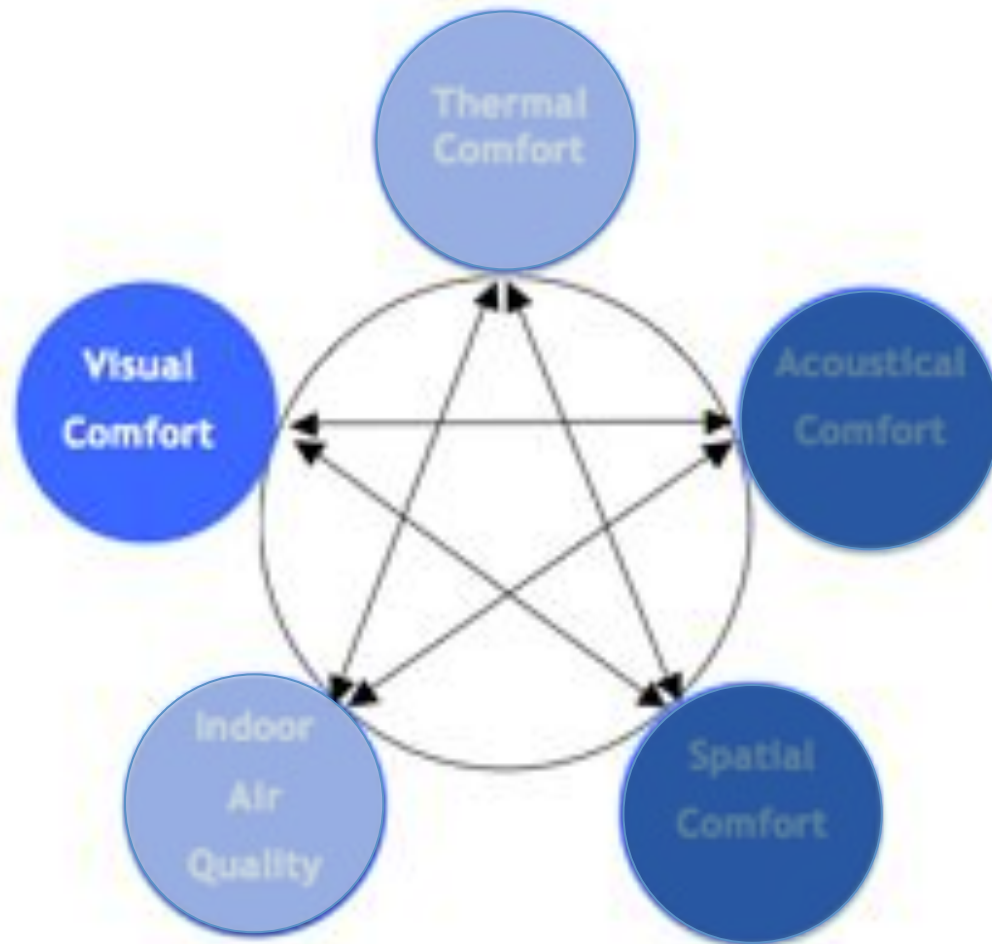
Course	Architectural (Building) Science
Level of Content	Intermediate

No.	Theme	Topics	Objectives	Activity
1	Climate Responsive Building	Tropical (South East Asian) Architecture	<ul style="list-style-type: none"> <li>Understand the environmental parameters i.e. solar radiation, temperature, humidity, and wind velocity influencing the architectural design under the Tropics.</li> <li>Understand the role of climate knowledge for designing architecture in SEA modern context.</li> </ul>	Tutorial, Discussion, Exercise
2		Bioclimatic Design		
3	Building Performance & Mandates	Thermal Performance (Natural Ventilation)	<ul style="list-style-type: none"> <li>Understand behaviour of thermal elements and indoor air quality of buildings</li> <li>Understand the passive design principles of thermal performance for good microclimate</li> </ul>	Tutorial, Discussion, Exercise
4		Indoor Air Quality (IAQ)		
5		Visual Performance (Natural Lighting)	<ul style="list-style-type: none"> <li>Understand the physic of light</li> <li>Understand the lighting interior design principles</li> <li>Understand the basic methods to calculate daylight factor and lumen.</li> </ul>	
6		Visual Performance (Artificial Lighting)		
7	Acoustic Performance	<ul style="list-style-type: none"> <li>Understand the physic of sound</li> <li>Understand basic design principle of room acoustic &amp; noise control</li> </ul>	Tutorial, Discussion, Exercise	
8	Building Simulation (optional)	Building Simulation (optional)	<ul style="list-style-type: none"> <li>Introduction to building simulation for assessing building performance and/or designing climate responsive building</li> </ul>	Training on <i>Ecotect</i> Simulation



# Building Performance

## Definition



the series of mandates relating to interior occupancy requirements and the elemental parameters of comfort—thermal, acoustic, visual, air and spatial comfort—dependent on **physiological, psychological, sociological, economic values.**

Source: *Feriadi (2003)*



No architecture  
without light!

