DAYLIGHTING MEASURES FOR ECOHOUSING

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2.2.2. Day-lighting

Ensure glare free & adequate day-lighting

Factors that affect Visual comforts inside the buildings

- Visibility
- Clarity
- Glare-free Light
- Window Design
- Shading
- Daylighting

Eco Housing
Building a better Tomorrow

prevalent wind direction to be determined through appropriate wind rose diagram.
- Total area of openings (inlet and outlet) should be a minimum of 30% of floor area.
- Provide a gap between horizontal louver and wall. Take rain protection.
- Provide verandas/balconies (any projection extending from building that is accessible and is minimum 1.2 m wide), which are open on three sides.
- Plant hedges at a distance of 2 m from building on the leeward side.

Submittal Requirement: Narrative (maximum 500 words with supporting drawings and sketches) should include climate responsive strategies for 1) natural ventilation 2) daylighting 3) solar control to ensure maximum thermal and visual comfort

Intent: To enable energy efficiency, thermal and visual comfort

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2.3 Roof should be protected against excessive heat gain by: appropriate insulation to give U-value as specified by Draft Energy Conservation Building Code 2005. Alternately provide roof garden for 100% of exposed roof area or provide 100% shading for 100% of exposed roof area — **10**

Submittal Requirement: Bill of quantities with roof specifications

Intent: To prevent roof heat gain

** Applicable only if space under the roof is a regularly occupied space*

2.4 Design for following daylight factors: — **10**
- Kitchen: 2.5
- Living room: 0.625
- Study room: 1.9

Lighting

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Eco Housing & daylight

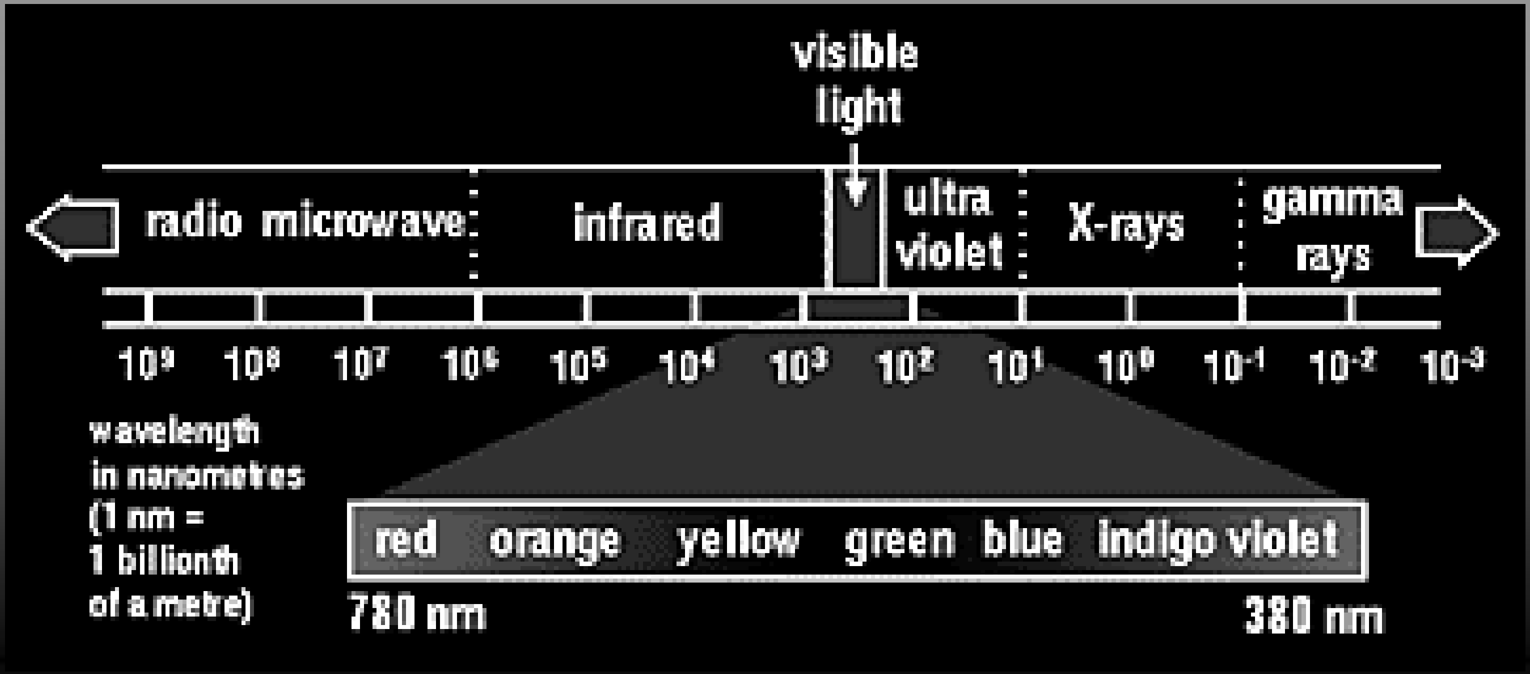
2.4	Design for following daylight factors: - Kitchen: 2.5 - Living room: 0.625 - Study room: 1.9	10

ERIA VERSION 1.0.

	- Circulation: 0.313 - 1 Daylight Factor = 80 lux - Demonstrate compliance by using an appropriate simulation tool
Submittal Requirement:	• Daylight based design • Simulated daylight levels under overcast sky conditions for a typical summer day
Intent:	Adequate daylight

Daylight Basics

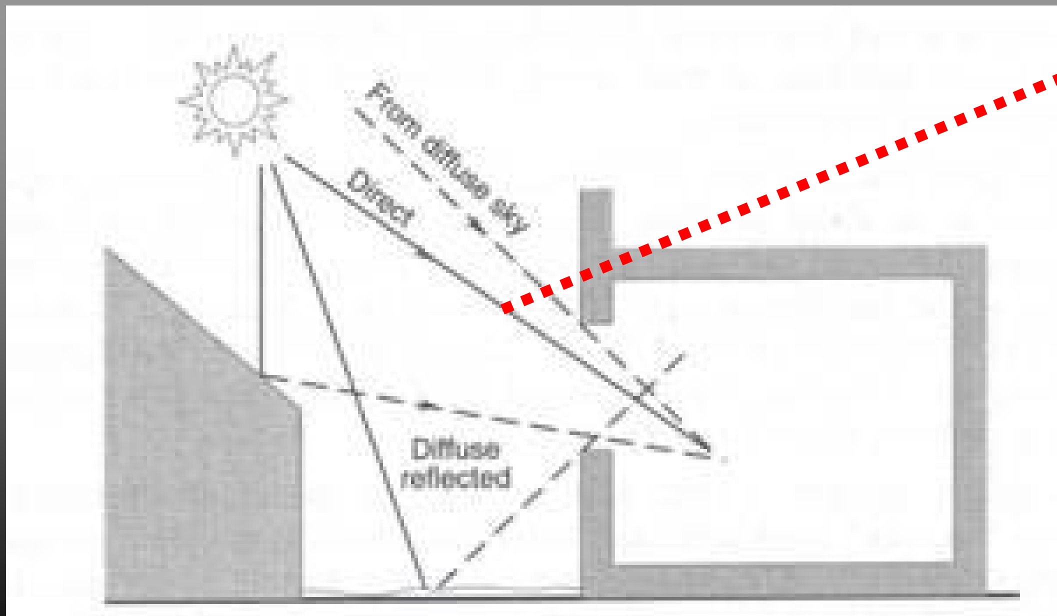
- **Sunlight**, in the broad sense, is the total spectrum of the electromagnetic radiation given off by the Sun. On Earth, sunlight is filtered through the atmosphere, and the solar radiation is obvious as daylight when the Sun is above the horizon.



- **Not all light beams have the same wavelength.**

- **The spectrum of visible light ranges from wavelength of 0,00078 mm or 780 nm (nanometer) to a wavelength of 0,00038 mm (380 nm).**

- We perceive the various wavelengths as different colors. The longest wavelength (which corresponds to the lowest frequency) is seen by us as the color red followed by the known colors of the rainbow: orange, yellow, green, blue, indigo, and violet which is the shortest wavelength (and highest frequency).
- White is not a color but the combination of the other colors.
- Wavelengths which we are unable to perceive (occurring just below the red and just above the violet area), are the infrared and ultraviolet rays, respectively.
- Nowadays, infrared is used for such applications as remote control devices.