# Visual Performance

## Impacts of Lighting



# Visual Performance

## Impacts of Lighting



# Visual Performance

## Impacts of Lighting



Exterior

Unique – light and fog

# Visual Performance

## Impacts of Lighting



**Attractive – Coloring**



Exterior



Attractive – Coloring

# Visual Performance

## Impacts of Lighting

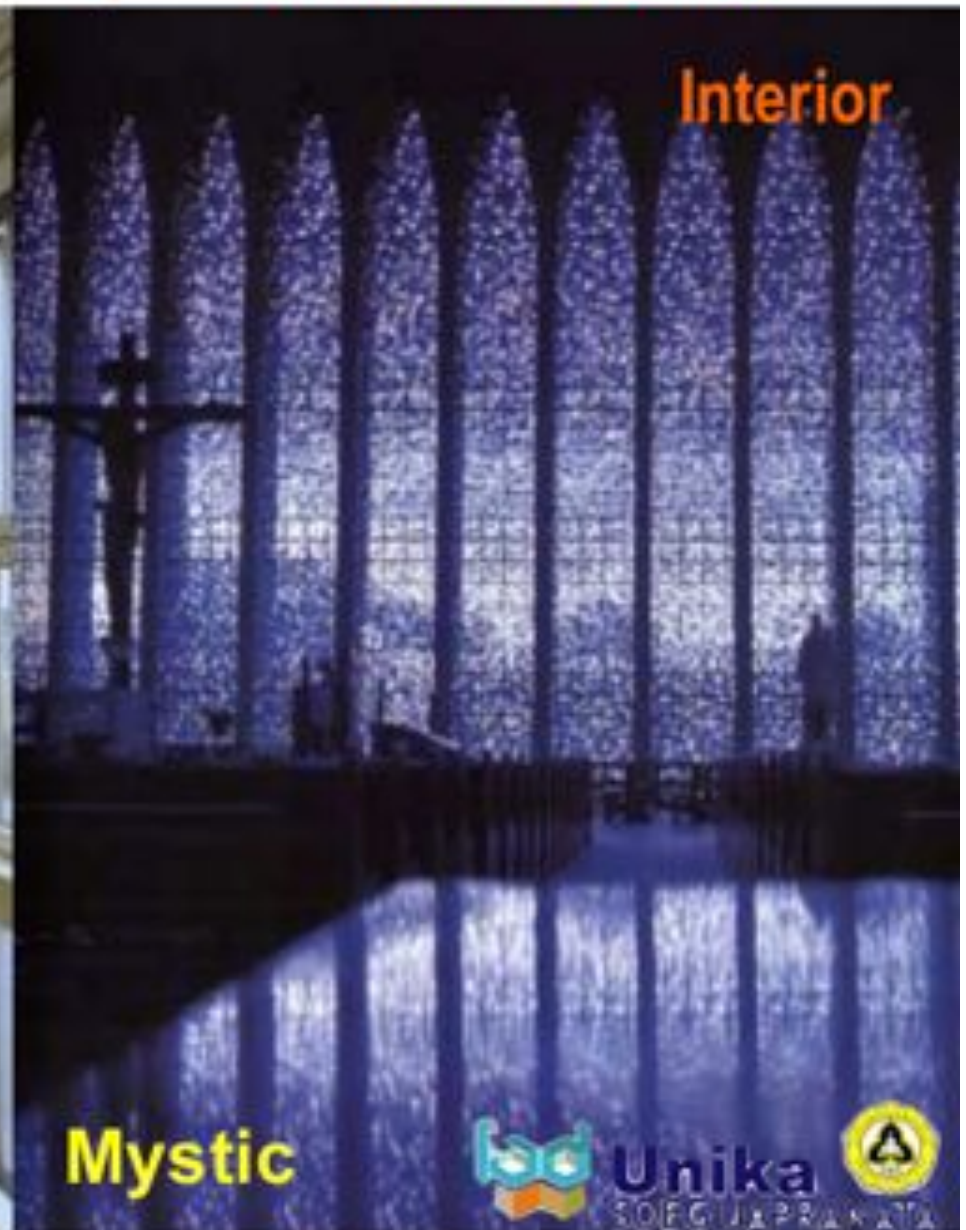


Cold

Warm

# Visual Performance

## Impacts of Lighting



# Visual Performance

## Impacts of Lighting



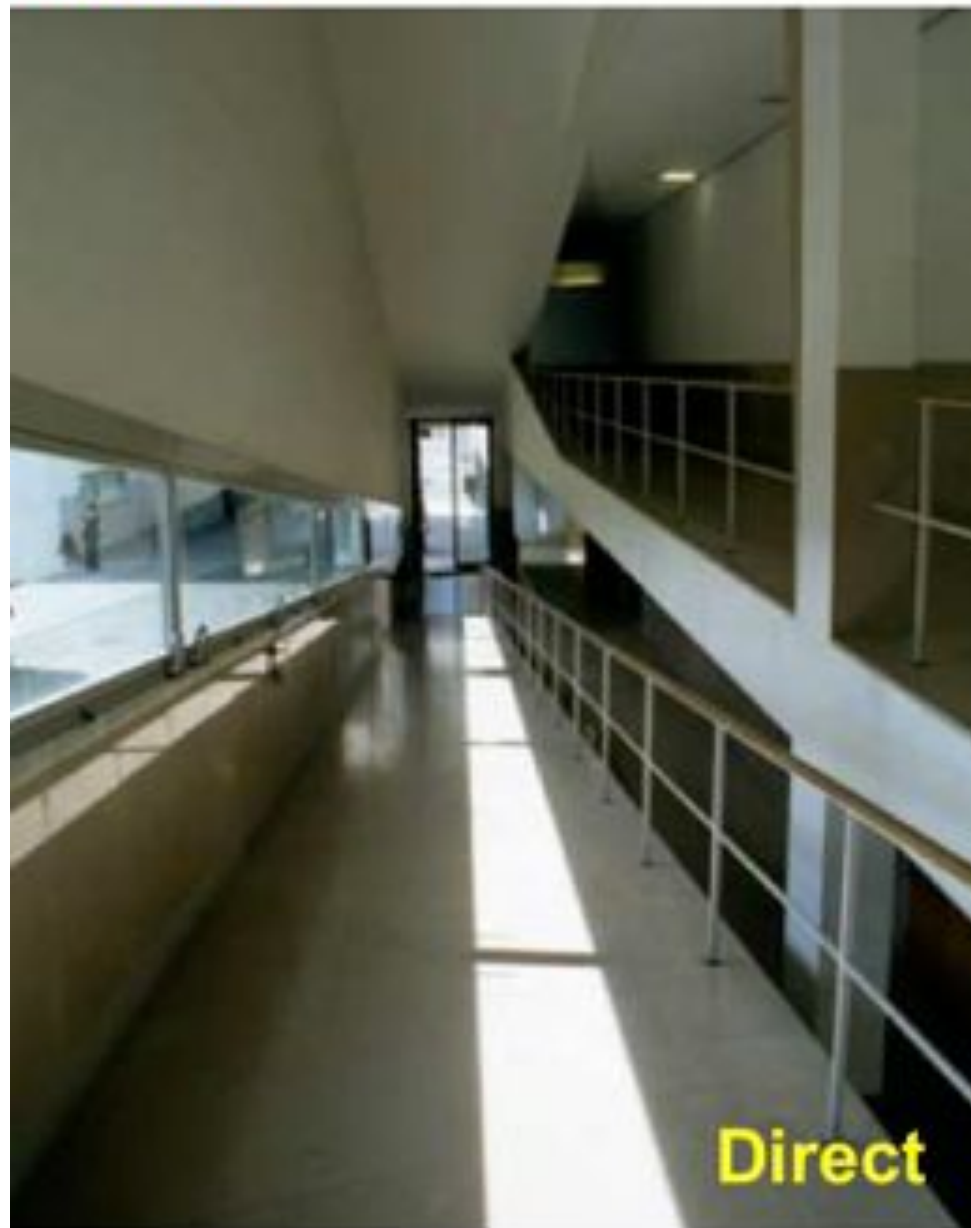
Interior

Attractive – Hologram



# Visual Performance

## Impacts of Lighting





Interior

Double facade

Attractive – Filtered Light

# Visual Performance

## Impacts of Lighting

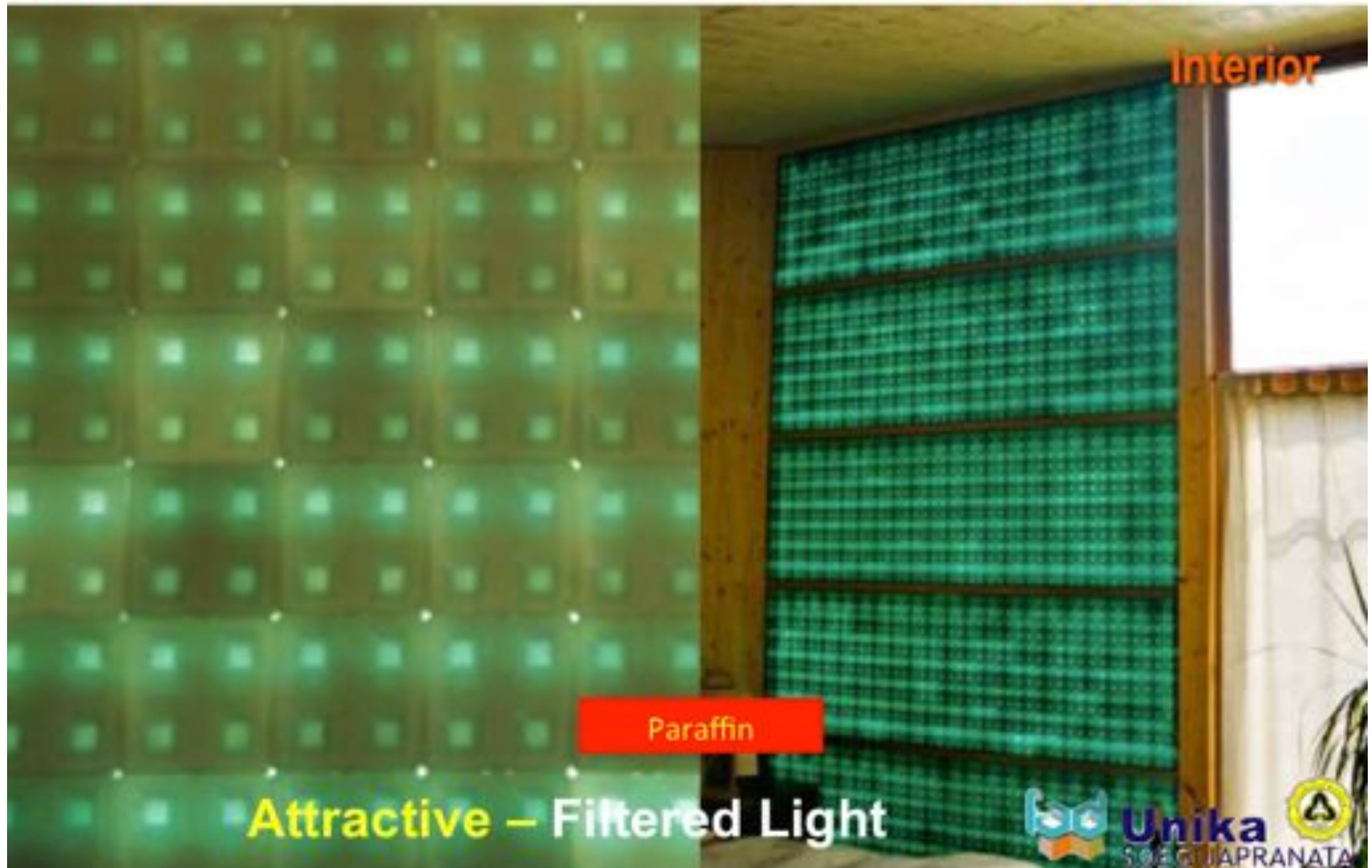


Interior

**Attractive – Unfiltered Light**

# Visual Performance

## Impacts of Lighting



Interior

Paraffin

Attractive – Filtered Light



# Visual Performance

## Impacts of Lighting



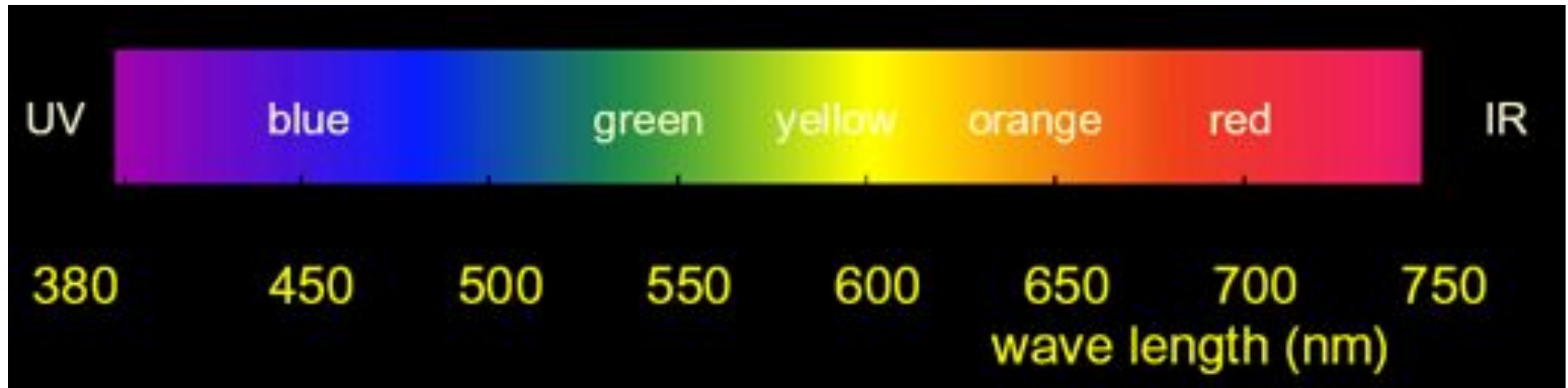
Interior

Attractive – Light and Shadow

### What is Light ?

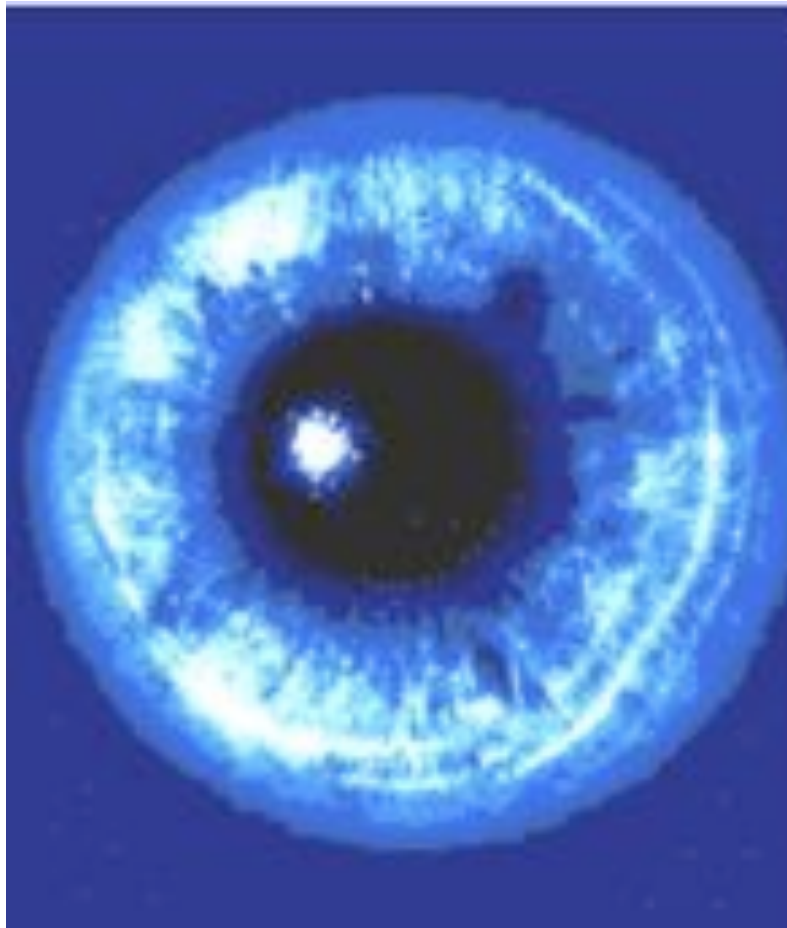
- *electromagnetic radiation which is travelling in space*
- *when enters our eyes, it creates sensation of 'vision'*
- *a perceived phenomenon & depends on the sensitivity of eye*

### Electromagnetic Spectrum



- wave length 380nm - 800 nm , known as **Visible Light**
- indicated by **Violet** to **Red**

# Visual Performance



**FISIOLOGIS**

# Impacts of Lighting

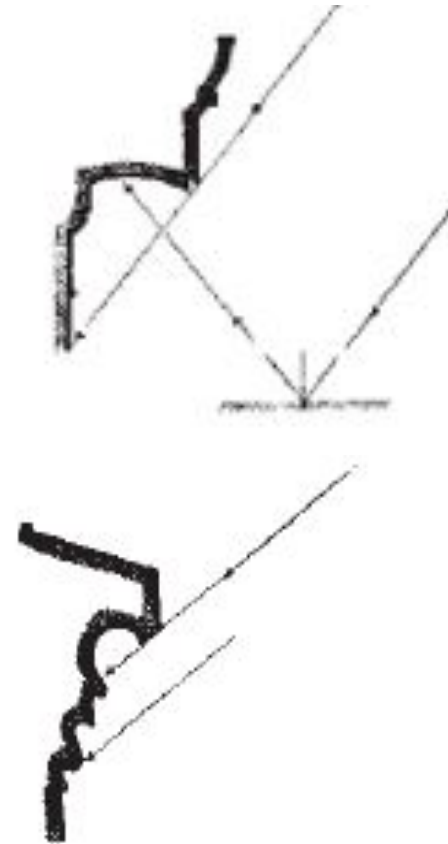


**PSIKOLOGIS**

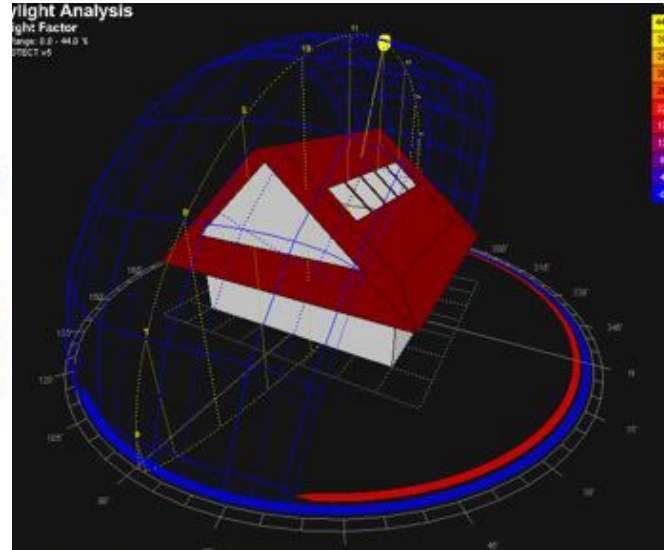
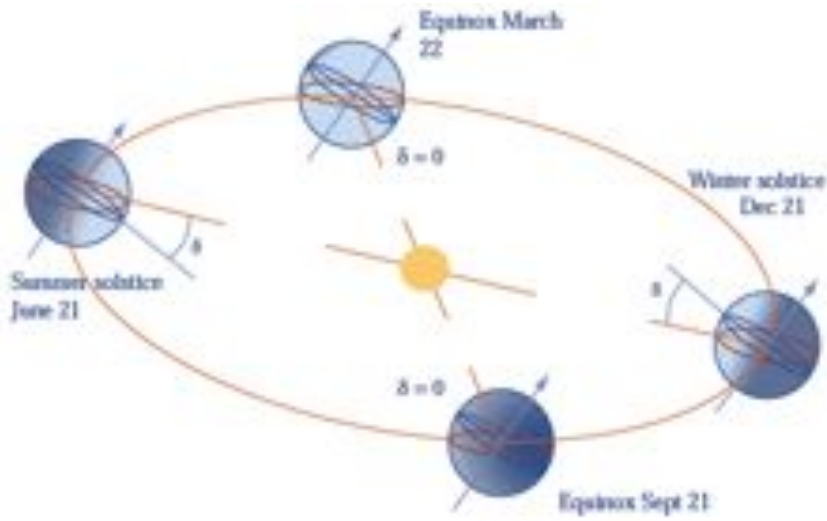
# Daylight architecture

### Daylight architecture

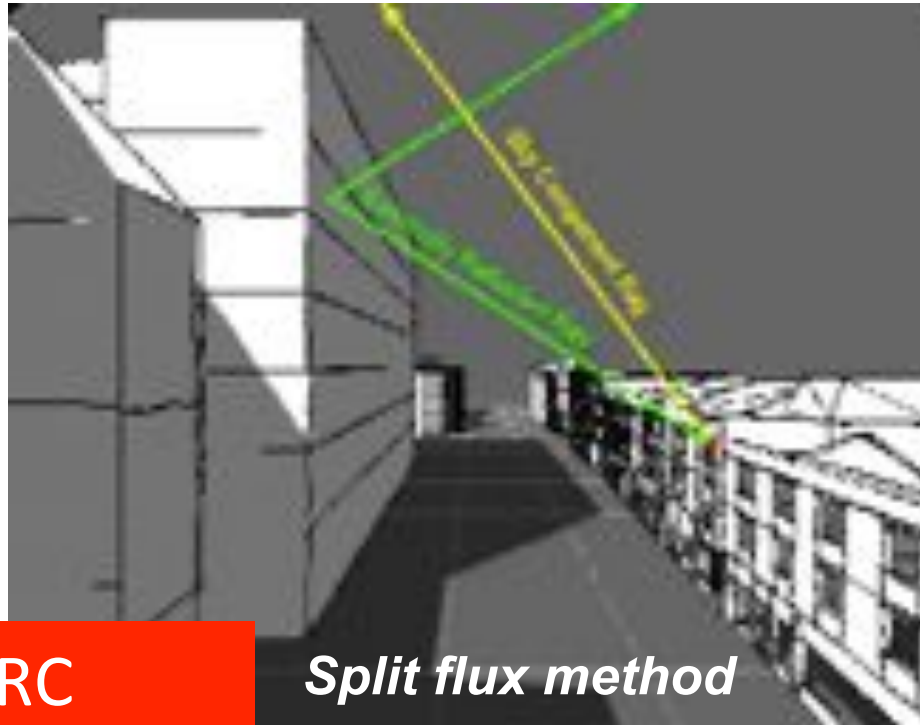
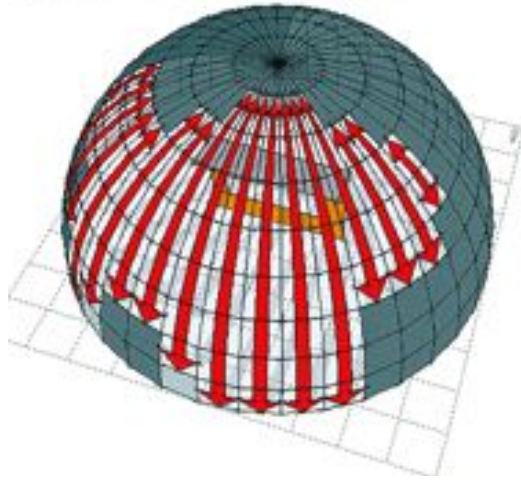
- Depends on conditions in the various climatic zones of the globe.
- To render spatial bodies three-dimensional. An excellent means for controlling our perception on a psychological level.



## Main parameters in daylight availability



Climate and weather  
Sun course (latitude, time/date)



$$DF = SC + ERC + IRC$$

*Split flux method*

**Sky Component (SC)** - Directly from the sky, through an opening such as a window.

**Externally Reflected Component (ERC)** - Reflected off the ground, trees or other buildings.

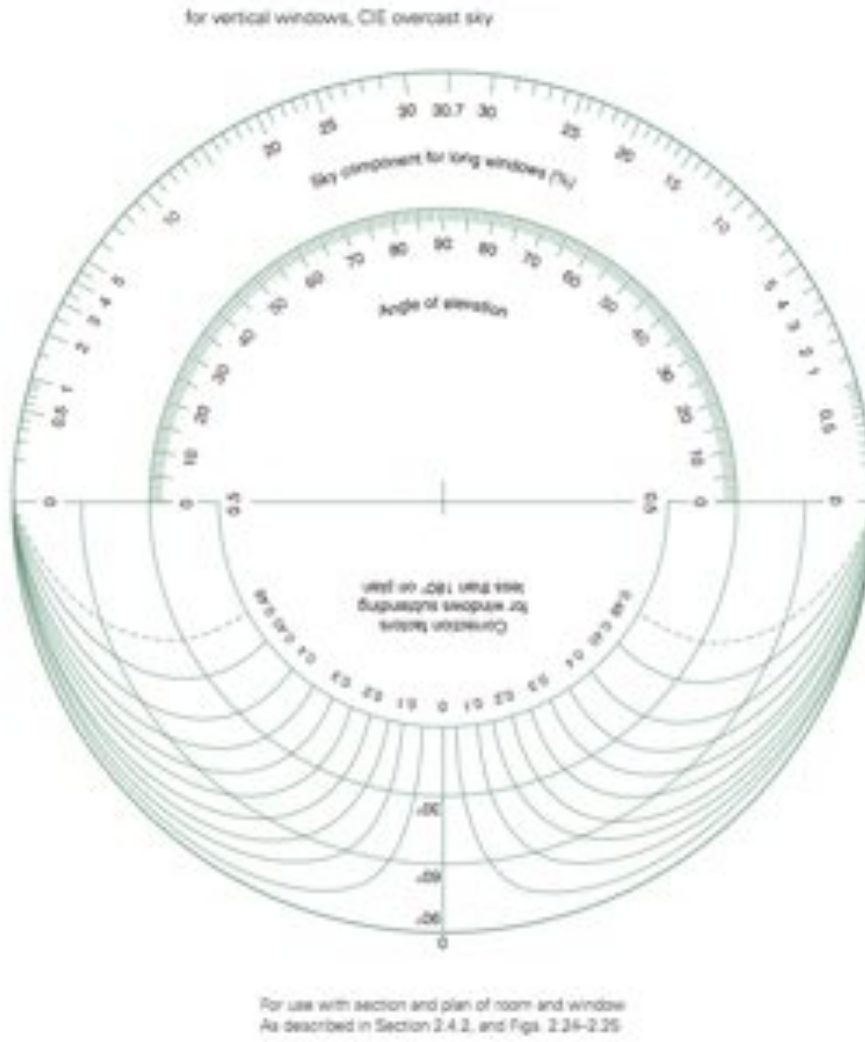
**Internally Reflected Component (IRC)** - The inter-reflection of 1 and 2 of surfaces within the room.



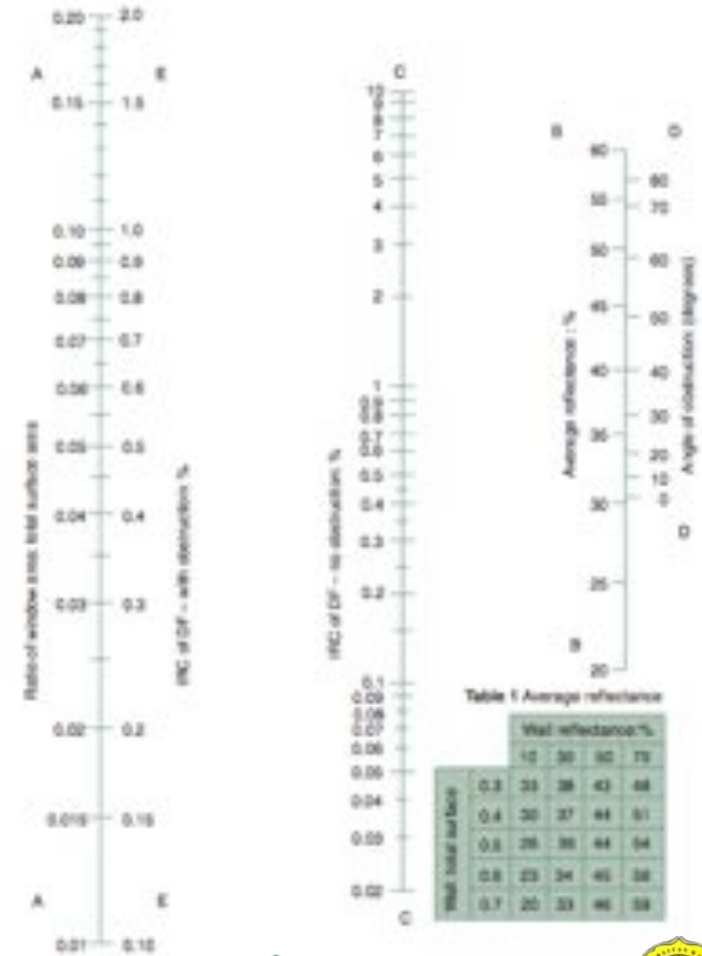


# Design Method

# Daylighting



Daylight factor: nomogram for the IRC (internally reflected component)