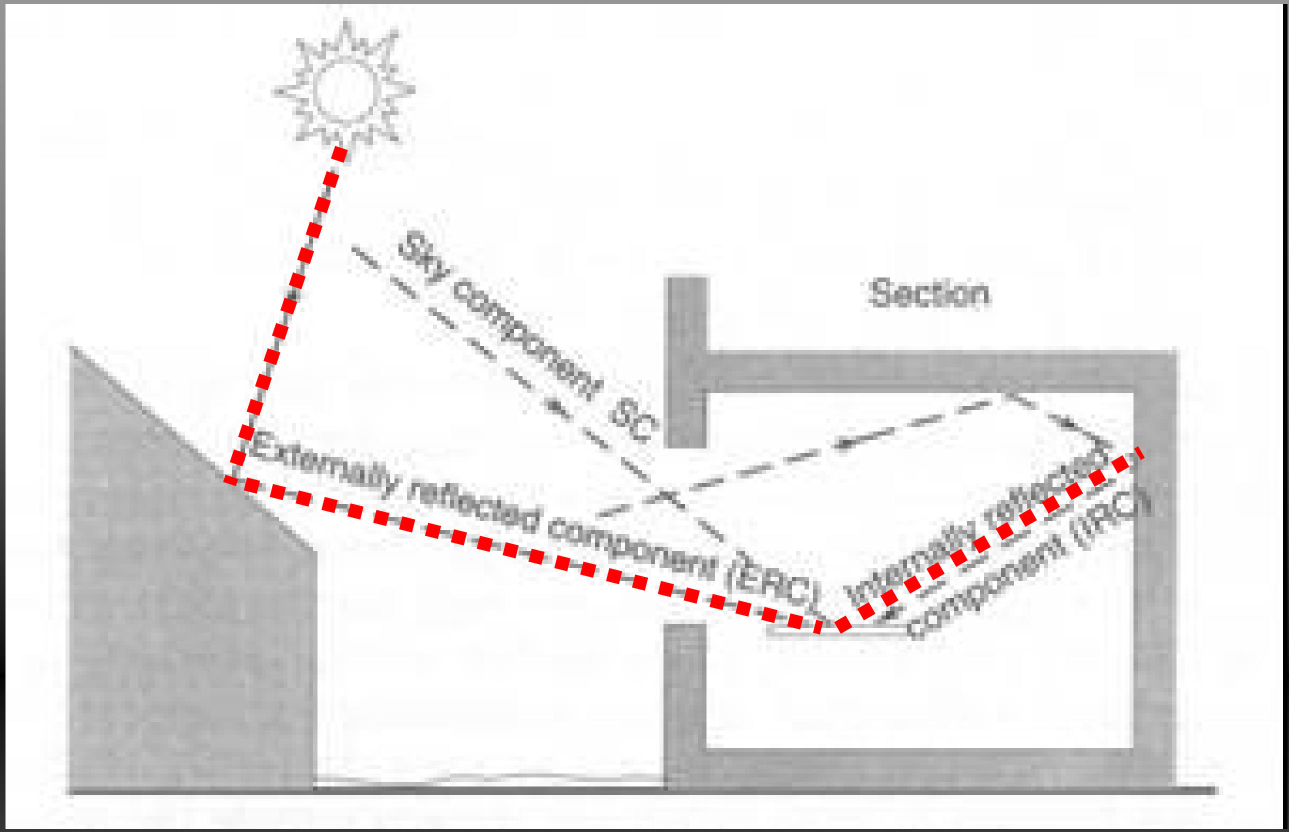


Direct sunlight is the most powerful source.

A summer sun can provide as much as 1000 W/m^2 of radiation measured in a plane normal to the sun's direction.

- Daylight or natural light which is visible radiation can reach is in three different ways:
  - Direct sunlight,
  - Skylight which is sunlight that has been scattered in the atmosphere,
  - Sunlight or skylight that has been reflected off the ground.

- When sunlight travels through the Earth's atmosphere, the light is scattered by water vapour, molecules and particles diffusing a certain proportion of it. Under normal conditions, this scattering is higher for short wavelengths (blue) than it is for long ones (red), which is why the sky dome appears blue.



- **The reflection of the outside ground is usually in the order of 0.2 or 20%. This means, that in addition to the sunlight and skylight, there is also an indirect component which can make quite a significant contribution to the light inside a building, especially since the light reflected off the ground will hit the ceiling which is usually very bright.**

The outdoor luminance can vary from 120,000 lux for direct sunlight at noon, which may cause eye discomfort, to less than 5 lux for the thickest storm clouds with the sun at the horizon.

Illuminance	Example
0.00005 lux	Starlight
0.0001 lux	Moonless overcast night sky
0.001 lux	Moonless clear night sky
0.01 lux	Quarter Moon
0.25 lux	Full Moon on a clear night
<1 lux	Moonlight
400 lux	Sunrise or sunset on a clear day.
32000 lux	Sunlight on an average day (min.)
100000 lux	Sunlight on an average day (max)

Length of Day at Various Latitudes (in Hours and Minutes on the 15th of Each Month)											
Month	Equator	10°	20°	30°	40°	50°	60°	70°	80°	Poles	Month
January	12:07	11:35	11:02	10:24	9:37	8:30	6:38	0:00	0:00	0:00	July
February	12:07	11:49	11:21	11:10	10:42	10:07	9:11	7:20	0:00	0:00	August
March	12:07	12:04	12:00	11:57	11:53	11:48	11:41	11:28	10:52	0:00	September
April	12:07	12:21	12:36	12:53	13:14	13:44	14:31	16:06	24:00:00	24:00:00	October
May	12:07	12:34	13:04	14:22	15:22	17:04	22:13	24:00:00	24:00:00	24:00:00	November
June	12:07	12:42	13:20	14:04	15:00	16:21	18:49	24:00:00	24:00:00	24:00:00	December
July	12:07	12:40	13:16	13:56	14:49	15:38	17:31	24:00:00	24:00:00	24:00:00	January
August	12:07	12:28	12:50	13:16	13:48	14:33	15:46	18:26	24:00:00	24:00:00	February
September	12:07	12:12	12:17	12:23	12:31	12:42	13:00	13:34	15:16	24:00:00	March
October	12:07	11:55	11:42	11:28	11:10	10:47	10:11	9:03	5:10	0:00	April
November	12:07	11:40	11:12	10:40	10:01	9:06	7:37	3:06	0:00	0:00	May
December	12:07	11:32	10:56	10:14	9:20	8:05	5:54	0:00	0:00	0:00	June

- This table shows the varying length of day with latitude. The day length is calculated as the period between the rising and setting of the sun. It does not include the period of twilight before and after sunrise and sunset.
- Read the months on the left of the table for the northern hemisphere, and the months on the right of the table for the southern hemisphere.

Photometric Quantities

- The ***Intensity (I)*** of the light source is measured in units of ***Candela (cd)***

- The *Flux* (flow of light) is measured in ***Lumens (lm)***
  - *One lumen* is the flow of light emitted by a unit intensity point source, within a unit solid angle.

- The amount of flux falling on unit area is the ***Illumination (E)*** ,measured in ***Lux (lm/m2)***

- ***Luminance (L)*** **is the measure of brightness of a surface**
- **If a light source of one cd intensity has a surface area of one m2,its luminance is 1cd/m2**

- Illumination of the point source reduces with the square of the distance

E (illumination)= I(lux)/d² (distance)

- Illumination from a linear source of infinite length reduces proportionately to the distance ,

- ***while from an infinitely large luminous surface the illumination does not vary with the distance***

Luminosity

- **Brightness Values:**
- Candle light at 20 cm 10-15 Lux
- Street light 10-20 Lux
- Normal living room lighting 100 Lux
- Office fluorescent light 300-500 Lux
- Halogen lamp 750 Lux
- Sunlight, 1 hour before sunset 1000 Lux
- Daylight, cloudy sky 5000 Lux
- Daylight, clear sky 10,000 Lux
- Bright sunlight > 20,000 Lux

- **Color Temperature**
- Color temperature relates to the fact that when an object is heated, it will emit a color that is directly related to the temperature of that object. The higher the color temperature, the more 'blue' the light, and the lower the color temperature the more 'red' the light. Color temperature of light can be measured in degrees Kelvin (K). Daylight has a color temperature between 6000 and 7000 K. The color temperature of artificial light is much lower: approximately 3000 K. In reality, color temperatures range from 1900 K (candlelight) up to 25,000 K (clear blue sky). Television is set to 6500 K, simulating 'standard daylight'.

Lighth source		Degrees Kelvin	Spectrum
sunrise		1000	towards red
candlelight		1900	
light bulb (100W)		2800	
fluorescent lamp		4500	
cloudy sky		6500	
hazy sky		9000	
clear blue sky		25000	towards blue

Various light sources with different color temperatures. Color temperature

Daylight and Architecture

- Day lighting-- the practice of utilizing natural light within a building, requires careful planning to balance heat gain and loss, control glare, and adjust for variations in daylight availability.

- This design strategy can significantly cut energy use in buildings

Day lighting planning objectives at each stage of building design:

Conceptual Design:

- As the building scheme is being created, day lighting design influences and/or is influenced by basic decisions about the
  - building's shape
  - proportions
  - apertures
  - integration and the role of building systems.

Design Phase:

- As the building design evolves, day lighting strategies must be developed for different parts of the building.
  - The design of facades
  - Interior finishing, and
  - the selection and integration of systems and services (including artificial lighting)

Objective of a good day lighting system

- The amount of light needed (illuminance)
- Visual Comfort (luminance contrast and glare index) and
- Psychological considerations (external view and perception of time and day)

The amount of light needed (illuminance)

- Definition of comfort illuminance levels for certain activities as per the NBC
- Living Room
- Kitchen
- Toilet
- Bedroom
- Passages

Factors that determine the required illumination in the design space

- How much day light is available outside
- Surrounding obstruction for daylight penetration in the design space
- Surroundings that will reflect the daylight in the design space
- Orientation of the fenestration
- Size of the fenestration
- Design of shading devices

Climate and Light

- In high altitude moderate climate, where typically the sky is overcast ,the whole of the sky dome acts as a light source.
- Direct sunlight may occur, but cannot be relied on
- The sky itself has a luminance sufficiently high to provide lighting to common interior spaces.(7000cd/m2)
- CIE (Commission Internationale de l'Eclairage has established the luminance distribution of a typical overcast sky
- $L_y = L_h * (1+ 2 * \sin y)$ where,
  - L_y = Luminance at y altitude angle
  - L_h = Luminance at horizon
- Hence illumination at zenith is $(L_z)= 3 \times L_h$ (75)

- In Hot dry desert climates, the sky is cloudless with strong direct sunlight. Sky is typically deep blue in color and luminance as low as 1700cd/m2.
- The clear sky usually is brightest around the sun and dimmest opposite it. The brightness of the horizon lies in between those two extremes.
- Dependency on diffused/reflected sunlight from sky is to be overruled, but at the same time direct sunlight also needs to be avoided for thermal reasons.
- The bare, dry sunlit ground and light colored walls of the surrounding built form will reflect much light which will be the main source of indoor lighting.

Absolute methods allow the designer to make predictions about the illumination from daylight at the point of interest. The complication is, however, that the daylight availability varies with time, season, and weather conditions. Newer, computer based methods, therefore combine such simple methods with statistical weather data that is available for a variety of places.

- Methods that determine absolute illuminance;
- Methods that determine relative illuminance.

- The advantage with analysis methods that produce relative illuminance values is that the results are independent of naturally occurring fluctuations of the available daylight.
- As a result, different design scenarios can be easily compared to one another, even for different sites.
- A typical example is the daylight factor approach.
- The drawback is, however, that no statement about the absolute illuminance can be made unless the sky conditions are well-defined, in which case absolute illumination method applies.

- The daylight factor (DF) is a very common and easy to use measure for the subjective daylight quality in a room.
- It describes the ratio of outside illuminance over inside illuminance, expressed in per cent. The higher the DF, the more natural light is available in the room.
- DF = 100 * Ein / Eext
  - E_{in} - inside illuminance at a fixed point
  - E_{ext} - outside horizontal illuminance under an overcast (CIE sky) or uniform sky.

- **The E_{in} illuminance can be considered as the sum of three different illuminances:**
  - the direct iluminance if the sky is visible from the considered point (ED)
  - the illuminance due to the reflections on the outside environment (EER)
  - the illuminance due to the reflections on the inside surfaces (EIR)
- Hence, the daylight factor depends on the sum of three components:

DF = DC + ERC + IRC

  - DC - direct component /SC (sky component)
  - ERC - externally reflected component
  - IRC - internally reflected component

DC - direct component /SC (sky component) depends on

Area of the sky visible from the point under consideration

(area of the window,quality of glass,external obstruction I.e.trees etc.)

ERC - externally reflected component

Area of the external surface visible from the point under consideration as well as the reflectance of these surfaces.

IRC - internally reflected component

Area of the room,the ratio of the walls to the window area and the reflection of the wall surfaces

STANDARDISED SKY MODELS

- As clouds form and move through the sky, the distribution of light can change almost minute by minute. This means that we cannot really design for any specific distribution, but must rely on 'average' conditions.
- The Commission International de ‘Eclairage (CIE) has developed a series of mathematical models of ideal luminous distributions under different sky conditions - of which the three most common are clear, uniform and overcast
- As a worst-case, the **overcast** sky condition is usually used. However in some tropical regions the **uniform** sky is considered

The Sky component (SC) and the externally reflected component (ERC) are found by using the daylight protractors

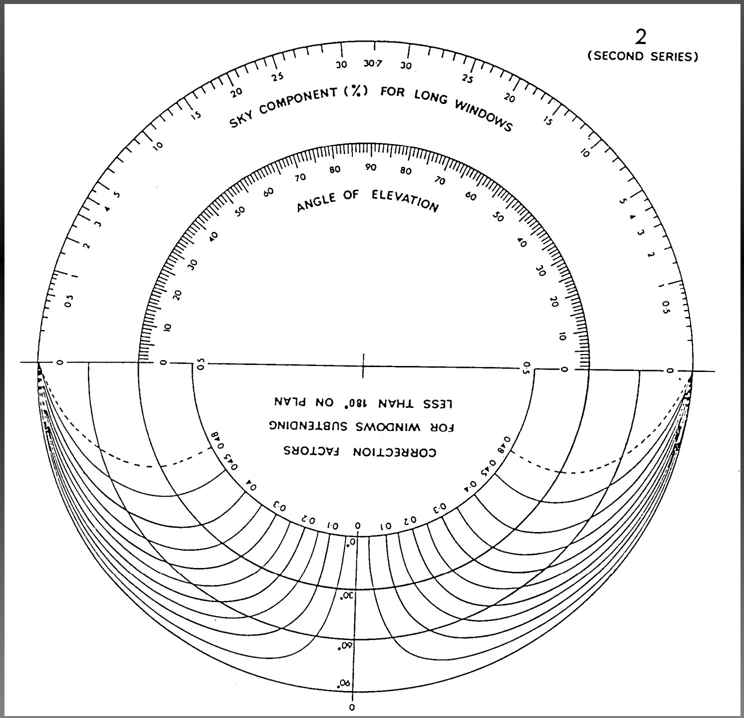
- There are 2 series of protractors
  - For the sky of uniform luminance
  - CIE sky luminance distribution

- Series 1 protractor to be used to predict SC under clear sky,tropical conditions.
- Series 2 protractors should be used In overcast sky conditions.

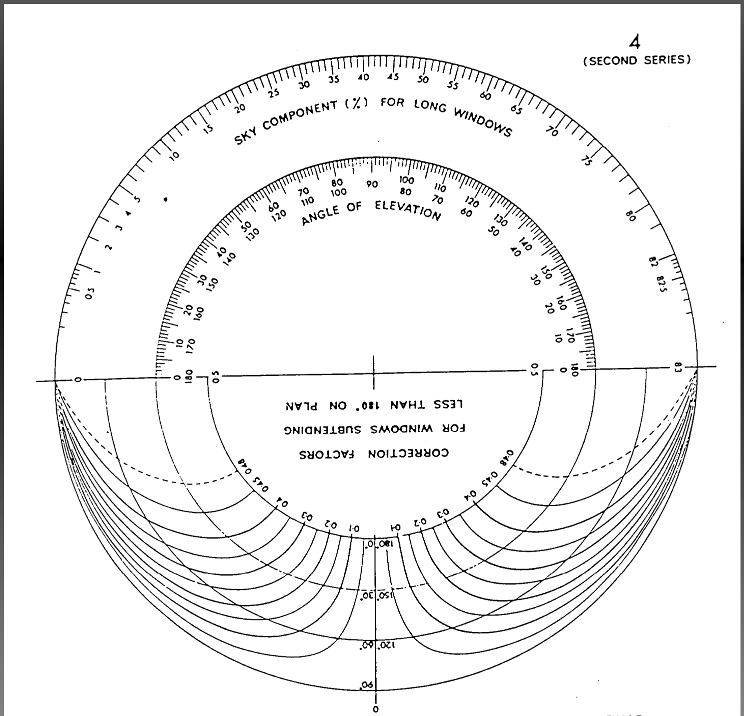
- Uniform sky protractors are available for the following window configurations:
  - Vertical glazing
  - Horizontal glazing
  - Glazing sloped 30° to horizontal
  - Glazing sloped 60° to horizontal
  - Unglazed vertical openings

BRE protractors

The Building Research Establishment BRE (formerly the Building Research Station BRS) developed a set of protractors which give direct reading of the sky component in percentages. There are ten nos. of such protractors, of which five are for the uniform sky and five for the CIE sky:



BRS Sky Component Protractor for Vertical Glazing



BRS Sky Component Protractor for Horizontal Glazing

Case Example for using BRE Protractor and Nomogram for checking the illumination level for a given task point

- Take a room which is to be used as bedroom, measuring 4m x 4m ,height 3m .
- Place a window of 1.2m x 1.2m in the center of any external wall.
- Sill level 0.9 m.
- Consider the walls painted with white distemper and vetrified ceramic tile flooring.
- Calculate the D.F. and check if this window provides the required illumination level at a working plane in the room at a distance of 2m from the window and 1 m from one of the longer sides, as prescribed in NBC.