BRS DAYLIGHT FACTOR PROTRACTOR NO. 2

# Exercise



# Design Method

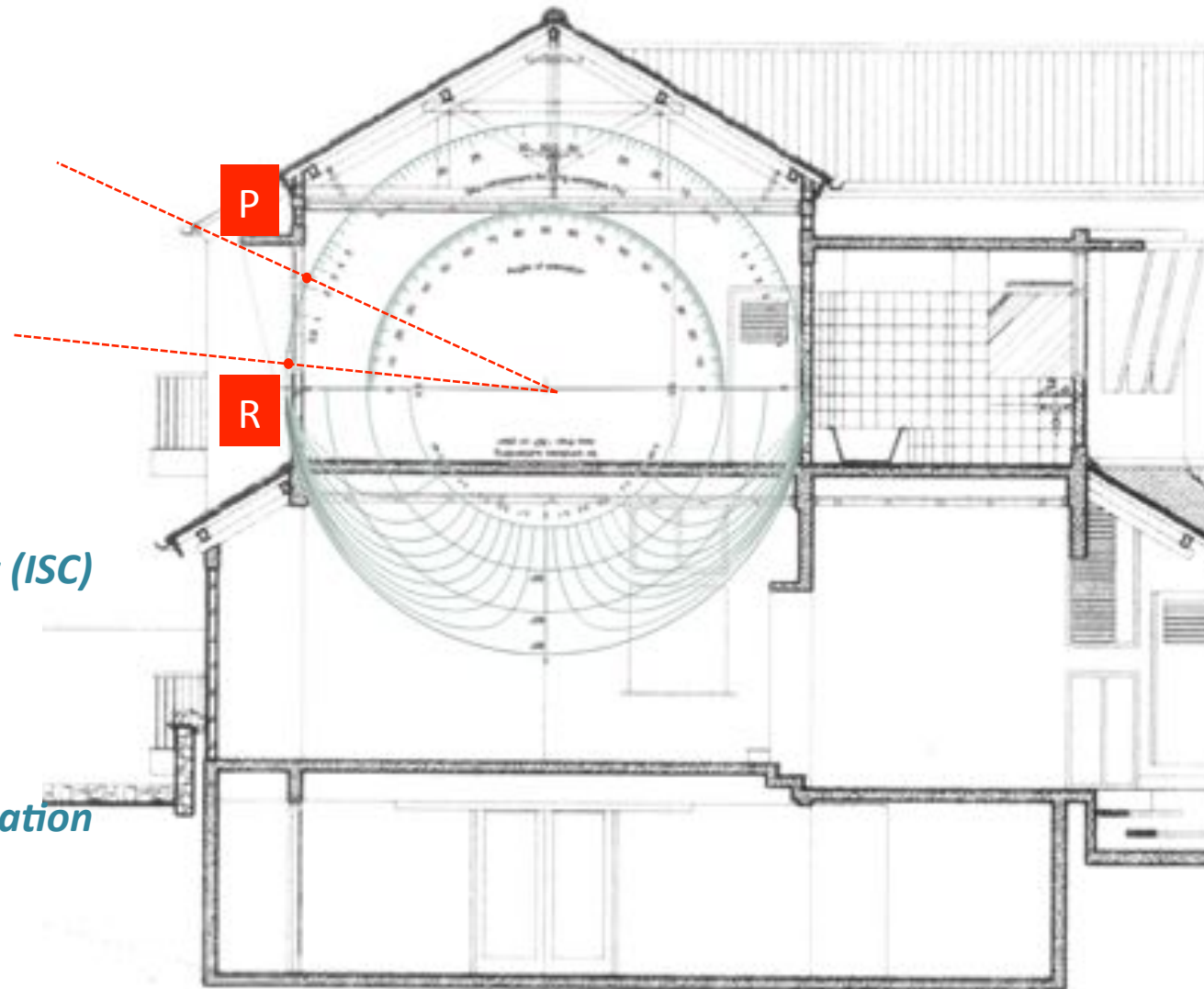
## Daylighting

From the outer scale:  
 $2.5 - 0.1 = 2.4\%$

*Initial Sky Component (ISC)*

From the inner scale:  
 $(25 + 5)/2 = 15$

*Average angle of elevation*



# Design Method

## Daylighting

Average angle of elevation  
**15 °**

Draw an arch of the  
average elevation angle

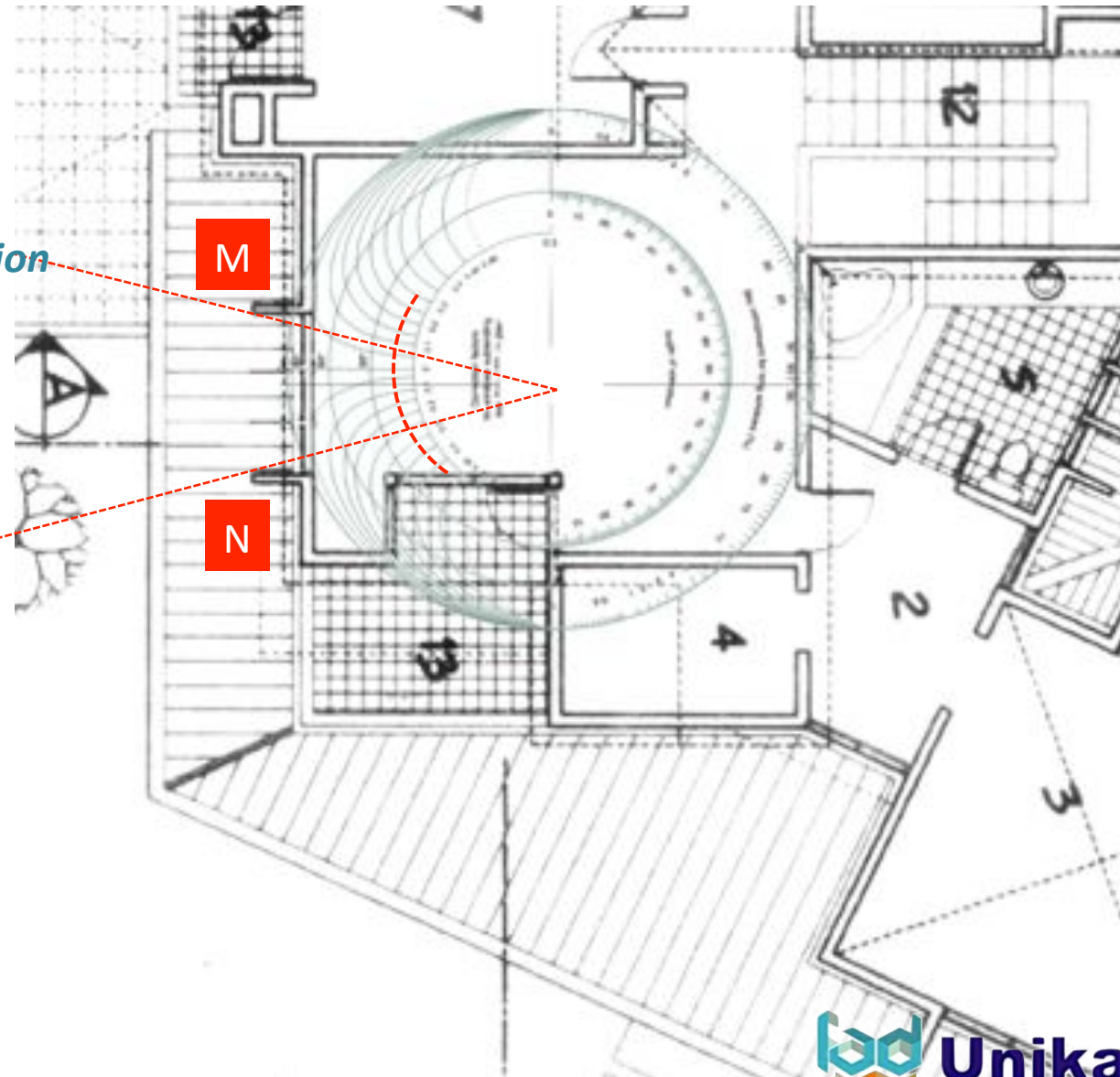
Following the drop lines,  
from the inner scale:

$$0.25 + 0.05 = \mathbf{0.3}$$

*Correction Factor*

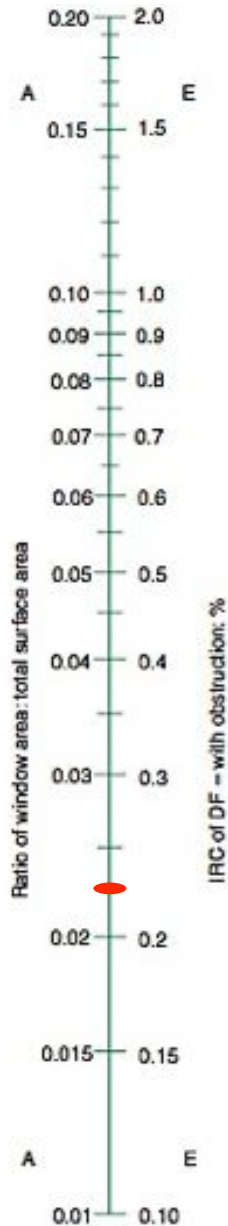
*Sky component:*

$$\mathbf{0.3 \times 2.4\% = 0.6\%}$$



# Design Method

## Daylighting



From the plan & section drawings

*Total wall surface area:*

$$2 (4.5 \times 2.75 \text{ m}) + 2 (5.5 \times 2.75 \text{ m}) + 2 (0.5 \times 2.75 \text{ m}) = \mathbf{57.75 \text{ m}^2}$$

*Total ceiling & floor surface area:*

$$2 (4.5 \times 5.5 \text{ m}) - 2 (0.5 \times 2 \text{ m}) = \mathbf{47.50 \text{ m}^2}$$

*Total surface area:*

$$\mathbf{105.25 \text{ m}^2}$$

*Window area:*

$$2 \times 1.25 = \mathbf{2.50 \text{ m}^2}$$

*Ratio window area to total surface area:*

$$2.50 \text{ m}^2 / 105.25 \text{ m}^2 = \mathbf{0.023}$$

Nomogram **A**

Ratio wall surface area to total surface area:

$$57.75 \text{ m}^2 / 105.25 \text{ m}^2 = 0.548$$

**Table 1** Average reflectance

		Wall reflectance:%			
		10	30	50	70
Wall: total surface	0.3	33	38	43	48
	0.4	30	37	44	51
	0.5	26	36	44	54
	0.6	23	34	45	56
	0.7	20	33	46	59

White/ light colors

*Interpolation*

$$(56-54)/(0.6-0.5)*(0.548-0.5) = 0.096$$

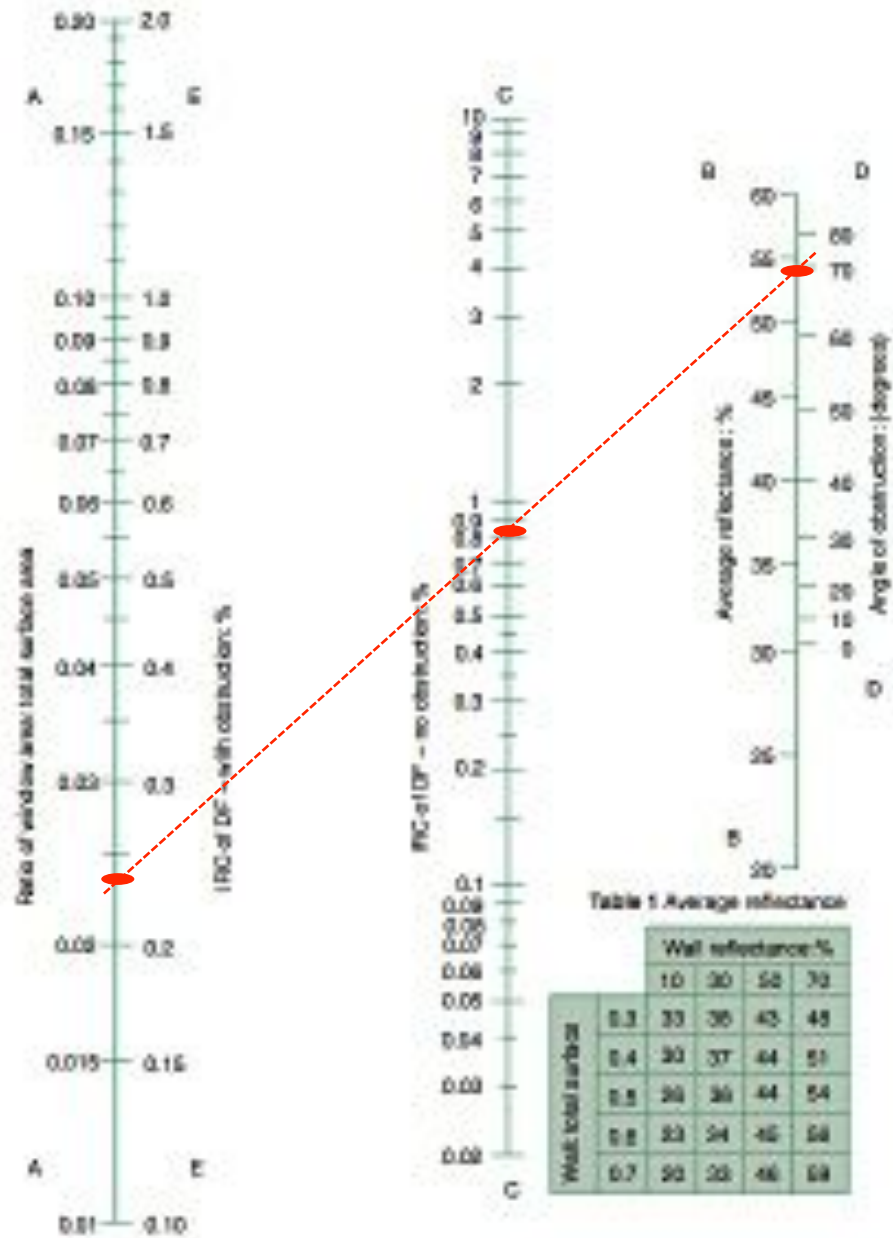
*Wall Reflectance*

$$54 + 0.096 = 54.096$$

Nomogram scale **B**

# Design Method

## Daylighting



Daylight Factor (DF) =

**SC + IRC + ERC**

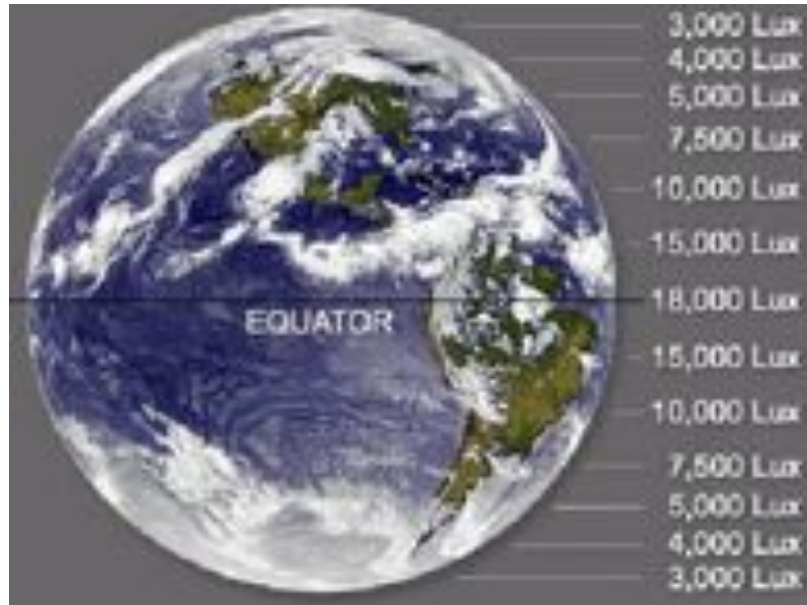
$$0.6 + 0.85 + 0 = \mathbf{1.45\%}$$

Based on sky illuminance of given location

$$1.45 \% \times 10.000 \text{ lux} = \mathbf{145 \text{ lux}}$$

# Design Method

## Standard

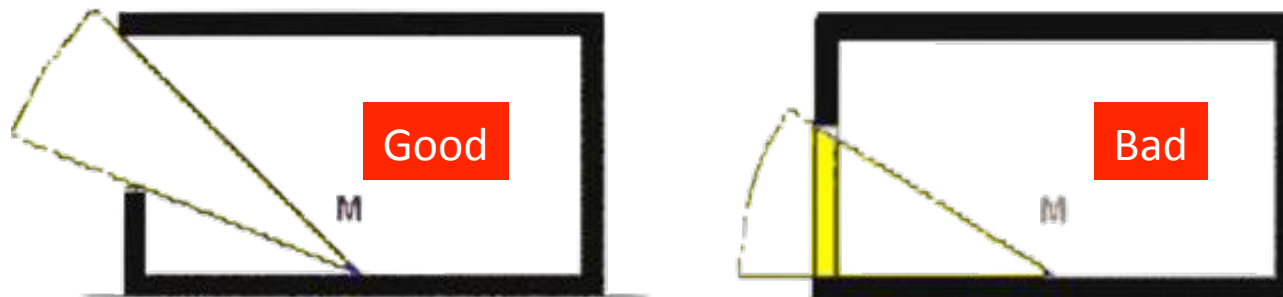


### IESNA Recommended Illuminance Values

Illuminance category	Ranges of illuminance maintained in service, lux (fc)	Type of activity
<b>Illuminance on task:</b>		
D	200-300-500 (20-30-50)	Performance of visual tasks of high contrast or large size: reading printed material, typed originals, handwriting in ink, and good xerography; rough bench and machine work; ordinary inspection; rough assembly
E	500-750-1000 (50-75-100)	Performance of visual tasks of medium contrast or small size: reading medium pencil handwriting, poorly printed or reproduced material; medium bench and machine work; difficult inspection; medium assembly
F	1000-1500-2000 (100-150-200)	Performance of visual tasks of low contrast or very small size: reading handwriting in hard pencil on poor-quality paper and very poorly reproduced material; highly difficult inspection

### Problem:

Useful day-lighting at wall side system can only be reached at a distance of **2.5 times** of height of the top of window.