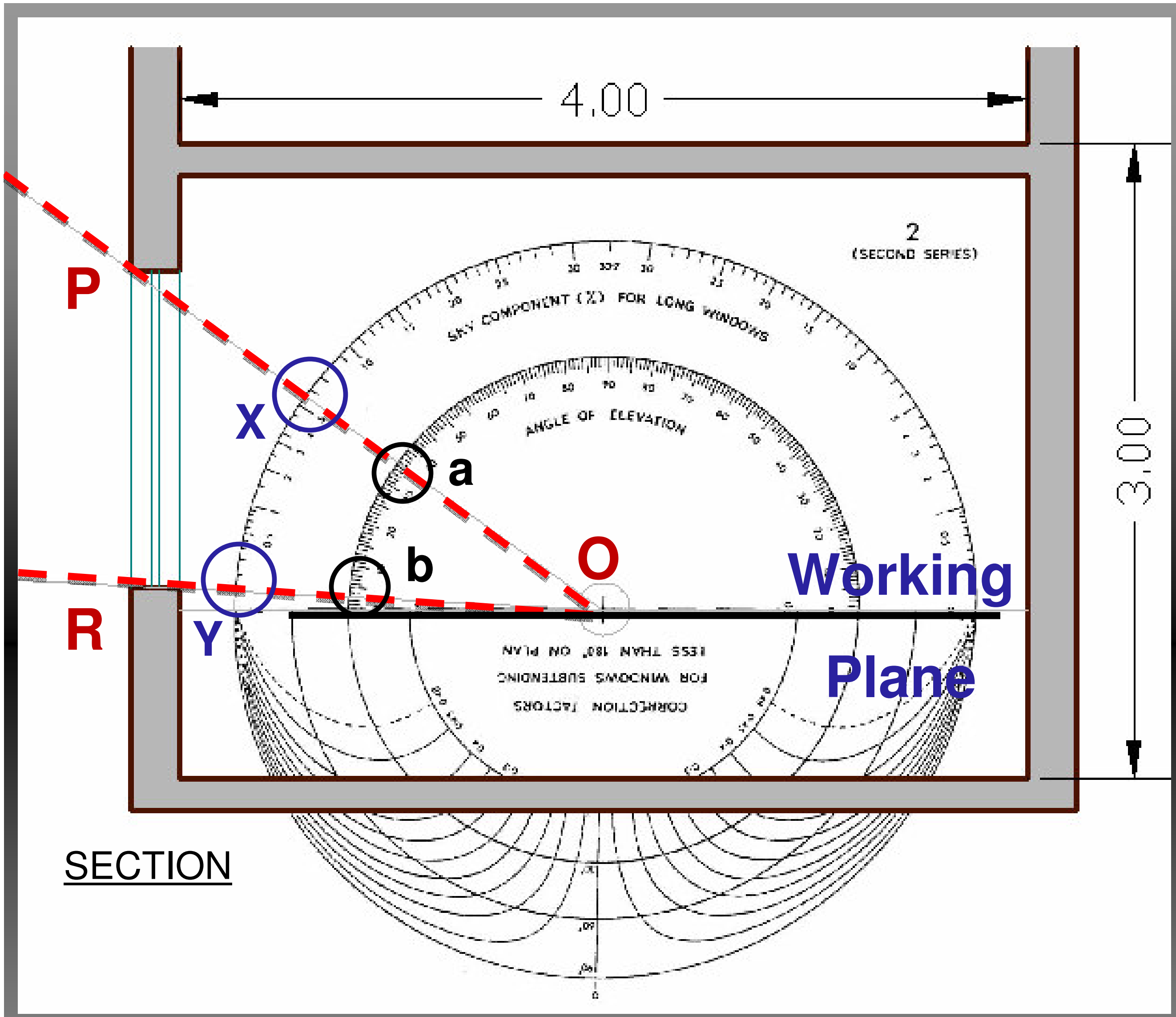
FINAL SKY COMPONENT

= (INITIAL SKY COMPONENT x CORRECTION FACTOR)

- TO FIND OUT THE INITIAL SKY COMPONENT……………

A SECTION THROUGH THE WINDOW AND 'A' SIDE OF THE APPROPRIATE BRE PROTRACTOR NEEDS TO BE USED.

- TO FIND OUT THE CORRECTION FACTOR………………..
- A PLAN AND 'B' SIDE OF THE APPROPRIATE BRE PROTRACTOR NEEDS TO BE USED



The steps to be taken in establishing the sky component are :

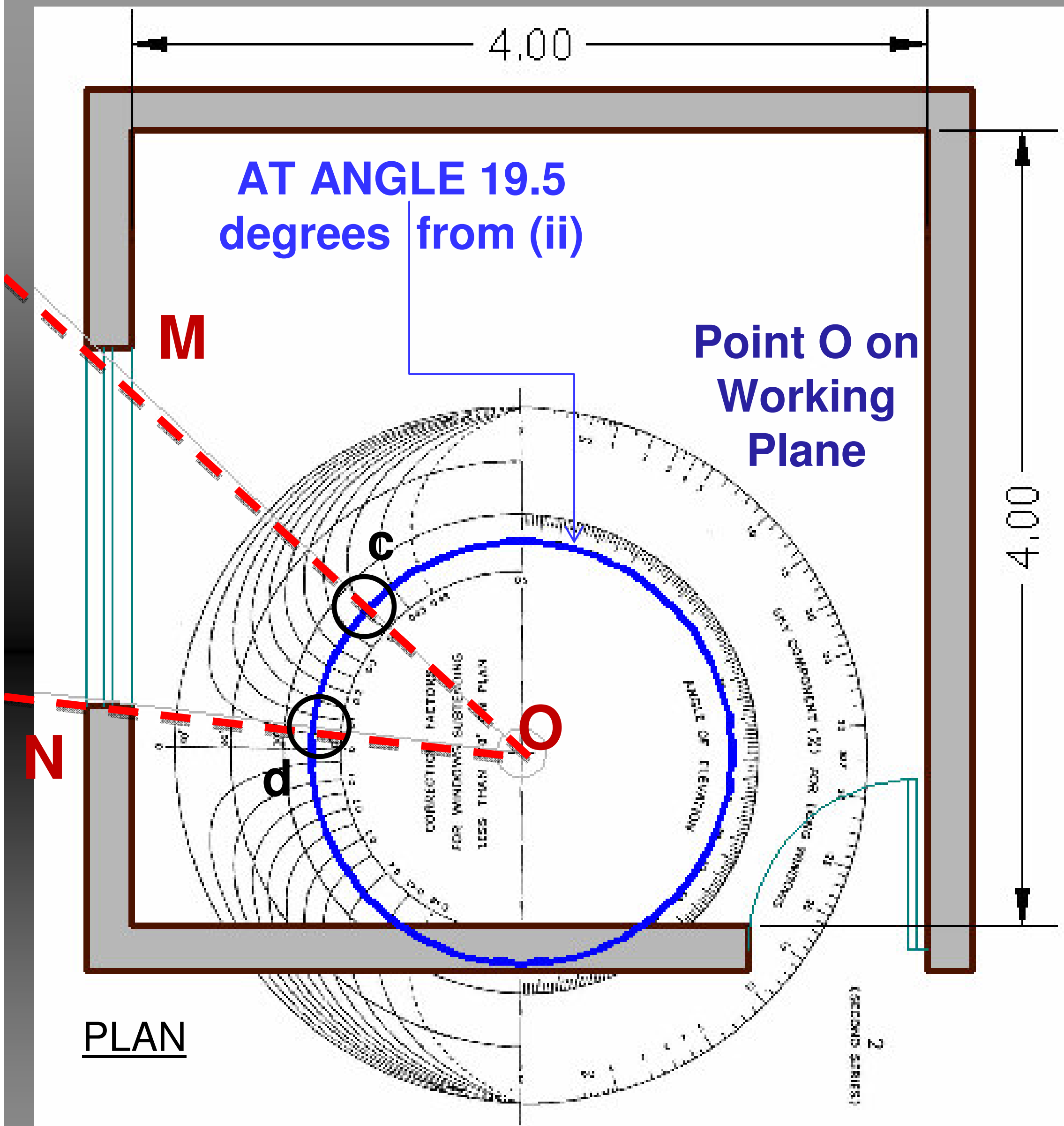
1. Take a section of the room, draw the working plane and on it the point to be considered (O).
2. Connect the limits of aperture (or edges of obstruction) to point O, i.e., lines PO and RO.
3. Place the protractor with scale A uppermost, base line on the working plane with the centre on point O.
4. Read the values where lines PO and RO intersect the perimeter scale: the difference of the two values is the initial SC.
5. Read the altitude angles where lines OP and RO intersect the 'angle of elevation' scale and take the average of the two readings.