# Problem



# Daylighting



Problem in **tropical regions:**

Minimizing radiant heat gain results in shaded windows – **NL minimal**



Office Building,  
Brisbane, Australia

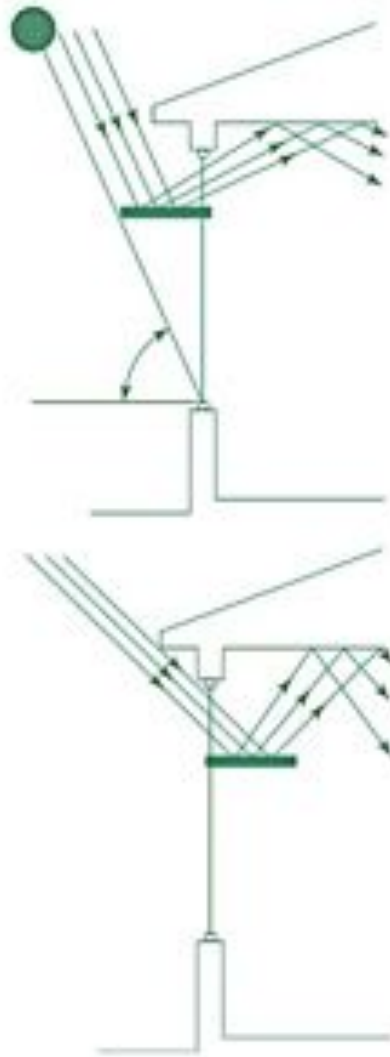


Wisma Dharmala Sakti,  
Jakarta, Indonesia

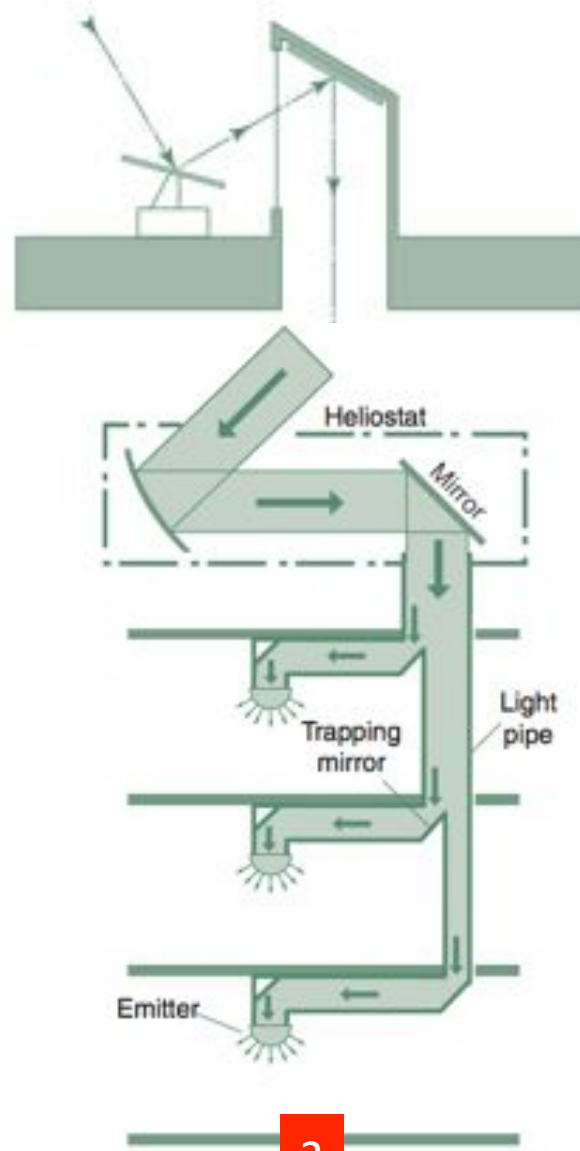
Do you have any idea in terms of  
architectural design + technology  
to solve these problems?

# Design Principles

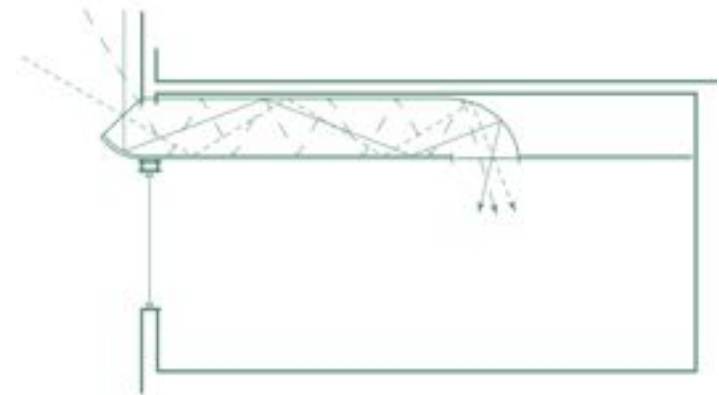
## Technology



1



2



3

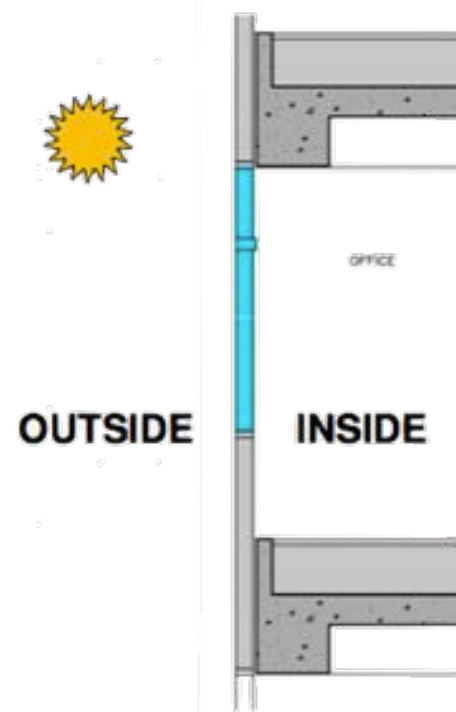
1. External and internal light shelves
2. Beam sun-lighting by heliostat and light pipes.
3. 'Anidolic' ceiling

# Design Principles

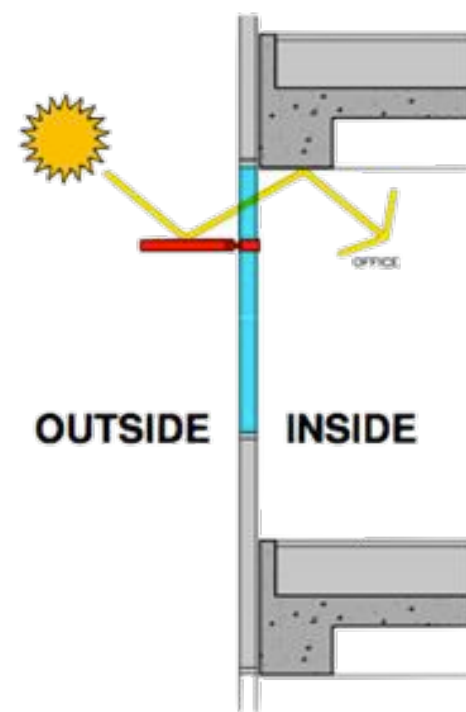
## Technology



1



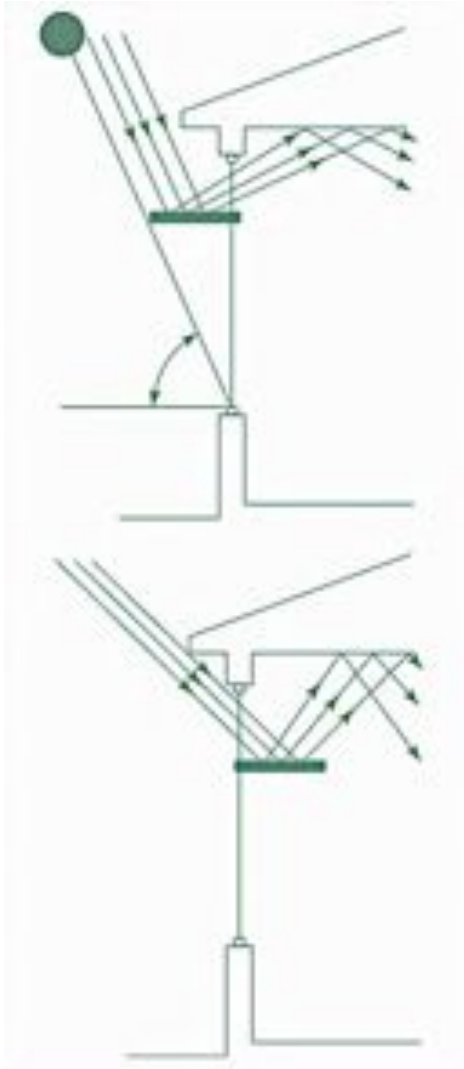
**A.** No lightshelf and no louvres



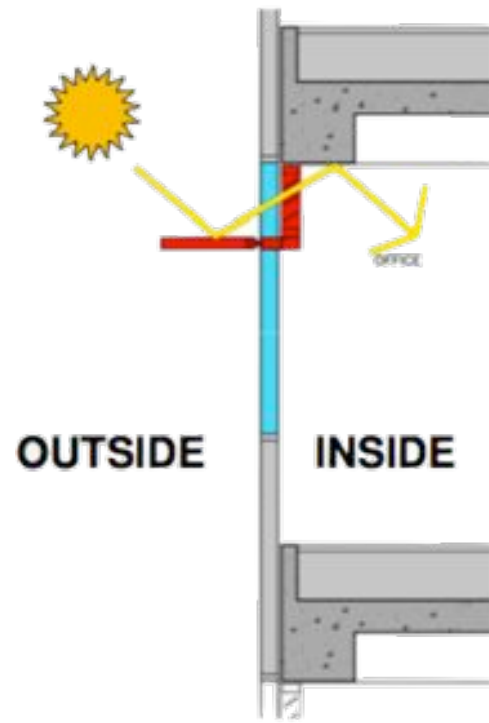
**B.** External lightshelf and no louvres

# Design Principles

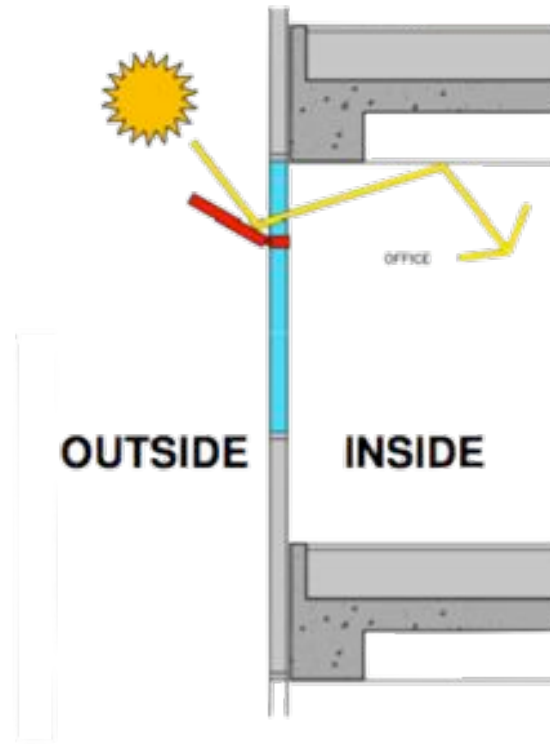
# Technology



1



C. With lightshelf and louvres



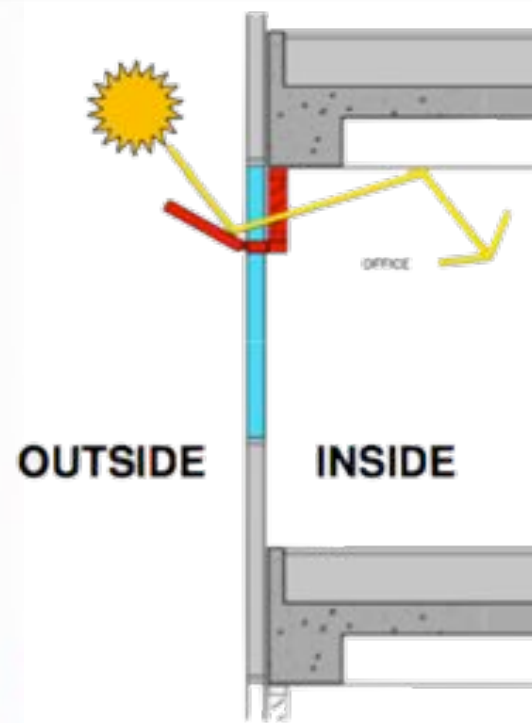
D. Lightshelf tilted at 30° and without louvres

# Design Principles

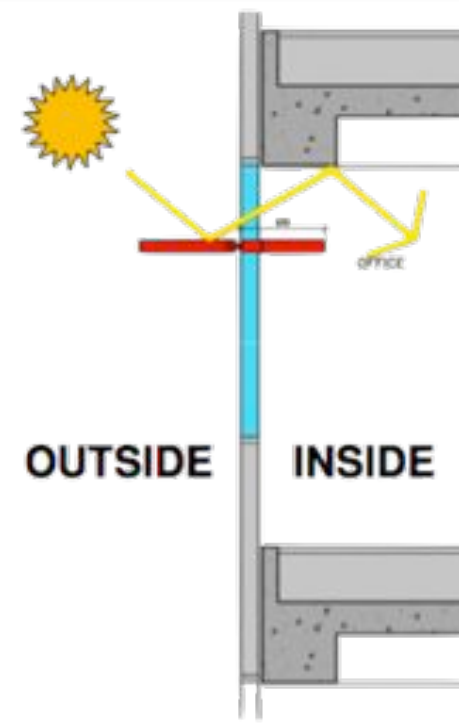
## Technology



1



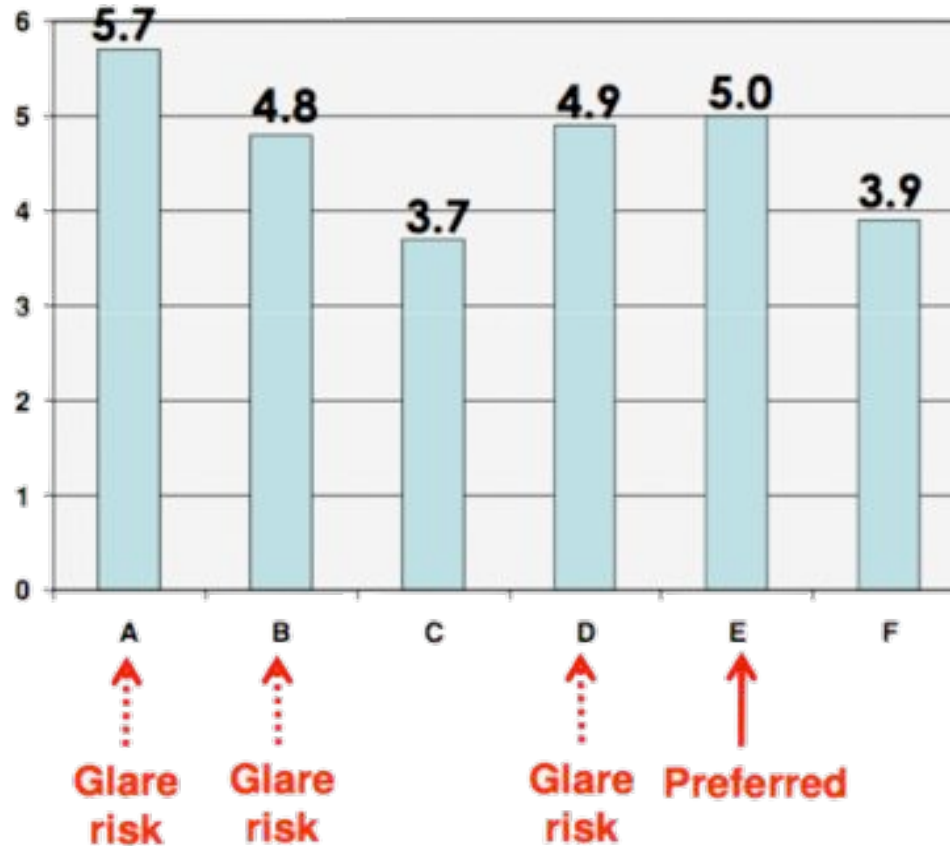
**E.** Lightshelf tiled at 30° and with louvres



**F.** With outer and internal lightshelves



1



Based on DF of 1.5%, ie approx 150 lux

## Lightshelf and Daylight Factor Performance

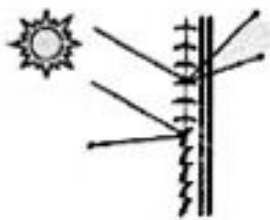
Shading systems primary using diffuse skylight

System	Climate	Attachment	Criteria for the choice of elements
Prismatic panels	All climates	Vertical windows, skylights	<ul style="list-style-type: none"><li>- Glare protection (D)</li><li>- View outside (D)</li><li>- Saving potential (artificial lighting)</li><li>- Need for tracking (D)</li><li>- Available</li></ul>





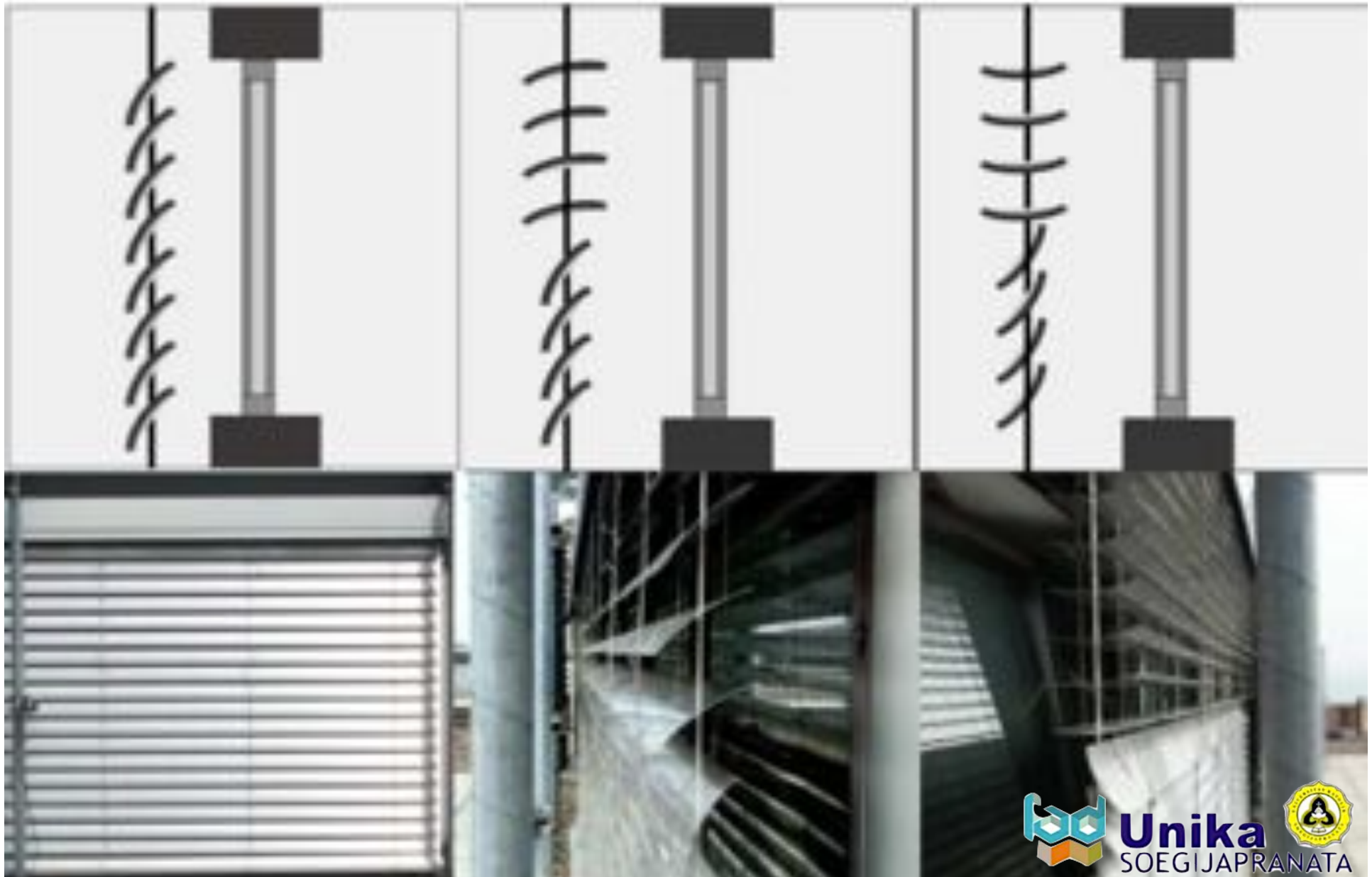
Shading systems primary using direct sunlight

System	Climate	Attachment	Criteria for the choice of elements
Louvers and blinds 	All climates	Vertical windows	<ul style="list-style-type: none"><li>- Glare protection</li><li>- Lightguiding into the depth of the room</li><li>- Homogeneous illumination</li><li>- Need for tracking</li><li>- Available</li></ul>



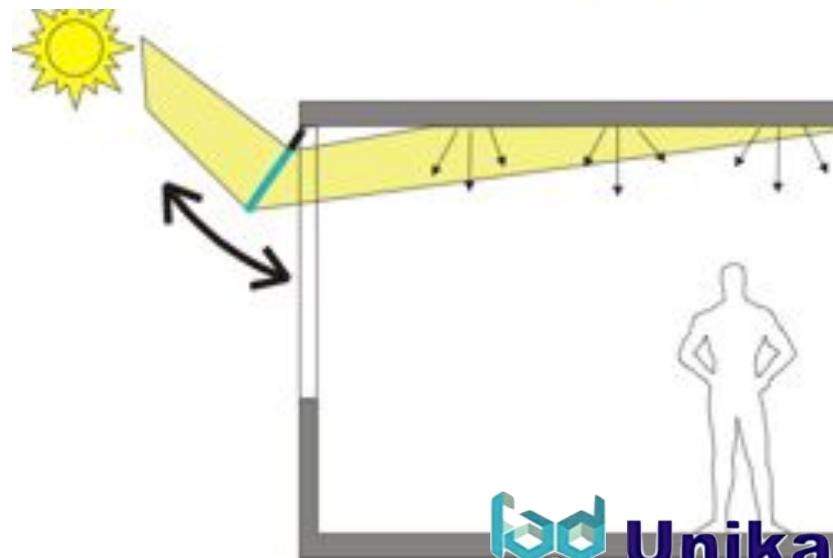
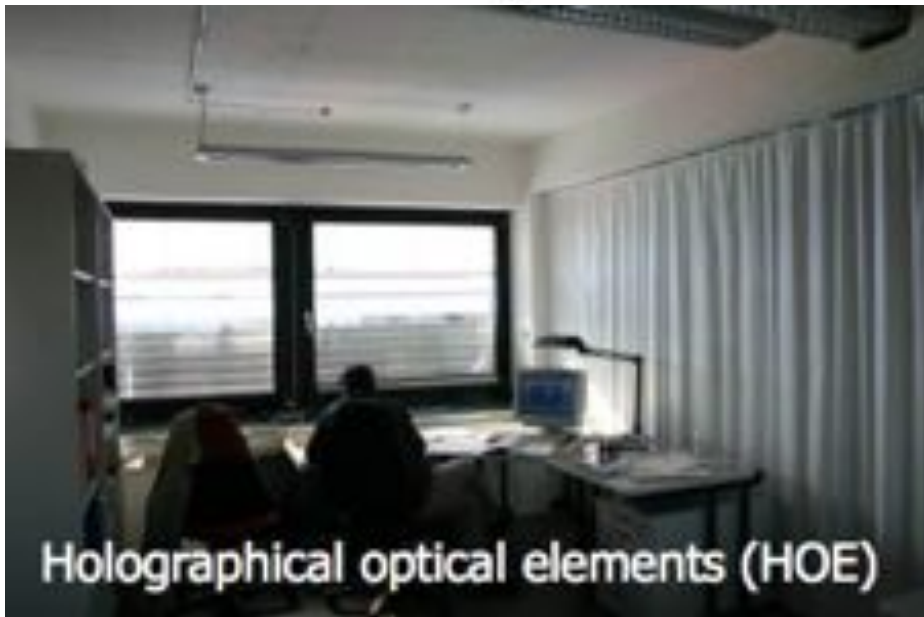
# Visual Performance

# Technology



Shading systems primary using diffuse skylight

System	Climate	Attachment	Criteria for the choice of elements
Directional selective shading system with concentrating HOE	All climates	Vertical windows, skylights, glazed roofs	<ul style="list-style-type: none"> <li>- Glare protection (D)</li> <li>- View outside</li> <li>- Saving potential (artificial lighting)</li> <li>- Need for tracking</li> <li>- Available</li> </ul>

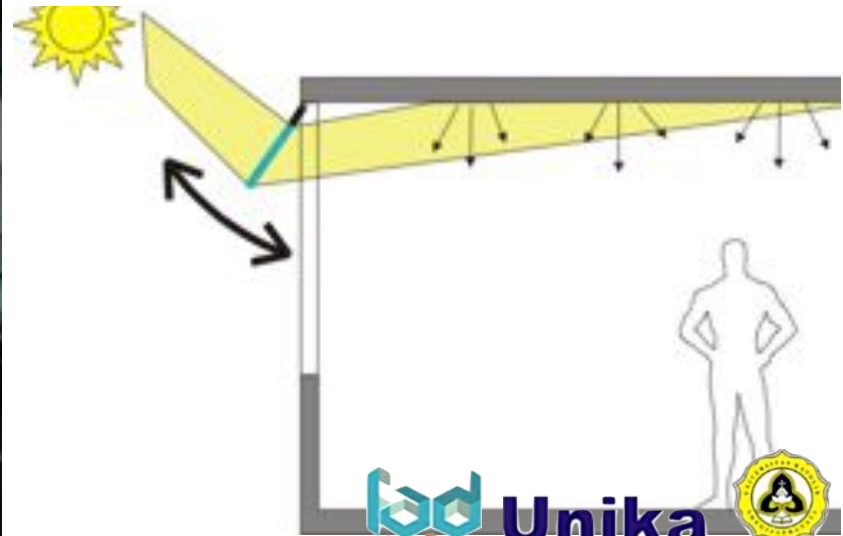


Shading systems primary using diffuse skylight

System	Climate	Attachment	Criteria for the choice of elements
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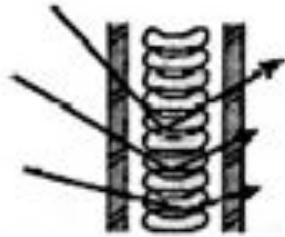


*Holographic Optical Element*



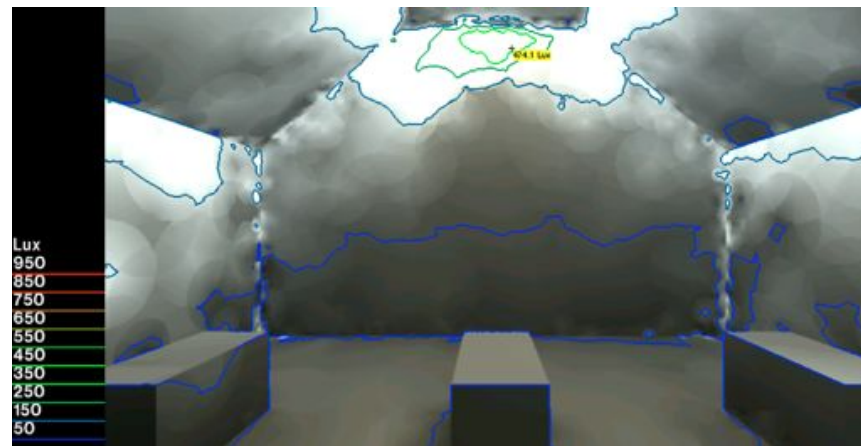
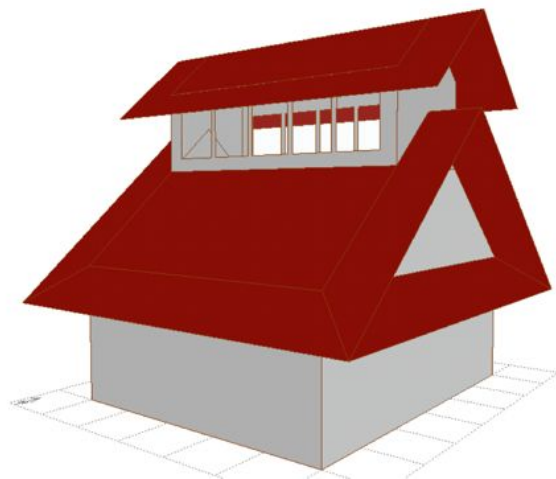
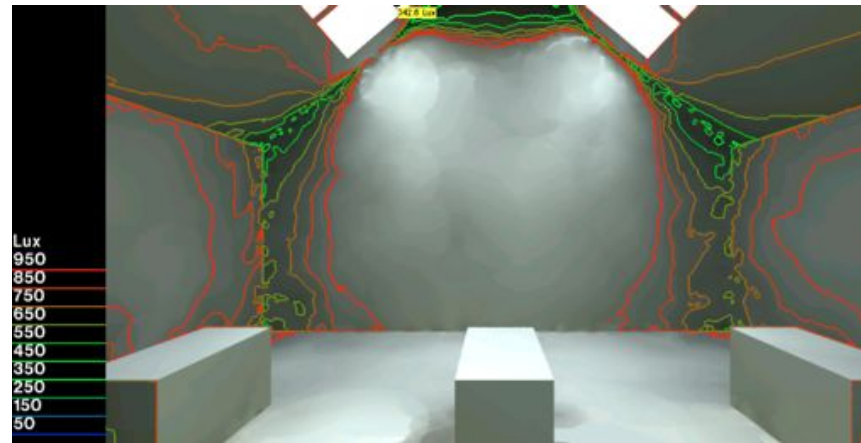
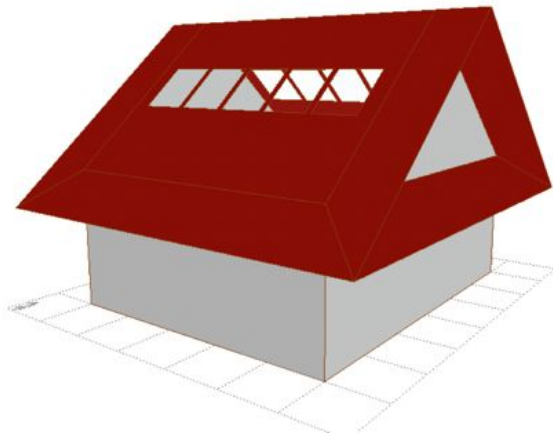
### Direct light guiding systems

System	Climate	Attachment	Criteria for the choice of elements
Light guiding glass	All climates	Vertical windows, skylights	<ul style="list-style-type: none"><li>- Glare protection</li><li>- View outside</li><li>- Lightguiding into the depth of the room</li><li>- Homogeneous illumination</li><li>- Saving potential (artificial lighting)</li><li>- Available</li></ul>



# Visual Performance

## Daylighting



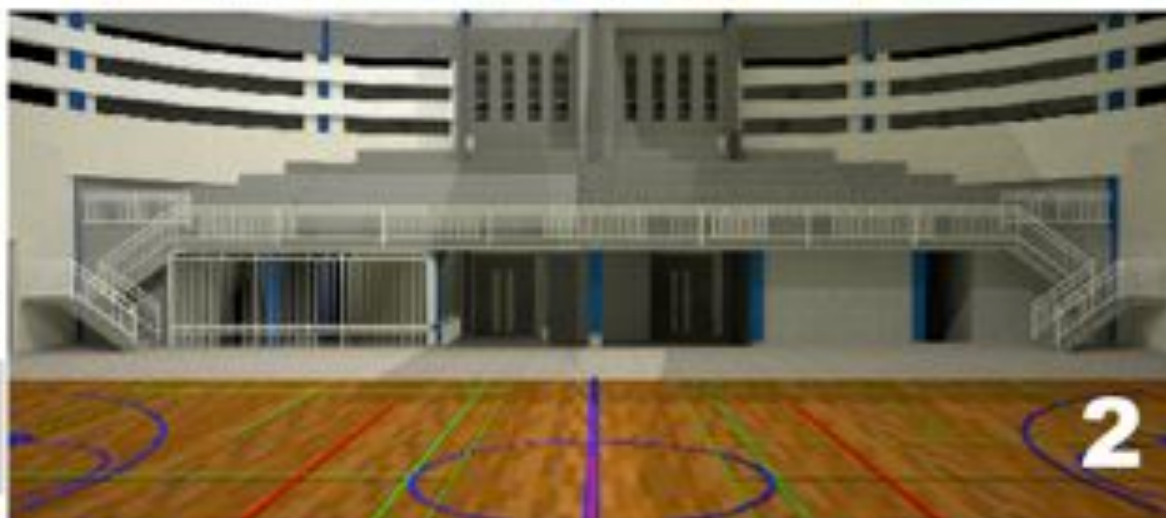
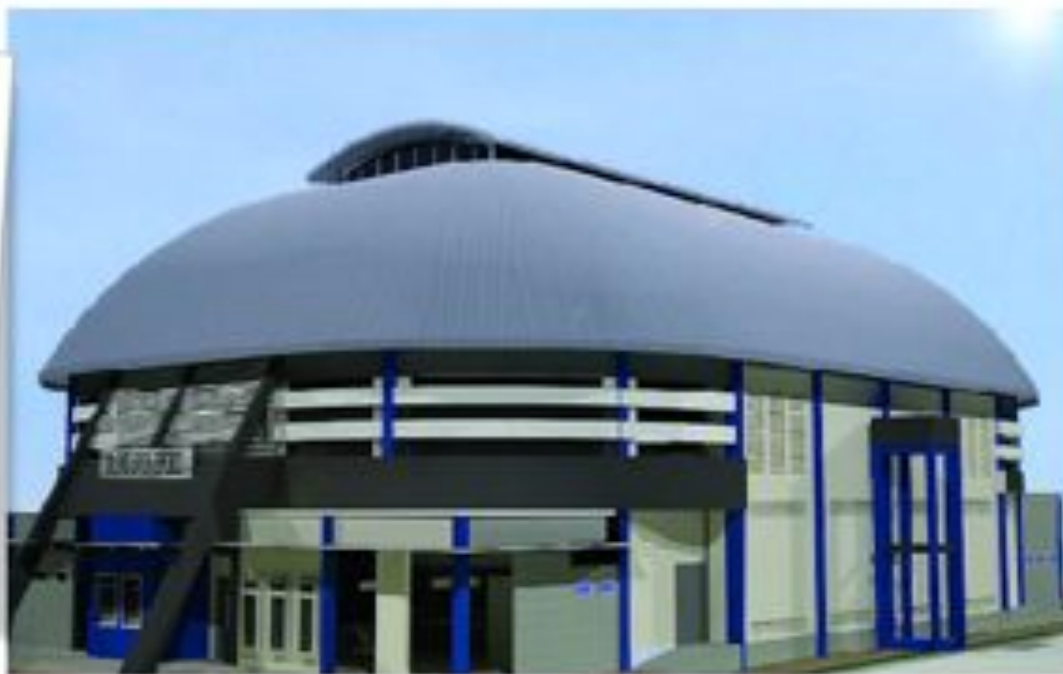
Moediartianto, 2008, *A Study of Daylighting Systems in Residential Building under Tropical Climates*,  
Journal Architecture TESA, Vol. 6 Number 1, ISSN 1410 - 6094