i) INITIAL SC = READING X – READING Y

INITIAL SC = (5.6 – 0.1) = 5.5

ii) AVERAGE OF ANGLE 'a' AND 'b'

= (36 + 3)/2 = 19.5 degrees



1. Take the room plan and mark position of the point to be considered (O).
2. Connect the limits of aperture with point O, i.e., lines MO and NO.
3. Place the protractor with scale B towards the window, base line parallel to the window with the centre on point O.
4. Four concentric semicircles are marked on the protractor 0 deg, 30 deg, 60 deg and 90 deg. Select the one according to the corresponding elevation angle obtained in step 5, if necessary interpolating an imaginary semi-circle. Unless the reference point is very close to the window, this will normally be well below 30 deg and will not have much effect.
5. Where Lines MO and NO intersect this semicircle read the values along the short curves on the scale of the inner semicircle.
6. If the two intersection points are on either side of the centre line, add the two values obtained: if they are on the same side, take the difference of the two values. This will be a correction factor.

iii) CORRECTION FACTOR

= (c - d)

= (0.41 – 0.07) = 0.34

Lighting

Multiply the initial SC (step i) by the correction factor (step iii) to obtain the sky component.

iv) THEREFORE FINAL SKY COMPONENT

= (5.5 X 0.34)

= 1.87

ERC

- If there are no obstructions outside the window, there will be no ERC.
- If, however, there are objects higher than the line RO, the light reflected from these objects will reach the point considered, and will contribute to the lighting at that point. This may make an important contribution to the day lighting, particularly in crowded urban situations.
- The magnitude of this contribution is expressed by the ERC, which can be found as follows:
  - Find the equivalent SC, which would be obtained from the same area of sky were it not obstructed, following the steps described above.
  - Multiply this value
  - If series 1 (uniform sky)by 0.5 times the average reflectance of obstructing surfaces, or if this is unknown, by a factor of 0.1.
  - If series 2 (CIE sky) by average reflectance of opposing surface or a value of 0.2

As we have used BRE Protractor series 2 we can multiply the Final sky component (step iv) by 0.2 as prescribed in order to obtain the EXTERNALLY REFLECTED COMPONENT (ERC)

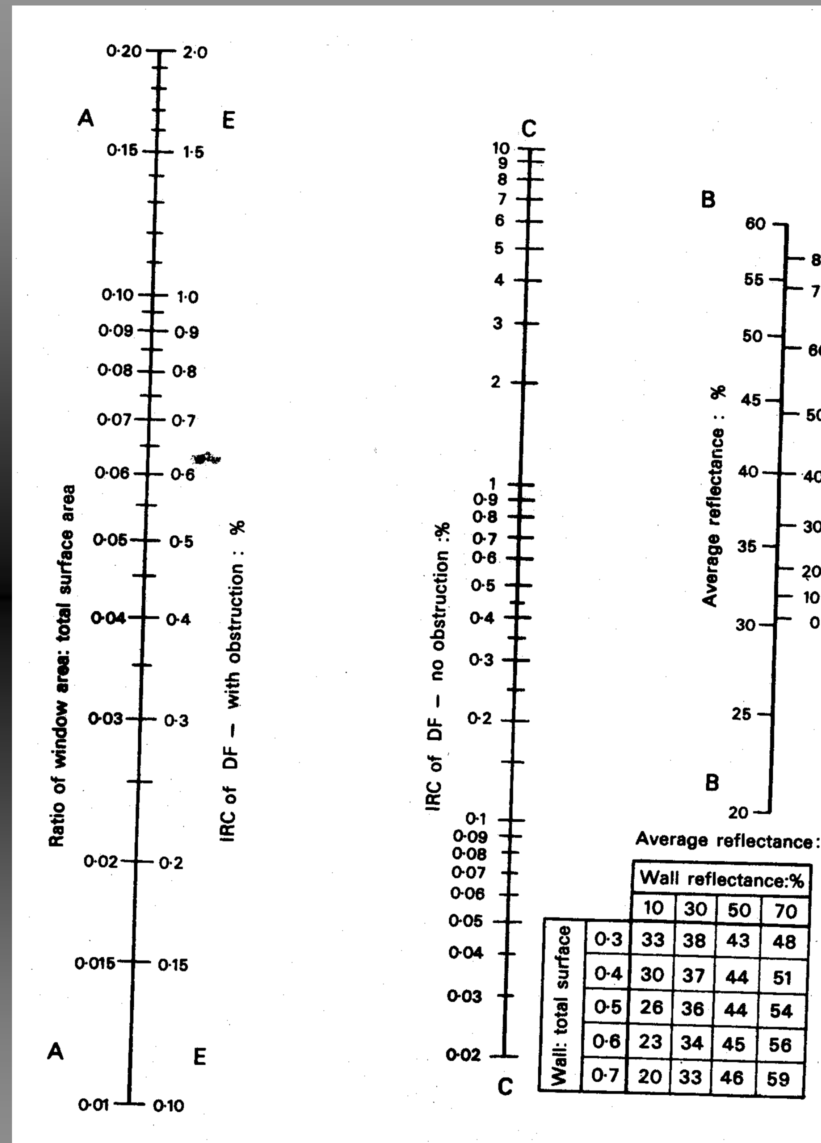
v) THEREFORE ERC = (1.87 X 0.2)

= 0.374

IRC-Internally Reflected Component

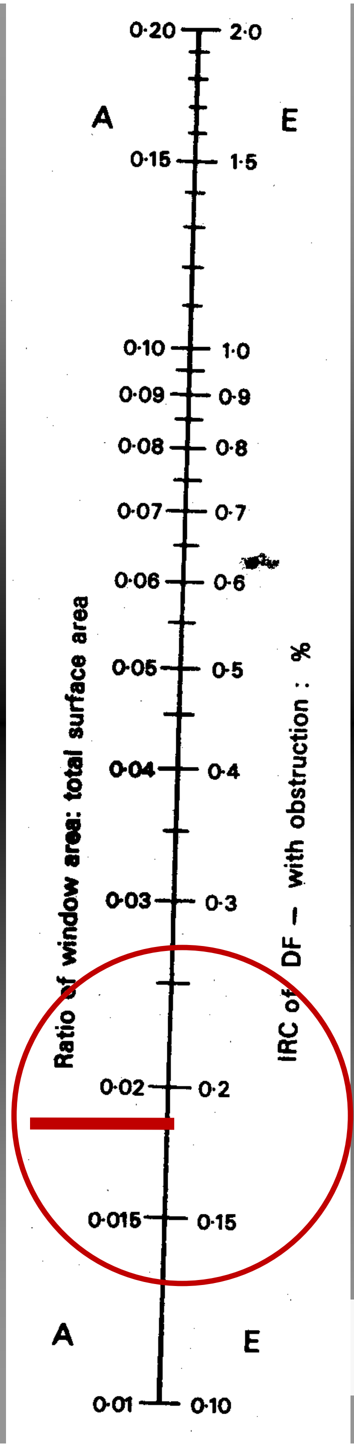
- Much of the light entering through the window will reach the point considered only after reflection from the walls, ceiling and other surfaces inside the room.

- The magnitude of this contribution to the day lighting of the point considered is expressed by the IRC. This will normally be fairly uniform throughout the room, thus for most problems it is sufficient to find the average IRC value. The simplest method uses the nomogram.



Wall: total surface	Wall reflectance:% 10	30	50	70
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

- **LRV -Light Reflectance Value** is a measure of how much light is reflected from a coloured material. It is given as a percentage where white has a value of 100% and black has a value of 0%.



1. Find the window area and find the total room surface area (floor,ceiling and walls, including windows) and calculate the ratio of window to total surface area. Locate this value on scale A of the nomogram.