*Information Systems Office of SCU*  
Moediartanto, 2011

# Visual Performance

## Design Application



2



# Challenge

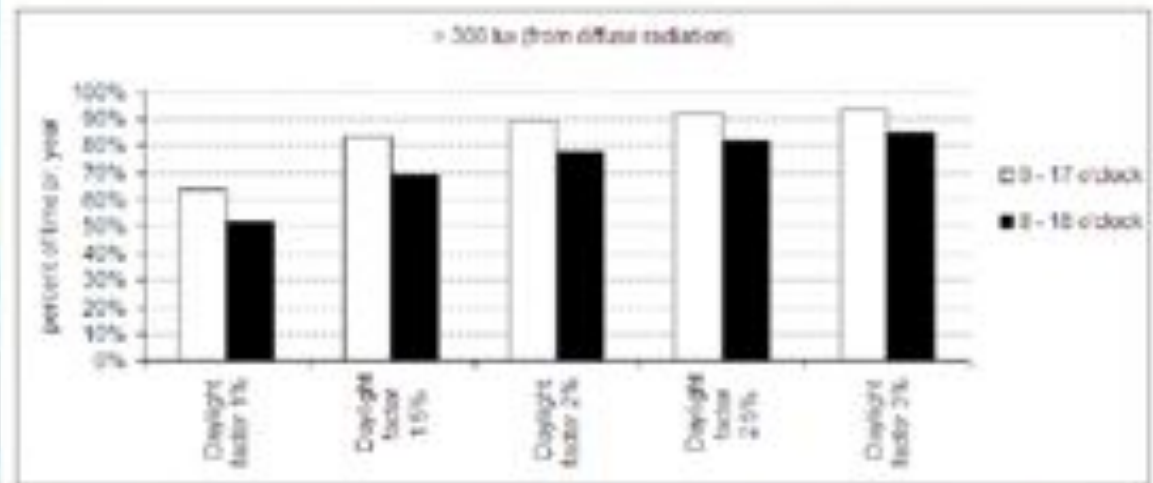
## Daylight, the most un-utilised Renewable Energy in the Tropics



Daylight Factor 1.5 or higher



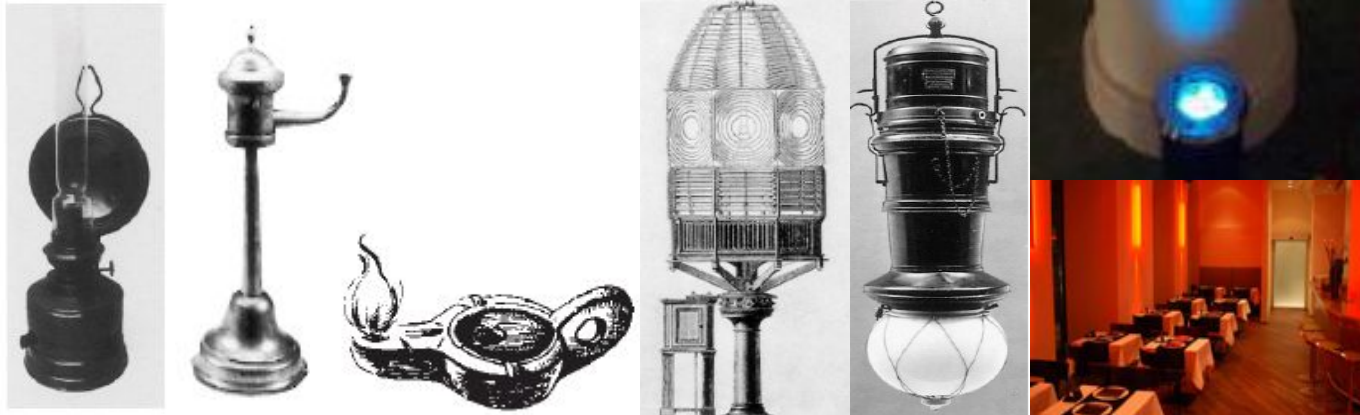
70 – 80% of lighting use can be covered  
( 8 – 18.00 or 9 – 17.00 hours )



# Artificial Lighting architecture

### Artificial lighting

- Confined by the inadequate luminous power provided by the light sources available.
- Give impacts to environment directly
- Fire → Prismatic/lens → Gas → Electric

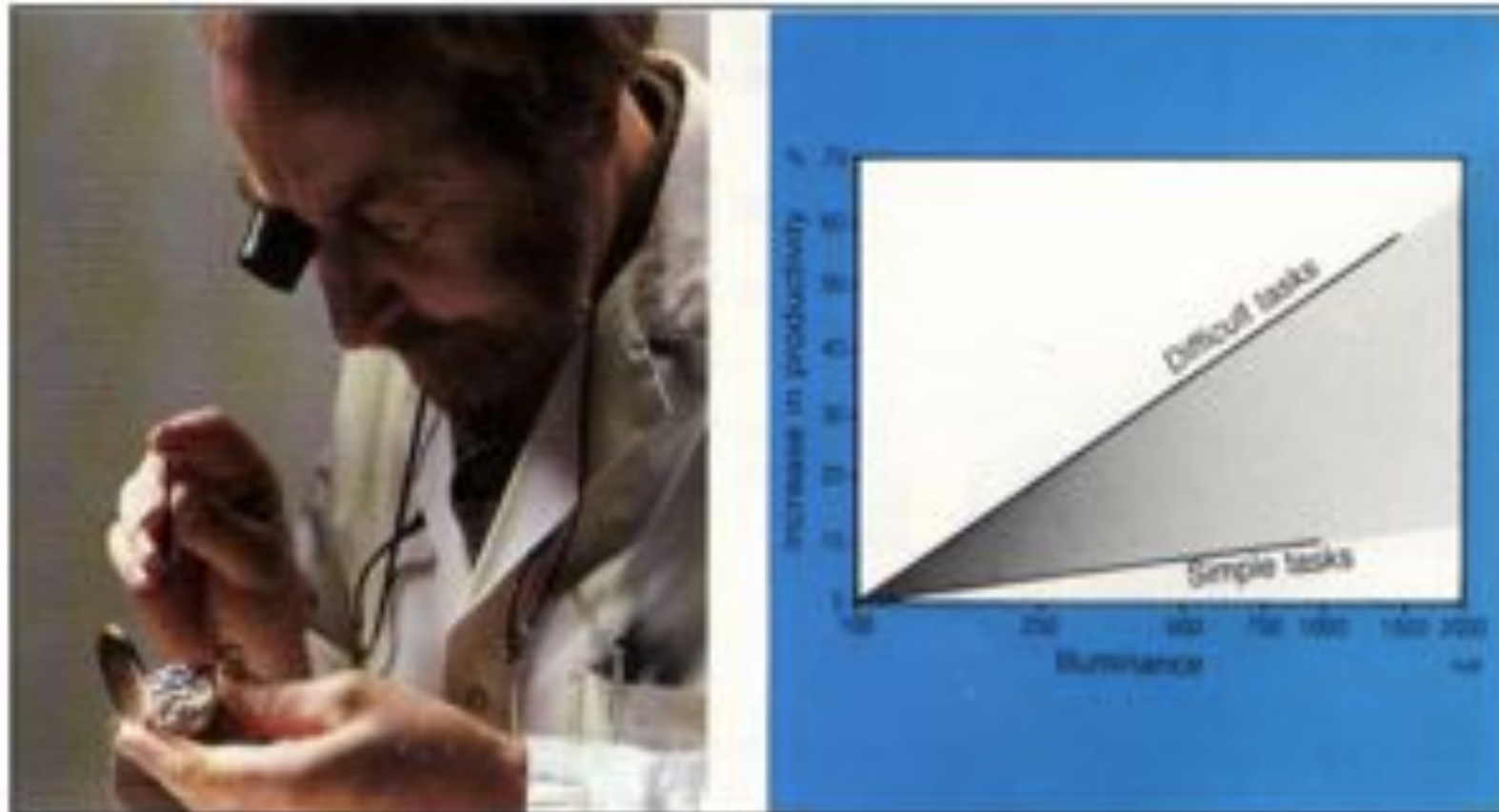


## Principal Lighting Criteria

- Lighting Level
- Luminance Distribution
- Freedom from Disturbing Glare
- Spatial Distribution of Light
- Light Color and Color Rendering

1

# Lighting Level



*Lighting Level is determined by the level of Eye Task*



Luminance  
Luminansi



Quantities	Symbol	Unit	Unit symbol
Luminous intensity	I	Candela, candlepower	cd
Luminous flux	$\Phi$	Lumen (=Watt)	lm
Illuminance	E	Lux (=W/m <sup>2</sup> )	lx
Luminance	L	cd/m <sup>2</sup>	Cd/m <sup>2</sup>

Photometric Quantities

## Artificial lighting

1

Requirements	Illuminance (lx)	Examples
Low	20 - 70	Circulation, stairs
Moderate	120 - 185	Entrance, restaurant
Medium	250 - 375	General task
High	500 - 750	Reading, writing
Very high	> 1000	Precision task

Type of space and function	Illuminance [lux]		
	Min	Mid	Max
Circulation, corridors, theatres, concert halls	50	100	200
Workshops, retail centres	200	300	400
Schools, offices, usual tasks, reading, writing, computer work, ...	300	400	500
Delicate work, drawing, technical tasks, ...	500	750	1000
Precision workshops, clockwork, color control, visual quality control, ...	1000	to	5000

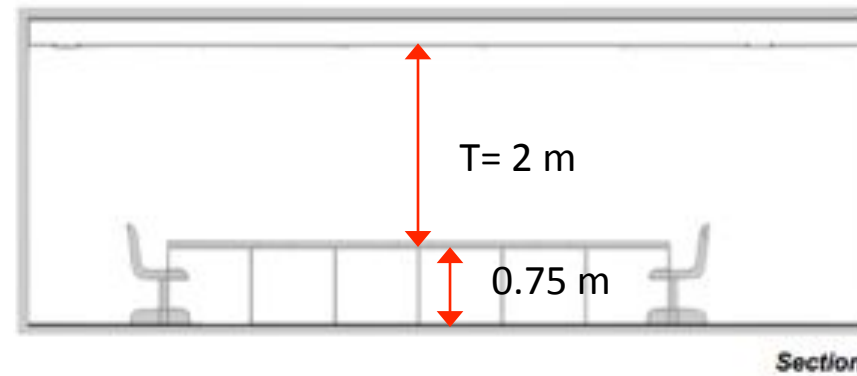
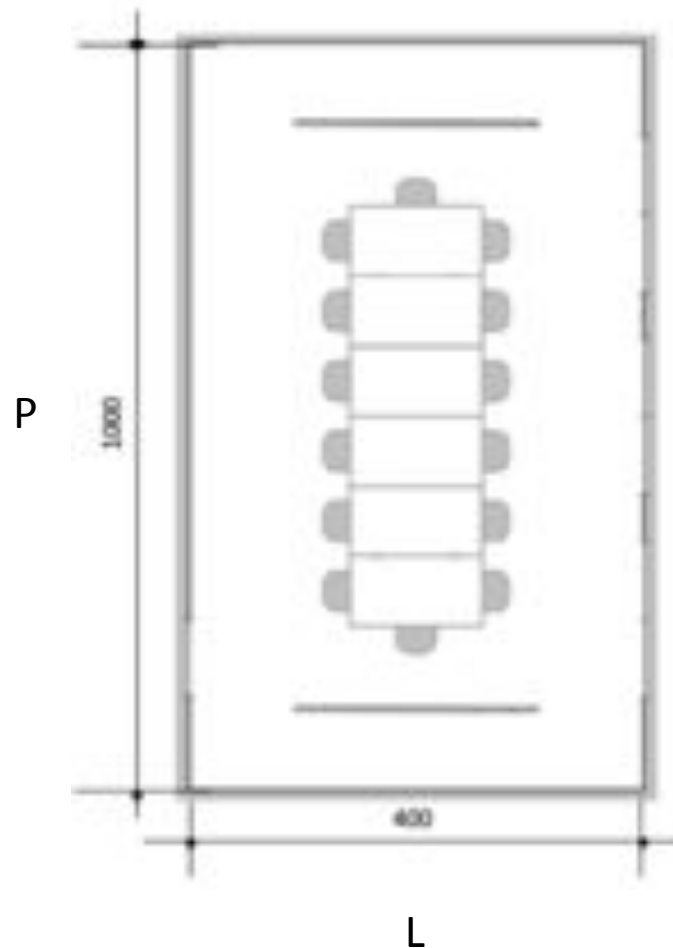
# Exercise





# Artificial lighting

## 1. Room Index



$$(K) = \frac{P \times L}{T(P+L)}$$

$$K = \frac{10 \times 4}{2(10+4)} = 1.43$$

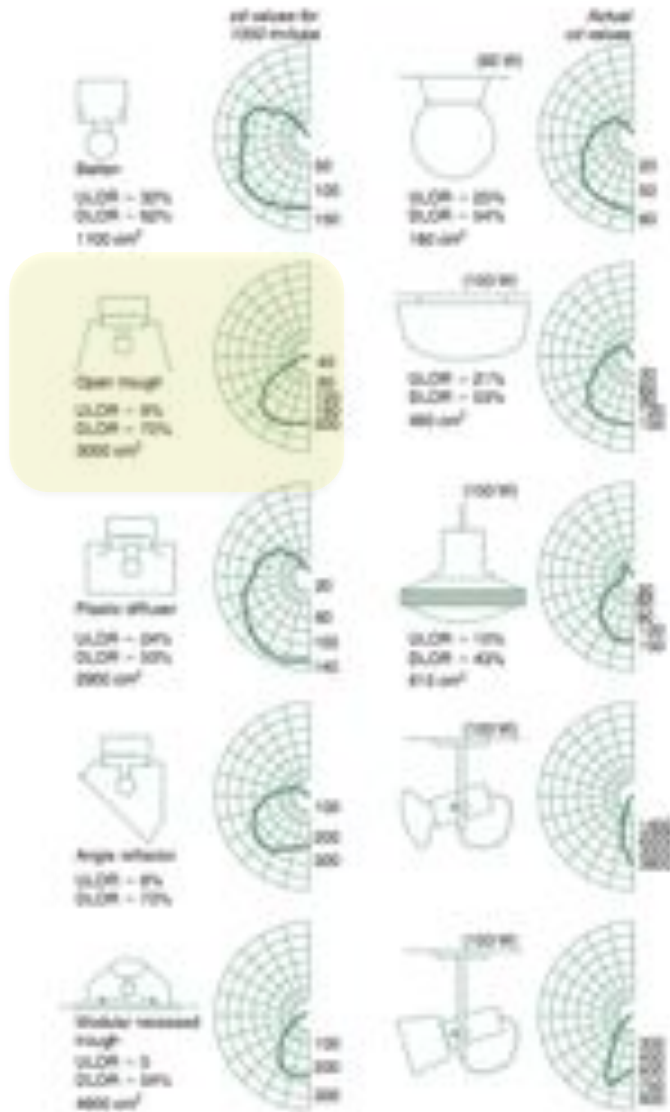
# Artificial lighting

Design Factor = Utilization Factor x Maintenance Factor



MASTER LED 18-100W 2700K PAR38 25D Dim

Light Output Ratio ( LOR )