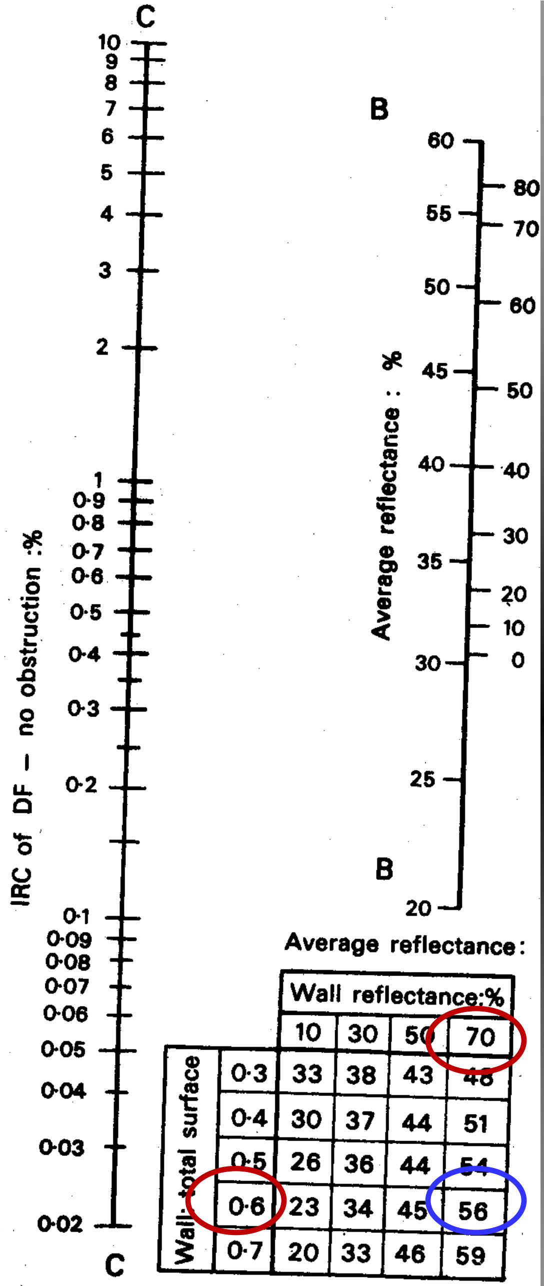
i) WINDOW AREA = (1.20 X 1.20)

= 1.44

ii) TOTAL ROOM SURFACE AREA = 80 sq.m.

iii) RATIO 1.44/ 80 = 0.018

Scale 'A' and 'E' of Nomogram



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2) Find the area of all the walls and calculate the ratio of wall to total surface area. Locate this value in the first column of the small table (alongside the nomogram).

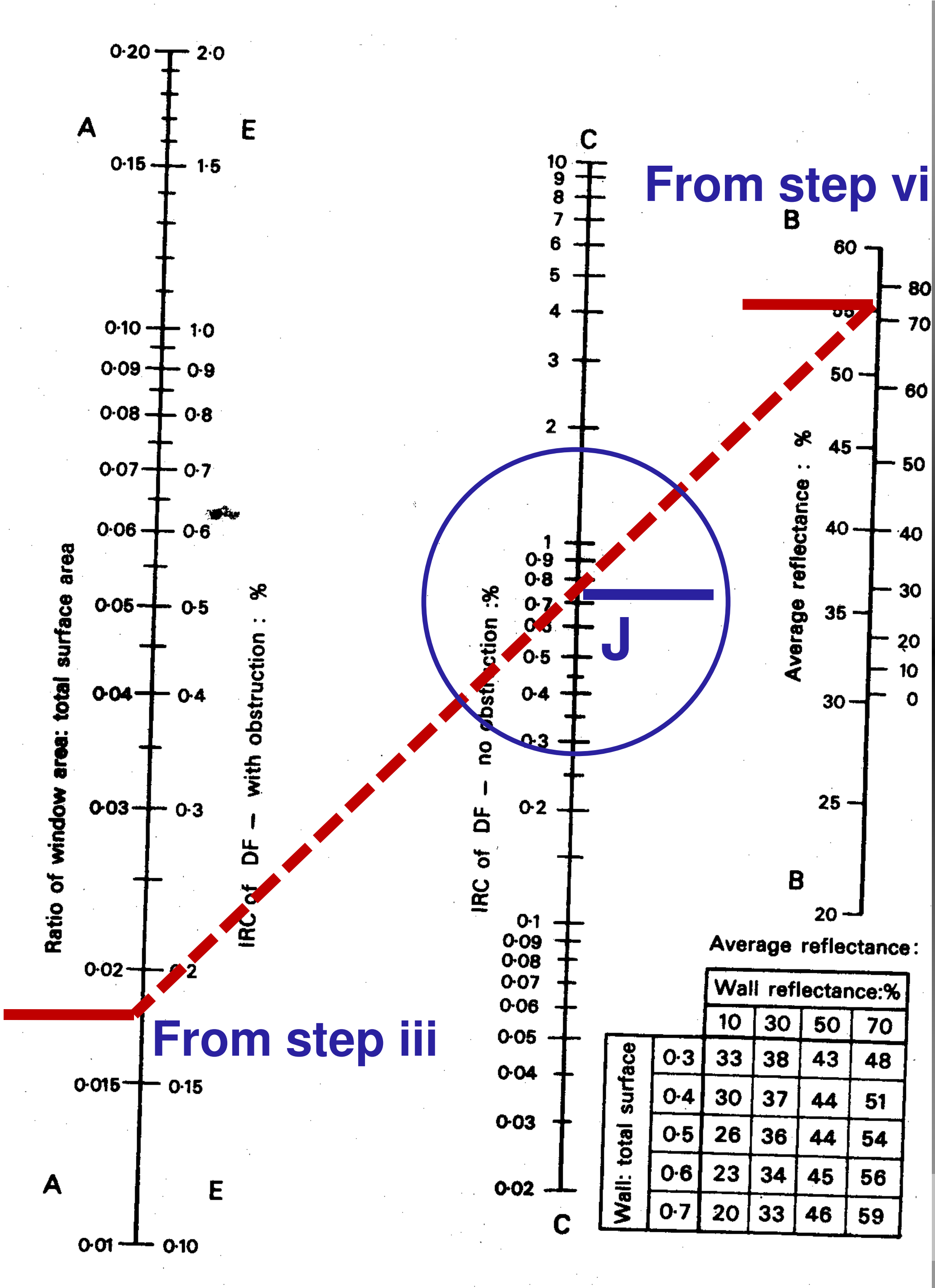
3) Locate the wall reflectance value across the top of this table and read the average reflectance at the intersection of column and line (interpolating, if necessary, both vertically and horizontally). Or calculate an area-weighted mean reflectance (assume glass reflectance is 20%).

iv) WALL AREA = 48 SQ.M.

v) RATIO OF WALL AREA TO TOTAL SURFACE AREA = 48/80 = 0.6

vi) THEREFORE AVERAGE REFLECTANCE = 56%

Scale 'B' and 'C' and Table for reflectance calculation



Wall: total surface	Wall reflectance: 10%	30	50	70
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

4. Locate the average reflectance value on scale B and lay a straight-edge from this point across to scale A (to value obtained in step iii).

5. Where this intersects scale C, read the value which gives the average IRC if there is no external obstruction.

vii) THEREFORE

AVERAGE IRC

VALUE = 0.75

Case without external obstruction

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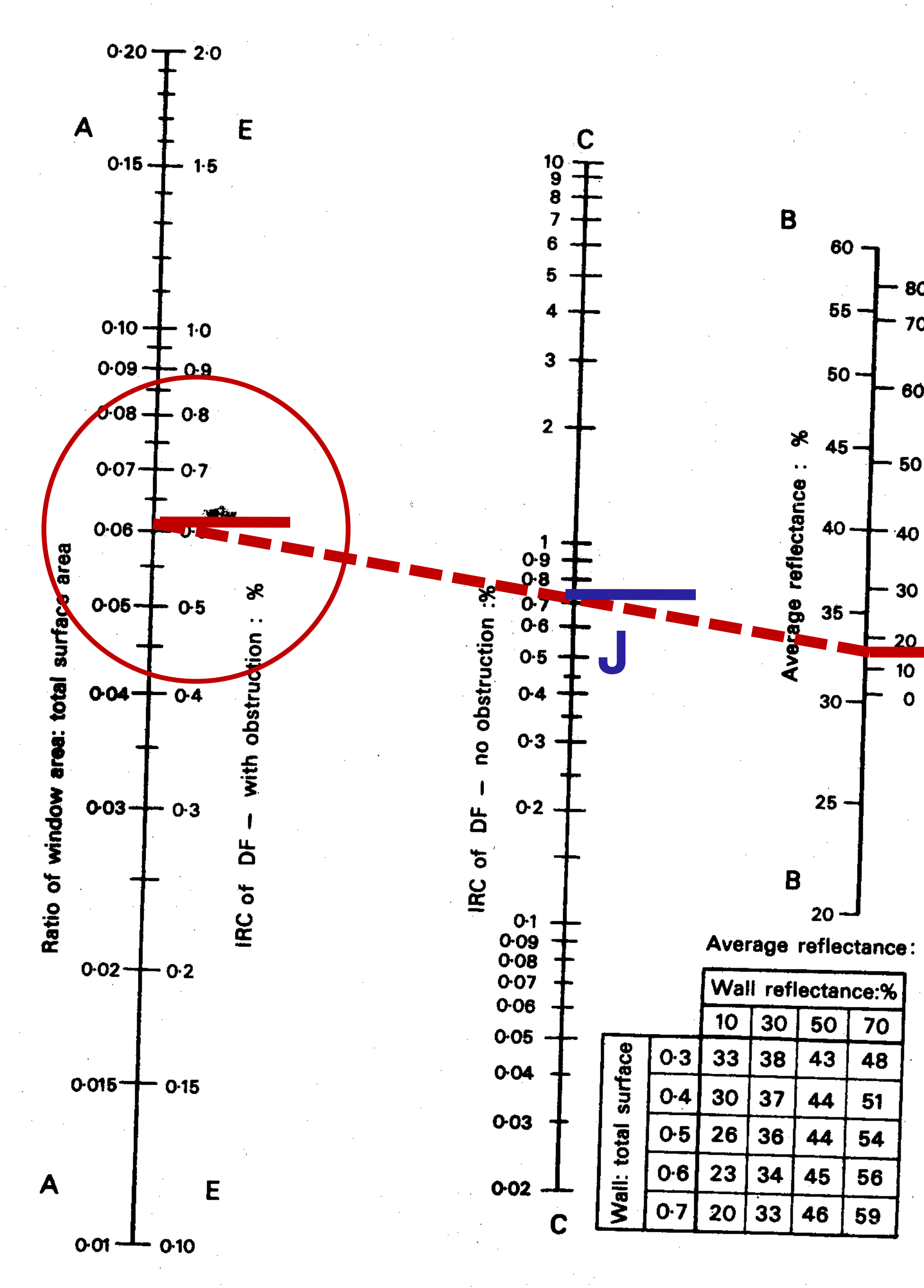
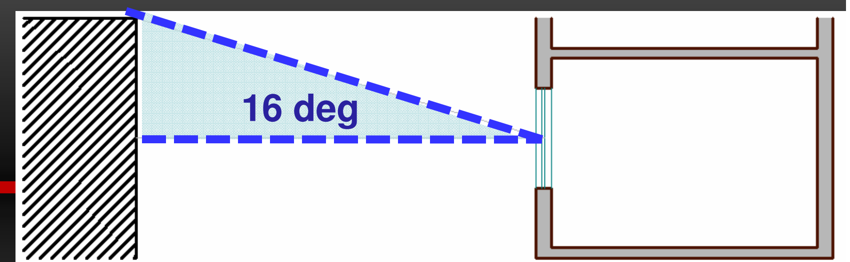


6. If there is an external obstruction, locate its angle from the horizontal, measured at the centre of window, on scale D.

7. Lay the straight-edge from this point on scale D through the point on scale C and read the average IRC value on scale E.



viii) THEREFORE AVERAGE IRC VALUE = 0.60

Case with external obstruction

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DF = SC + ERC + IRC

= (1.87 + 0.374 +0.60)

= 2.844

Average External Ilumination in Indian context is taken to be 8000 lux

Therefore, the Internal illumination at the point on working plane,

$$DF = \frac{\text{Internal illumination}}{\text{External illumination}} \times 100$$

$$\text{Internal illumination} = \frac{2.844 \times 8000}{100} = 227.52 \text{ LUX}$$

AS PER NBC, LUX LEVEL REQUIREMENT FOR BEDROOM IS 300 LUX.

HENCE INSUFFECIENT ILLUMINATION

LEED – Lighting

Design approach:

Calculations:

There are two sections for calculations:

- Day lighting
- Views

The calculation method aims to provide a minimum of 2% DF at the

MR EQ ID

dit 8

Equation 1:

$$\text{Daylight Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

Table 1: Daylight Design Criteria

Window Type	Geometry Factor	Minimum T_{vis}	Height Factor	Best Practice Glare Control
sidelight daylight glazing	0.1	0.7	1.4	Adjustable blinds Interior light shelves Fixed translucent exterior shading devices
sidelighting vision glazing	0.1	0.4	0.8	Adjustable blinds Exterior shading devices
toplighting vertical monitor	0.2	0.4	1.0	Fixed interior Adjustable exterior blinds
toplighting sawtooth monitor	0.33	0.4	1.0	Fixed interior Exterior louvers
toplighting horizontal skylights	0.5	0.4	1.0	Interior fins Exterior fins Louvers

Calculations:

Create a spreadsheet and identify all regularly occupied rooms. Determine the floor area of each applicable room using construction data.

For each room identified, calculate the window area and use Table 1 to indicate the acceptable window types. Note that the window areas above 2’6” are considered to be daylight glazing. Glazing at this height is the most effective at distributing daylight deep into the interior space. Window areas from 2’6” to 7’6” are considered to be vision glazing. These window areas are primarily used for viewing and lighting interior spaces close to the building perimeter.

Calculation of D.F

The calculation method aims to provide a minimum of 2% DF at the back of the space.

Calculations:

1. Create a spreadsheet and identify all regularly occupied rooms. Determine the floor area of each applicable room using construction data.
2. For each room identified, calculate the window area and use Table 1 to indicate the acceptable window types. Note that the window areas above 2'6" are considered to be daylight glazing. Glazing at this height is the most effective at distributing daylight deep into the interior space. Window areas from 2'6" to 7'6" are considered to be vision glazing. These window areas are primarily used for viewing and lighting interior spaces close to the building perimeter.

Window areas below 2’6” do not contribute to day lighting of interior spaces and are excluded from the calculations.

3. For each window type, insert the appropriate geometry and height factors as listed in table 1. The geometry factor indicate the effectiveness of a particular aperture to distribute daylight relative to window location while the height factor indicates where the light is introduced to the space.

4. For each window type, indicate the visible transmittance (T *vis*), a variable number that differs for each product. It is the recommended level of transmittance for selected glazing.

5. Calculate the Daylight factor for each window type using equation 1 given in table 1. For rooms having more than 1 window type, sum all window types to obtain a total Daylight Factor for the room.

6. If the total daylight factor is less 2% or greater, then the square footage of the room is applicable to the credit.

7. Sum the square footage of all applicable rooms and divide by the total square footage of all regularly occupied spaces. If this percentage is greater than 75%, then the building qualifies for the first point of the credit.

SS	WE	EA	MR	EQ	ID

Credit 8

Table 3 : Daylighting Calculations

Room	Floor Area [SF]	Glazing Area [SF]	Window Geometry Type	Window Geometry Factor	Transmittance (T^{vis}) Actual	Transmittance (T^{vis}) Minimum	Window Height Factor	Daylight Factor Each	Daylight Factor Room	Daylight Area [SF]	Glare Control
A	820	120	vision	0.1	0.9	0.4	0.8	2.6%	3.3%	820	2
		40	daylight	0.1	0.7	0.7	1.4	0.7%			3
B	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
C	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	2
D	95	25	vision	0.1	0.4	0.4	0.8	2.1%	2.1%	95	2
E	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
F	820	75	vision	0.1	0.9	0.4	0.8	1.6%	2.1%	820	2
		25	daylight	0.1	0.7	0.7	1.4	0.4%			3
G	600	36	vision	0.1	0.4	0.4	0.8	0.5%	0.5%	0	2
H	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	6
I	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	6
J	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	1
K	410	36	sawtooth	0.33	0.4	0.4	1.0	2.9%	2.9%	410	4
Total	3,730									3,395	
Percentage of Daylit Area										85%	

Table 2 : Common Glare Control Strategies

Glare Control Chart	
Type	**Description**
1	Fixed Exterior Shading Devices
2	Light Shelf, exterior
3	Light Shelf, interior
4	Interior Blinds
5	Pull-down shades
6	Fritted glazing
7	Drapes
8	Electronic black-out glazing

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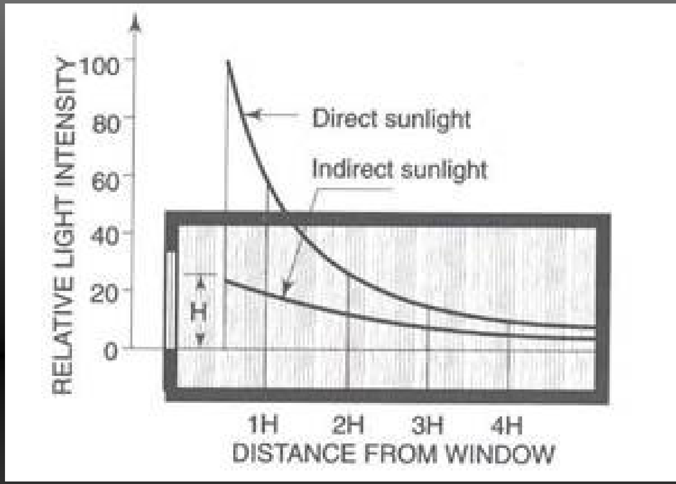
8. **Note that glare control is also required for each window. Table 2 provides best practice glare control measures for different window types.**

Once Enough lighting levels are achieved.........the next step to prevent luminous contrast and glare