## 2. Design Factor

Design Factor = Utilization Factor x Maintenance Factor

Utilization factors of typical luminaires

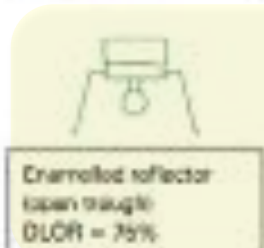
Room index	Reflectance of ceiling and walls								
	C: 0.7	0.5	0.3	0.1	0.9	0.7	0.5	0.3	0.1
0.5	0.29	0.24	0.19	0.27	0.22	0.19	0.24	0.21	0.18
0.8	0.31	0.27	0.22	0.30	0.25	0.22	0.31	0.28	0.24
1.0	0.34	0.30	0.25	0.33	0.28	0.25	0.35	0.32	0.28
1.25	0.40	0.42	0.38	0.45	0.43	0.38	0.45	0.43	0.39
1.5	0.51	0.47	0.43	0.50	0.46	0.42	0.52	0.49	0.45
2.0	0.60	0.52	0.48	0.54	0.49	0.45	0.58	0.54	0.49
2.5	0.64	0.57	0.53	0.57	0.53	0.49	0.63	0.59	0.55
3.0	0.67	0.61	0.57	0.60	0.57	0.53	0.66	0.62	0.58
4.0	0.71	0.66	0.62	0.64	0.61	0.57	0.69	0.65	0.62
5.0	0.74	0.70	0.66	0.69	0.66	0.61	0.72	0.68	0.64
0.5	0.26	0.21	0.18	0.25	0.21	0.18	0.25	0.21	0.18
0.8	0.28	0.24	0.20	0.27	0.23	0.20	0.28	0.25	0.21
1.0	0.29	0.25	0.21	0.28	0.24	0.21	0.29	0.26	0.22
1.25	0.33	0.30	0.26	0.33	0.29	0.26	0.34	0.31	0.27
1.5	0.38	0.34	0.30	0.37	0.33	0.30	0.39	0.36	0.32
2.0	0.44	0.39	0.35	0.41	0.37	0.34	0.43	0.40	0.36
2.5	0.48	0.43	0.39	0.45	0.41	0.38	0.47	0.44	0.40
3.0	0.51	0.46	0.42	0.48	0.44	0.41	0.50	0.47	0.43
4.0	0.55	0.50	0.46	0.52	0.48	0.45	0.54	0.51	0.47
5.0	0.58	0.53	0.49	0.55	0.51	0.48	0.57	0.54	0.50
0.5	0.27	0.23	0.19	0.26	0.22	0.19	0.27	0.24	0.20
0.8	0.29	0.25	0.21	0.28	0.24	0.21	0.29	0.26	0.22
1.0	0.31	0.27	0.23	0.30	0.26	0.23	0.31	0.28	0.24
1.25	0.35	0.32	0.28	0.35	0.31	0.28	0.36	0.33	0.29
1.5	0.40	0.37	0.33	0.40	0.36	0.33	0.41	0.38	0.34
2.0	0.46	0.42	0.38	0.46	0.42	0.38	0.47	0.44	0.40
2.5	0.50	0.46	0.42	0.50	0.46	0.42	0.51	0.48	0.44
3.0	0.53	0.49	0.45	0.53	0.49	0.45	0.54	0.51	0.47
4.0	0.57	0.53	0.49	0.57	0.53	0.49	0.58	0.55	0.51
5.0	0.60	0.56	0.52	0.60	0.56	0.52	0.61	0.58	0.54

$$UF = 0.55 + 0.022 = \mathbf{0.57}$$

$$MF = 0.8$$

$$DF = 0.57 \times 0.8 = \mathbf{0.456}$$

$$\frac{0.58 - 0.55}{1.5 - 1.25} \times 0.18 = 0.022$$



$$E = \frac{\text{Lumen} \times (\text{Design Factors})}{\text{Area}}$$

$$\text{Lumen} = \frac{300 \text{ lx} \cdot 40 \text{ m}^2}{0.456} = 26315.7$$



MASTER LED 18-100W 2700K PAR38 25D Dim.  
810 lm

Artificial lighting

$$\text{Lamps} = 26316 / 810 = 33$$

Artificial lighting

2

# PERCEPTION (Lighting Distribution)



# Uniformity

2



*High uniformity is desired in Areas like offices*



*Non Uniform lighting can create interesting effects in social areas*

# Luminance Contrast

2



*Low contrasts  
result in flat  
visual scene*



# Luminance Contrast

2



*High contrasts result in adaptation problem for eye when changing from one visual target to another*



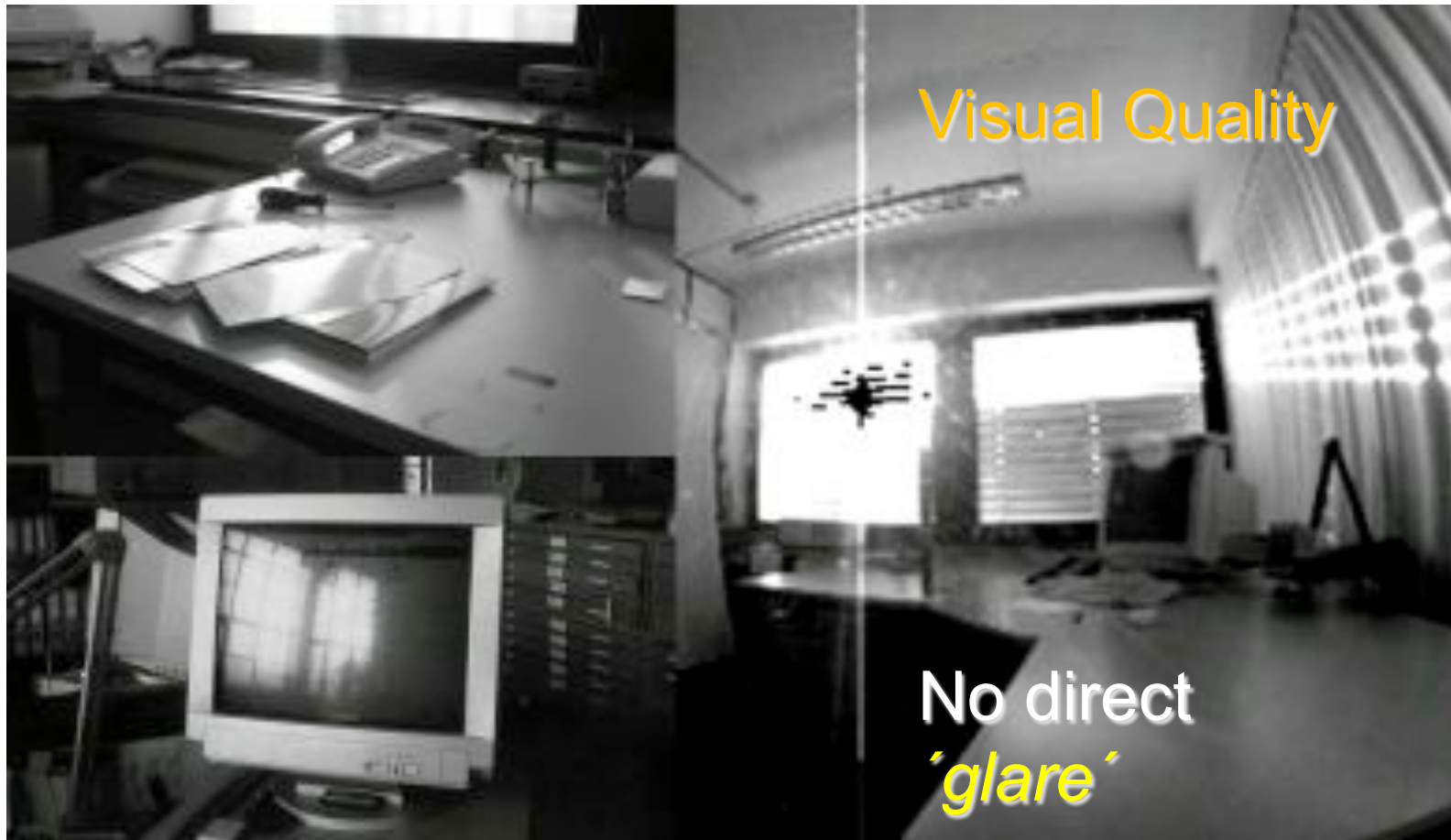


## Luminance Contrast



*Well Balanced  
Contrasts result  
in visual comfort  
and satisfaction*





Glare is caused by brightness of any objects within the visual field which is **brighter than the adaptation level of eye**  
It can lead to discomfort : Discomfort Glare

## Spatial Distribution of Light



Uniform General  
Lighting with  
Indirect light  
distribution

# Spatial Distribution of Light

4



Local Lighting can create interesting effects specially in social areas

## Color Rendering

# CRI (Ra)

describes lighting quality using scale (0 – 100)



RA = 20



RA > 80



## Color Rendition



Color perception under  
incandescent lamp with  
Yellow filter



Color perception under  
Low pressure Sodium  
Vapour Lamp

## Color Rendition of Typical Lamps

Lamp Type	Ra
Incandescent	100
Fluorescent Colour 33	66
Fluorescent Colour 54	77
Fluorescent Colour 84	85
Fluorescent Colour 94	93
High Pressure Sodium(SON)	26
High Pressure Mercury(HPL)	45
Low pressure Sodium(SOX)	(0)

Artificial lighting

# Laboratory of Building Science

Faculty of Architecture & Design - SCU



• **Grant from**  
PHILIPS Lighting  
Indonesia

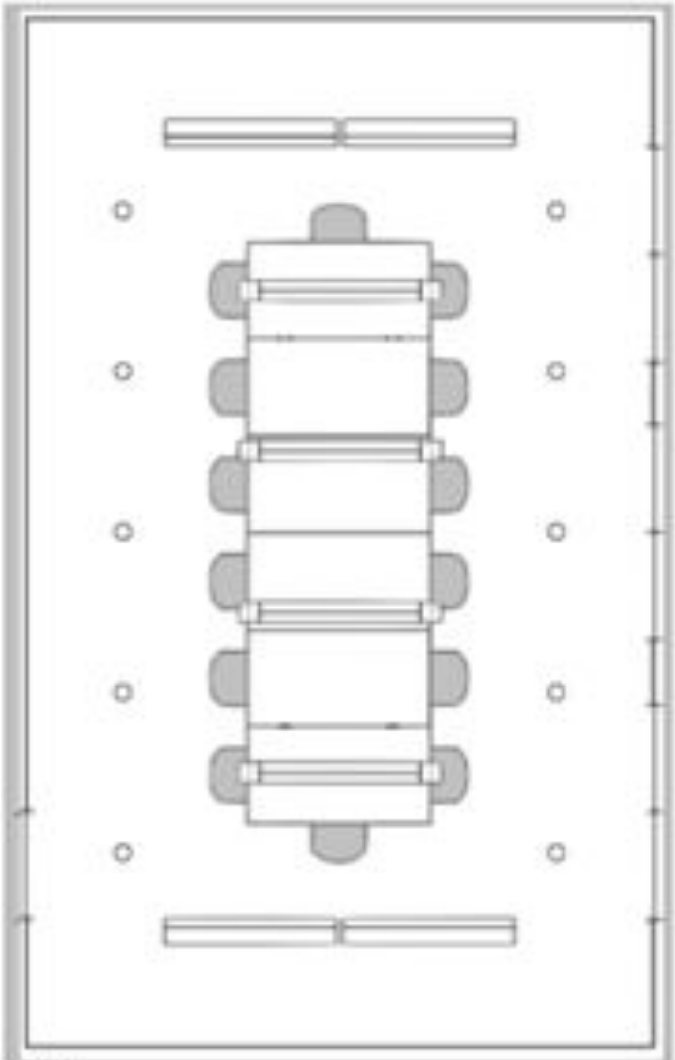


# Exercise



# Artificial lighting

Design



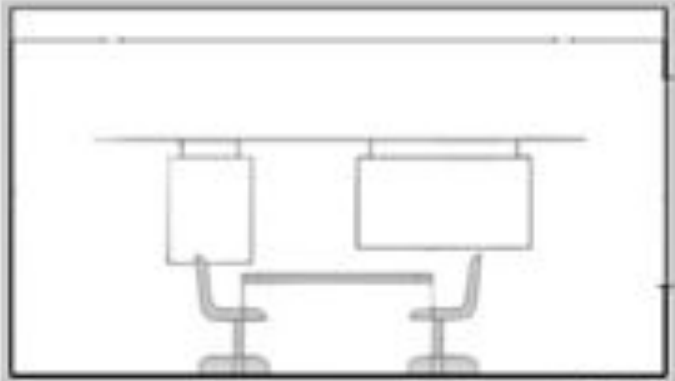
Plan



Recessed downlight



Pendant direct/indirect luminaire



Section



Section

**TODAY EVERYTHING HAS CHANGED.**

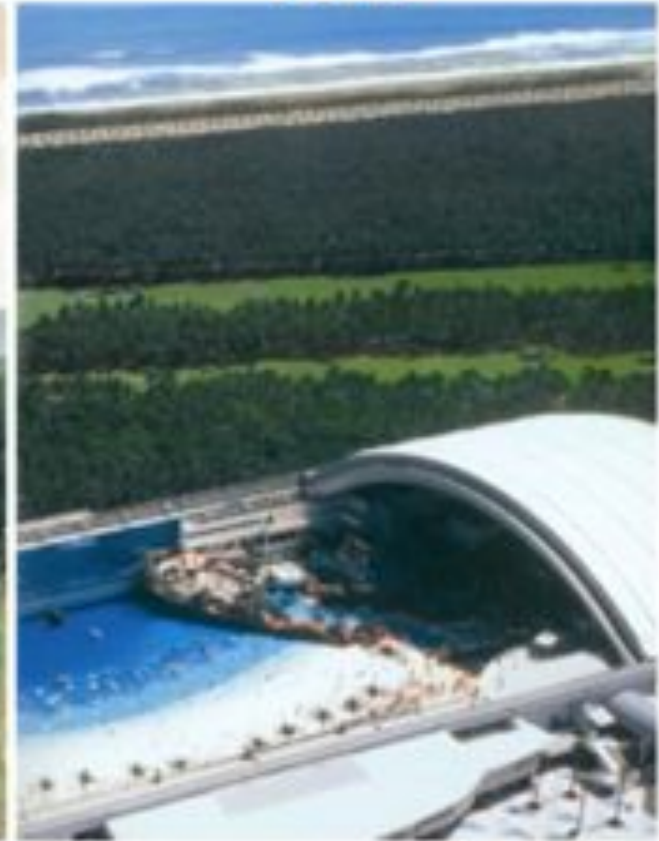
**Technologies**



**Work**



**Life**



### Trend in Lighting System

Application ;

- **Dynamic Environment / Ambience**
- **Lower Cost of Ownership**



Products ;

- **Miniaturization**
- **Dynamic System**
- **Color Quality**
- **Energy Saving**
- **Long lasting**
- **Environment Friendly**



### Dynamic Lighting

#### **Contact with the outside world**

People like the dynamics of day light

#### **Privacy and flexibility**

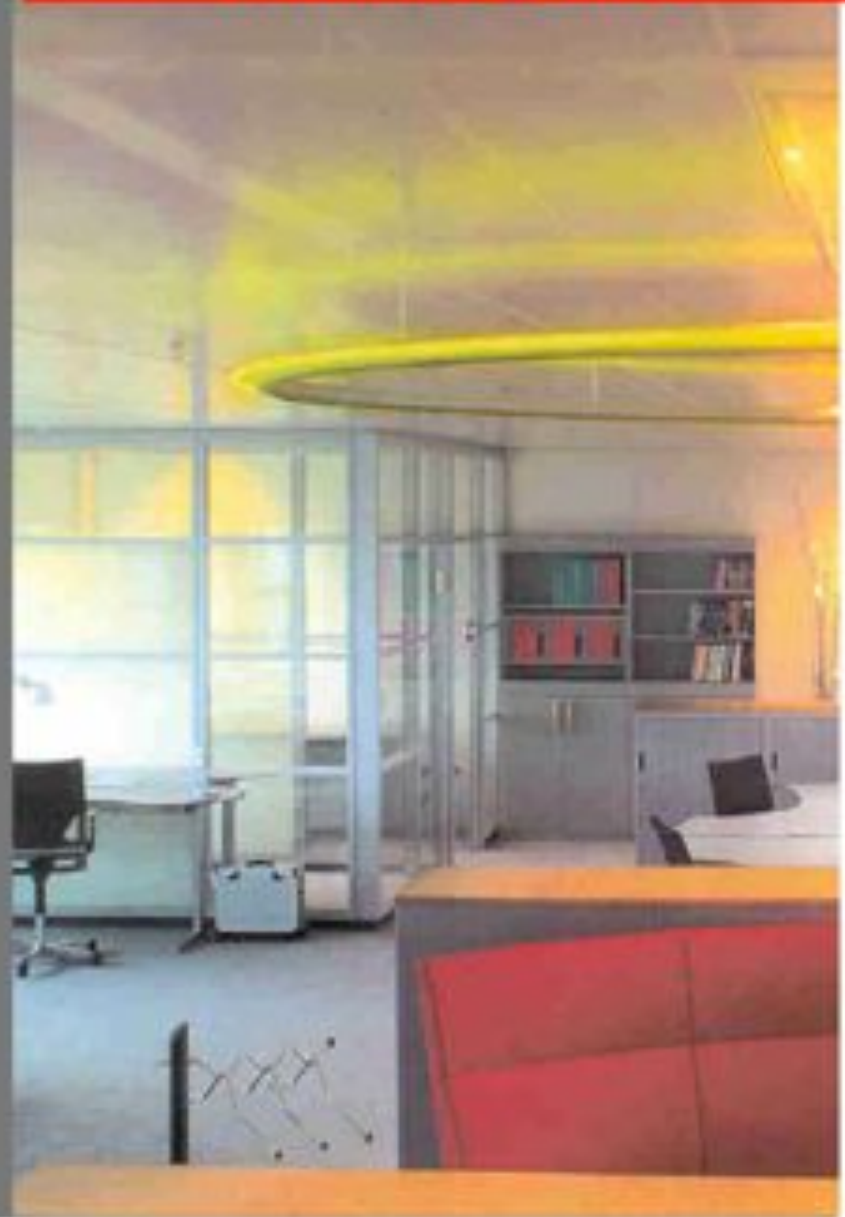
Different people have different preferences in lighting. So, flexibility in light level and color.

#### **Comfort**

Lighting that makes you feel at ease.

#### **Emotion**

People like surprising light effects. It stimulates, activates, and motivates.