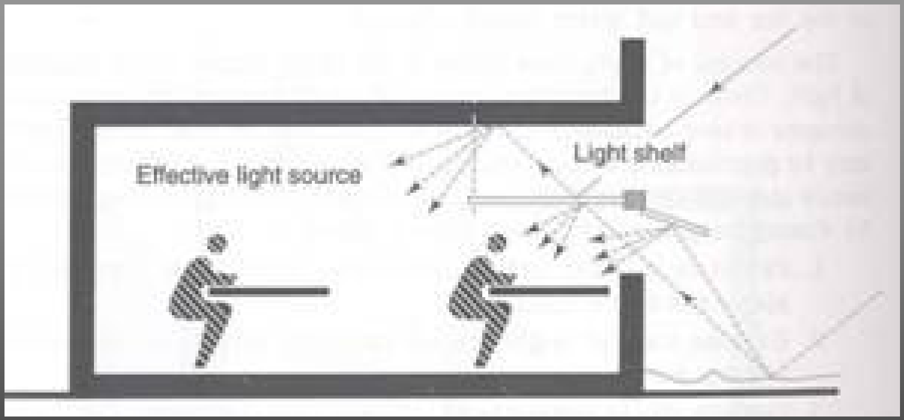


- Contrast is a measure of the difference of luminance levels between two areas, or between an object and its background.
- $C = (L_{object} - L_{background}) / L_{background}$

In overheated climates where occupants are near to conditions of heat stress, there may be psychological association between glare and thermal discomfort- hence control becomes doubly important. Three guidelines offered by Koenigsberger et al. [1] are quoted below:

- Permit view of sky and ground near to horizon only within 150 above and below horizon.
- Exclude view of bright ground and sunlit louvres or surfaces of shading devices.
- Daylight should preferably be reflected from the ground and louvre surfaces onto the ceiling which itself should be of light color.

- For shallow rooms the daylight penetration is normally across the depth
- When deep rooms are a must, then strategies like roof lights, monitor lights for single stories or top most floor of multistoried buildings could be used
- When this is not possible, heterogenous windows need to be designed. i.e
  – View Windows and Daylight Windows or a mere light shelf can be used to carry the light to the inner most section



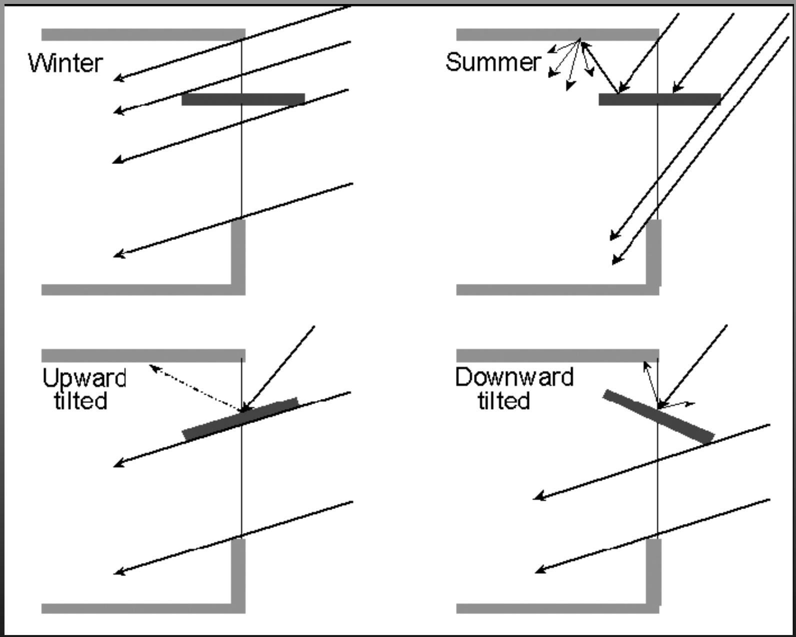
- A light shelf is generally a horizontal or nearly horizontal baffle positioned inside and/or outside of the window facade.
- The light shelf can be an integral part of the facade or mounted on the building.
- A light shelf is usually positioned above eye level.
- Light shelves sometimes employ advanced optical systems to redirect light to deep areas of the building interior.
- The light shelf is typically positioned to avoid glare and maintain view outside; its location will be dictated by the room configuration, ceiling height, and eye level of a person standing in the space.
- An internal light shelf, which redirects and reflects light, will reduce the amount of light received in the interior relative to a conventional window.
- An external light shelf increases exposure to the high luminance area near the sky zenith.

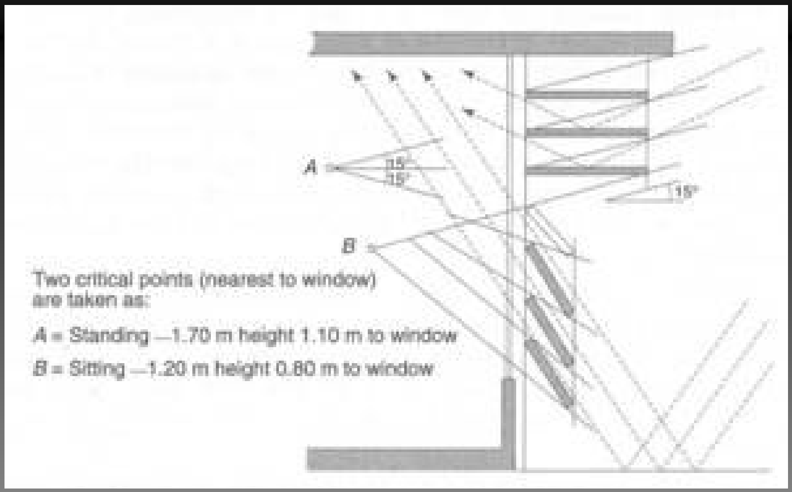
They affect the architectural and structural design of a building and must be considered at the beginning of the design phase because they require a relatively high ceiling in order to function effectively.

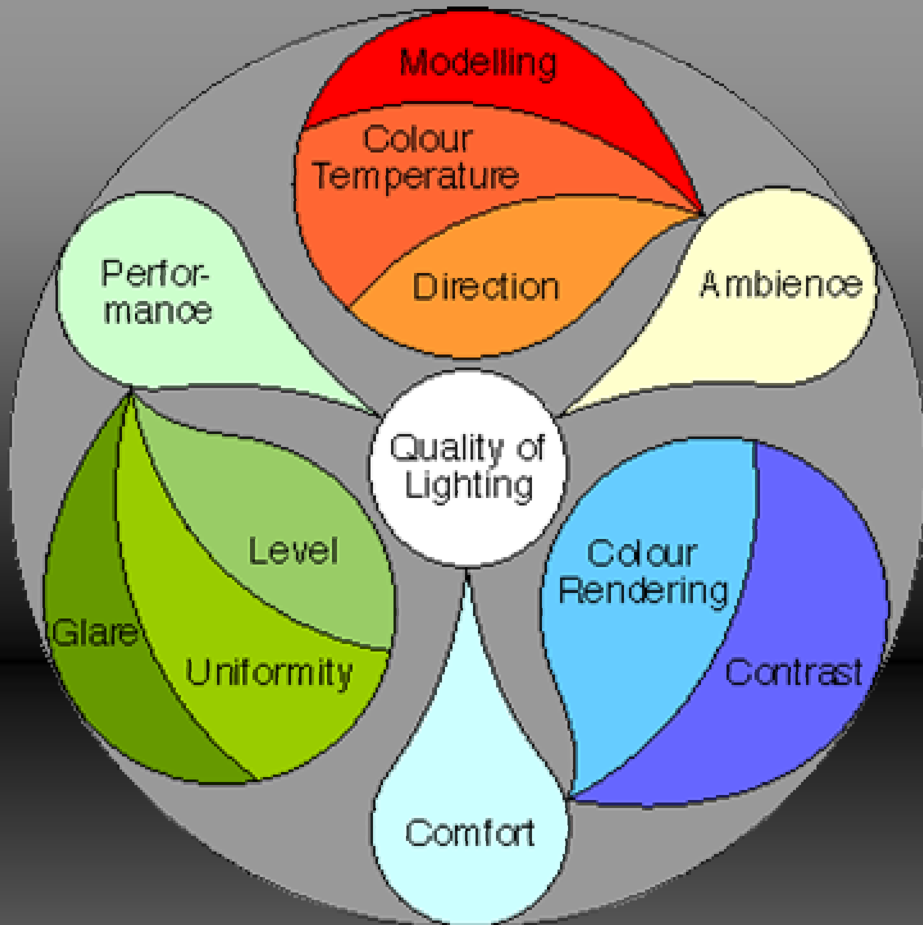
They should be designed specifically for each window orientation, room configuration, and latitude.

They can be applied in climates with significant direct sunlight and are applicable in deep spaces on a south orientation in the northern hemisphere (north orientation in the southern hemisphere).

They do not perform as well on east and west orientations and in climates dominated by overcast sky conditions.







- **Lighting quality is not inherent in a space or a lighting design, but in its effects on people. It cannot be measured, but it is linked to the ambiance and both visual comfort and performance.**