## Contact with Outside World ..Why ?

Contact with the outside world  
The essence of 'Daylight' is information:



time



view



weather



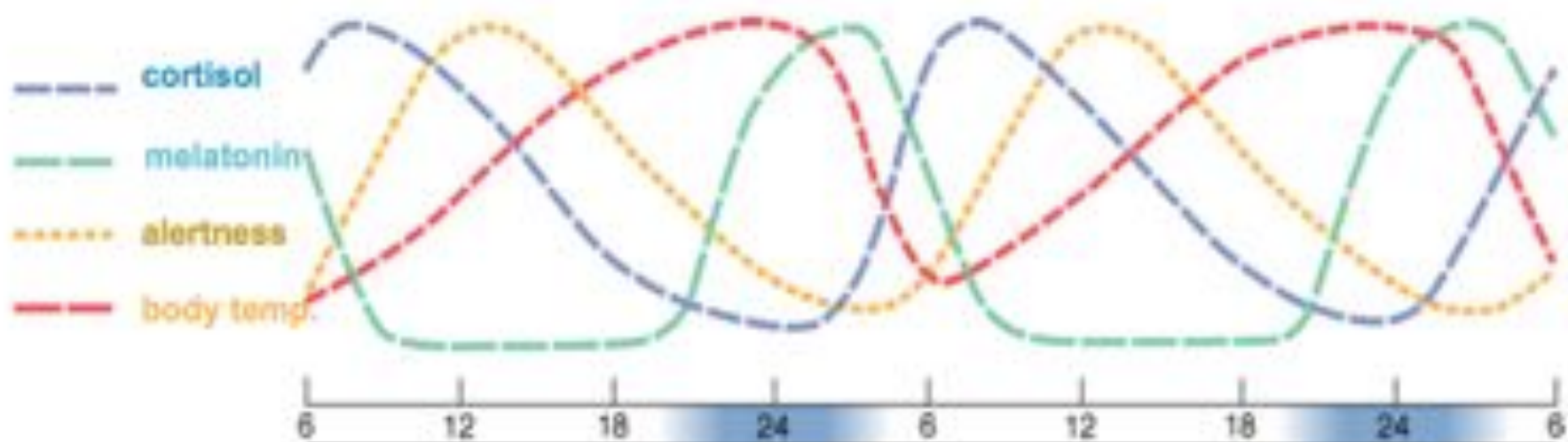
stimuli

Humans are adapted  
to the natural dynamics  
of daylight.



## Rhythm of the body

- All life on earth is related to the 24 hours cycle of light and darkness
- Body processes, like our heart beat, hormone levels, blood pressure, body temperature are controlled by the biological clock in our body.
- The biological clock is synchronised with the 24 hours cycle of light and darkness
- Well balanced body rhythms are essential for human health and well-being



# Contact with Outside World

- Dynamic ambience follows the rhythms of
  - The rhythm of the day
  - The rhythm of the body
- Dynamic ambience means automatic variation in
  - Light level
  - Light colour (warm white, cool white)

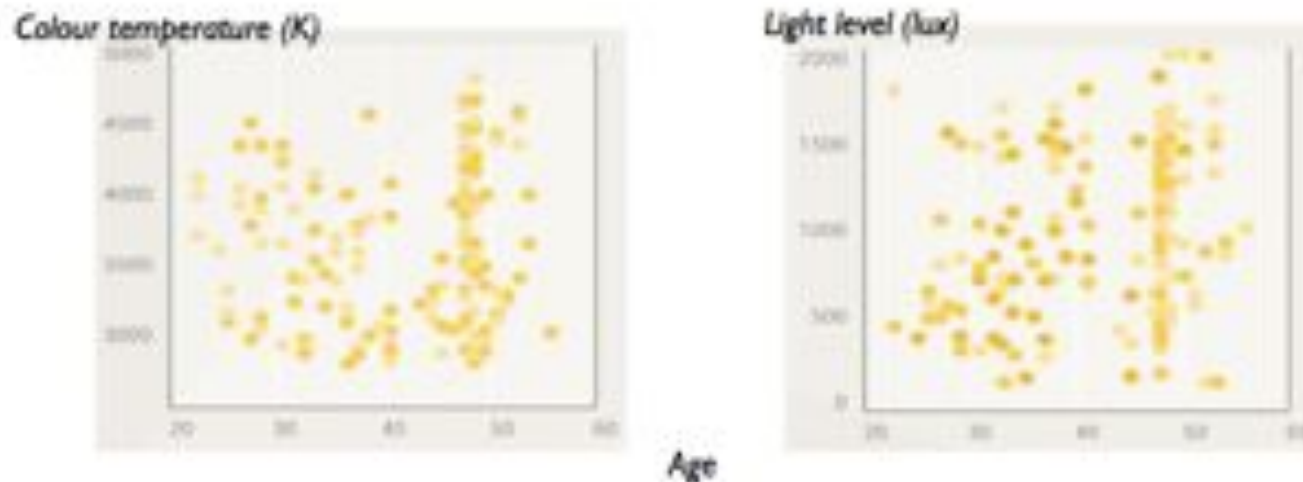




## Privacy & Flexibility .Why ?

### Personal Light

- Different people have different preferences in lighting



- Preferences depend on the kind of activity
- Preferences change

# Privacy & Flexibility

Personal Light

Man in nature



Man at work



*personal  
zone*

Artificial lighting



**Different people have  
different preferences  
in lighting**

With 'Personal light'  
everyone can set  
his own lighting preference

# Creating Emotion and Mood

## Artificial lighting



Hotel Anna in Munich



- Style – Small size
- Dynamics white point and color control
- Dimming
- Energy Saving Directed Light
- Long Life, Reduced Maintenance

Artificial lighting

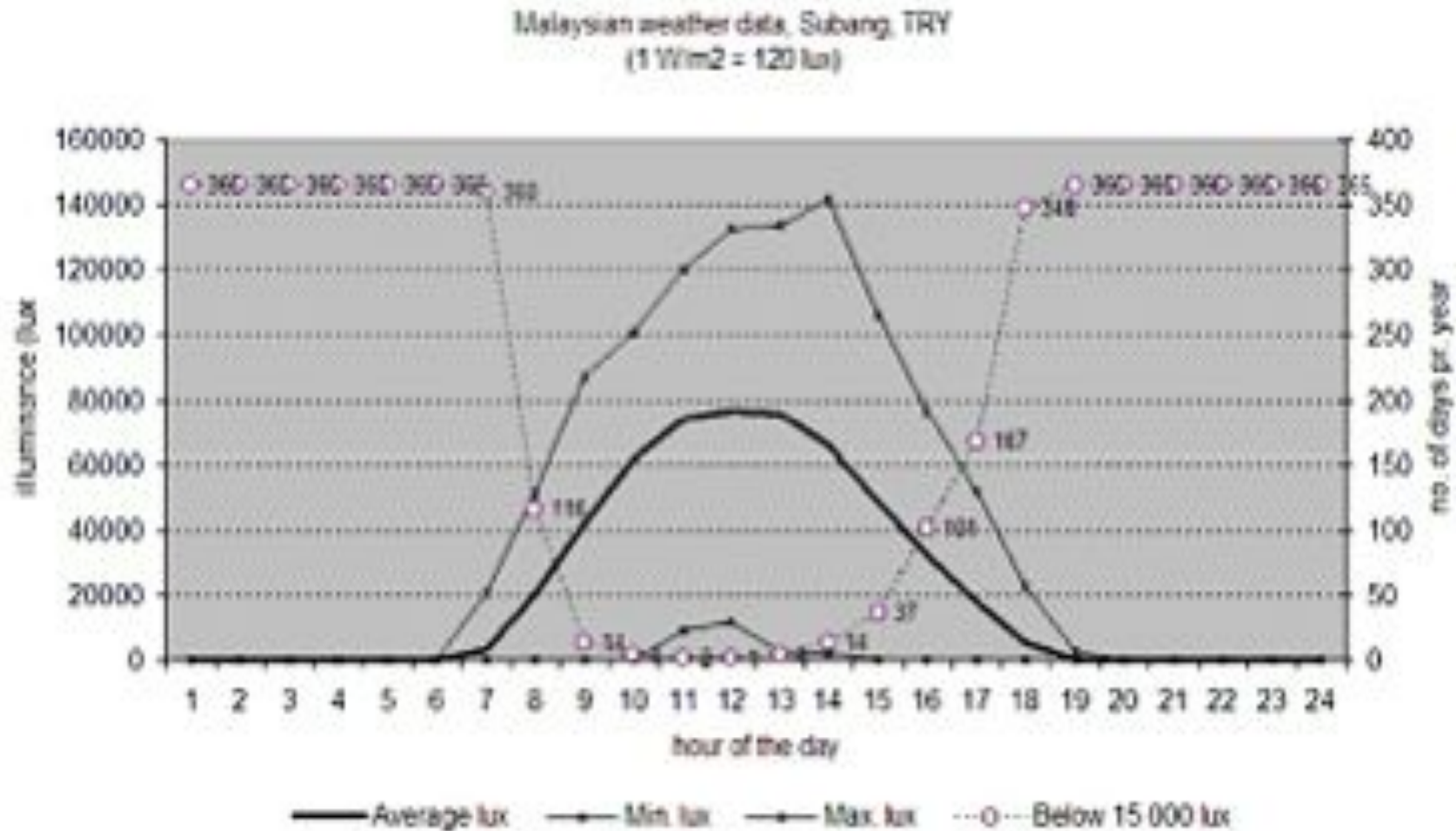


**LIGHT EMITTED DIOED (LED)**

What should we do  
to implement “green” concept  
on the lighting design  
under the tropical climates?

# Challenge

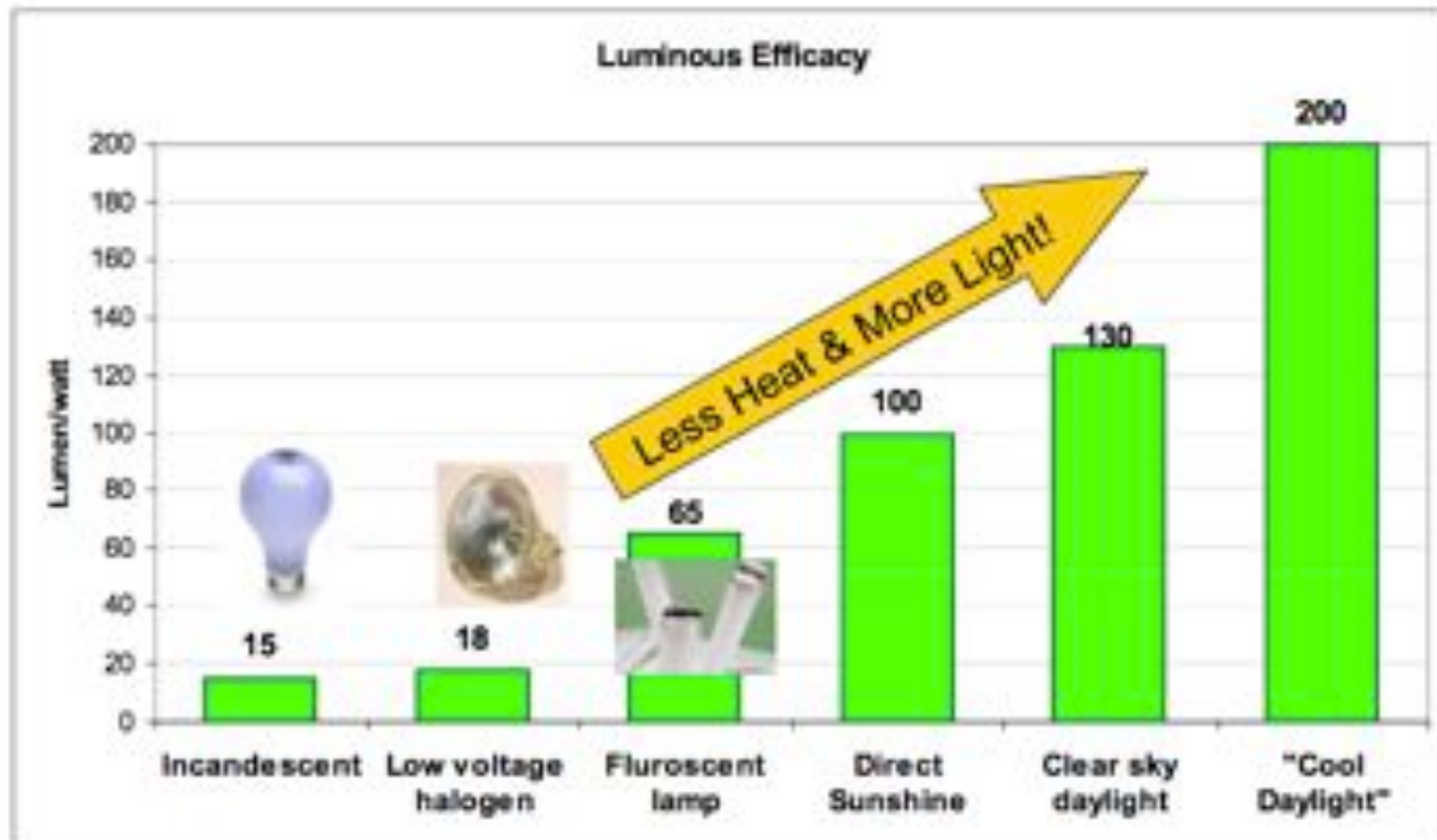
Daylighting Potential is the Highest in Tropics!



## Challenge

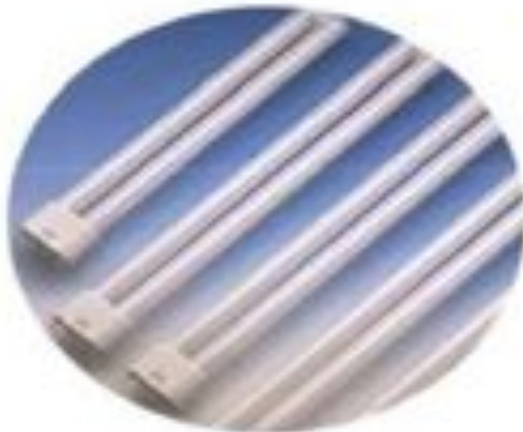
# Daylighting

- Daylight is Cool!



## Challenge

# Energy Efficient Lights & Ballast





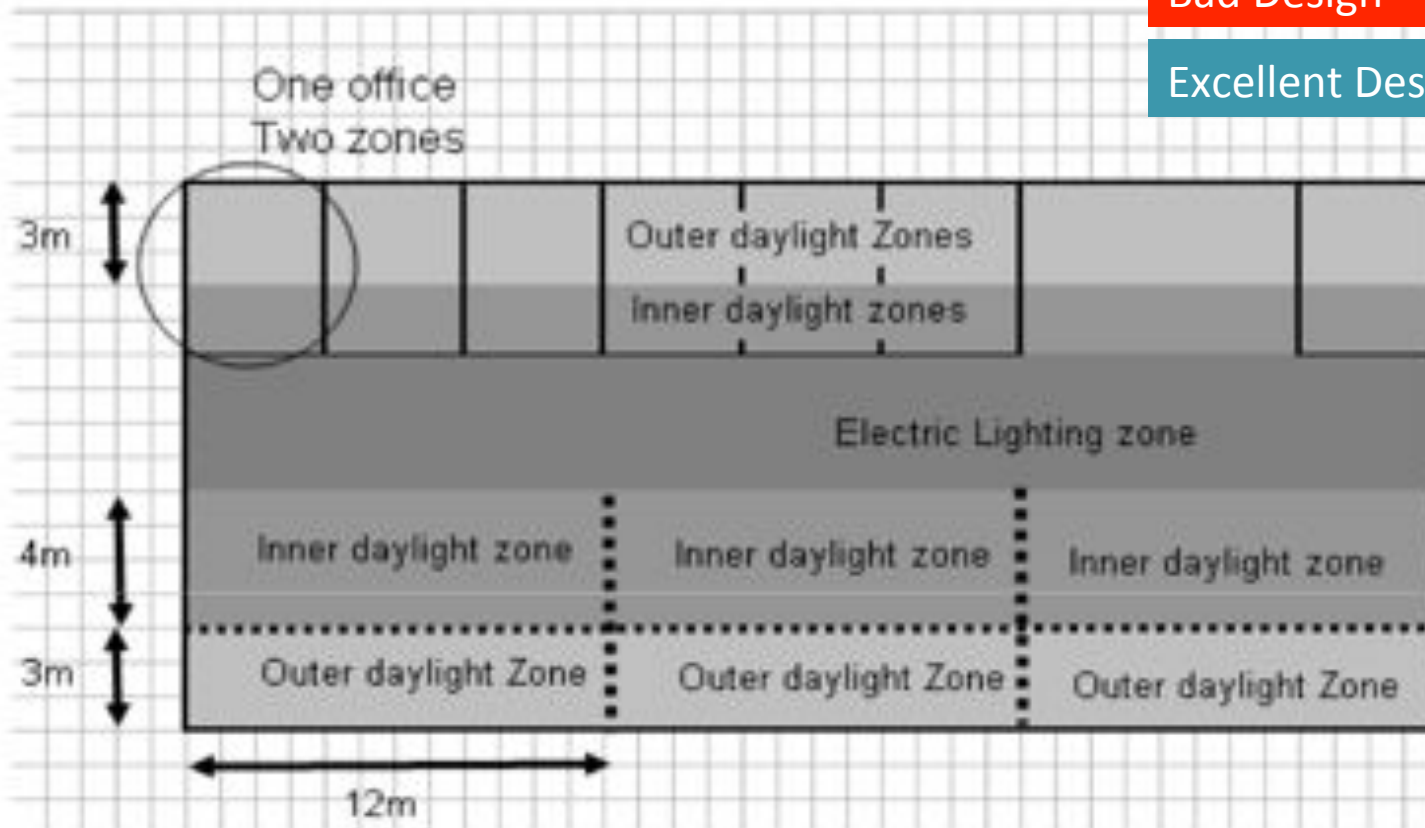
# Challenge

## Lighting Zone

- Occupancy Sensor
- Lighting Switch next to Exit Door
- Daylight Sensor

Bad Design : 25 – 40 W/m<sup>2</sup>

Excellent Design: 4.8 W/m<sup>2</sup>



A wide-angle, high-angle photograph of a modern, multi-level shopping mall. The mall features several levels connected by escalators and glass railings. The ground floor is filled with people walking and shopping. The upper levels also have people, and some storefronts are visible. The lighting is bright and modern, with recessed ceiling lights and decorative elements. The overall atmosphere is busy and contemporary.

**Maraming Salamat!**  
**Magandang linggo sa iyo!**

**Moediantanto,**  
Faculty of Architecture & Design  
<http://www.unika.ac.id/staff/Moediantanto>