Daylight design

Chapter 14 in your text book

Daylight provides

- Visual comfort
- Health, productivity and well-being
- View

The most preferred views from a window include the sky, the horizon, and the ground

The functional advantage is that people can look into the distance to reduce eye fatigue after doing close desk tasks.

- Reduce dependency on electric energy (energy efficiency)

- Daylight should provide balance to heat gain and loss. through shading devices, light shelves, glazing, atria, courtyards, and material finishes

- Daylighting is an easily achievable LEED strategy if a building can provide a minimum daylight factor of roughly 2% in 75% of all occupied spaces.

Issues with daylight

potential problems—such as glare or substantial cooling loads—caused by uncontrolled quantities and qualities of light and that can be controlled through:

- Provide exterior fixed shades that exclude sunlight for all sun positions.
- Use systems that diffuse the incident sunlight sufficiently to eliminate glare potential.
- Provide occupant-controlled adjustable shades.
- Lights shelves,
- high-reflectance interior surfaces,
- low-transmittance glazing (though such glazing will reduce light flux through the window).
- Furniture should be oriented to work with side lighting (as opposed to having an occupant face a window)

Daylighting goal

Key goals in daylighting design are to provide

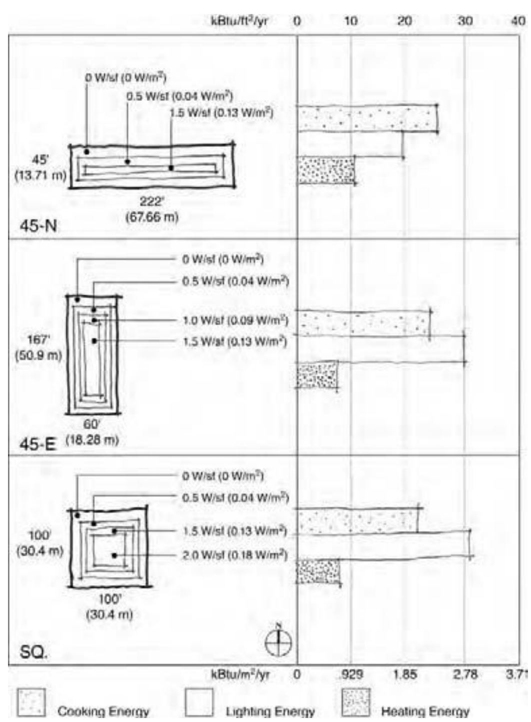
- sufficient illuminance,
- minimize the perception of glare,

provide for overall visual comfort.

Planning for daylight – site strategies

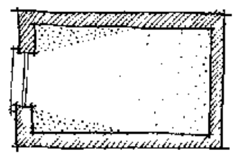
- Form (The width of the long, narrow plan will determine how much of the floor area will have access to usable daylight. Generally, a (4.5-m) perimeter zone can be completely daylight, a (4.5- to 9.0-m) area can be partially daylight, and an electrically light area beyond (9 m) can be used to determine the width of a building)
- Orientation (the north and south façades of the building maximum exposure to more easily controllable daylight)

Form

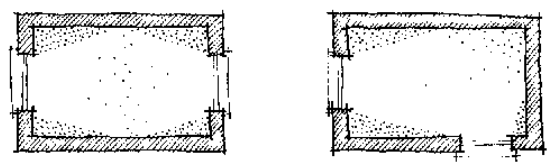


Window and glazing types
Aperture strategies – side lighting

- *Design for bilateral lighting*

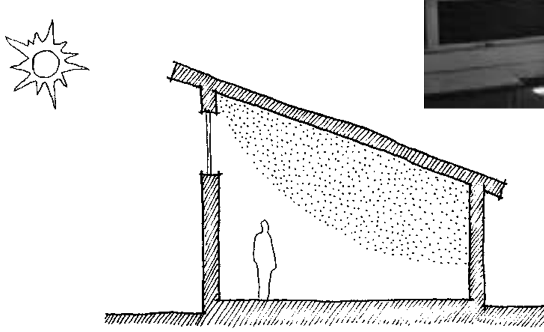


Unilateral lighting

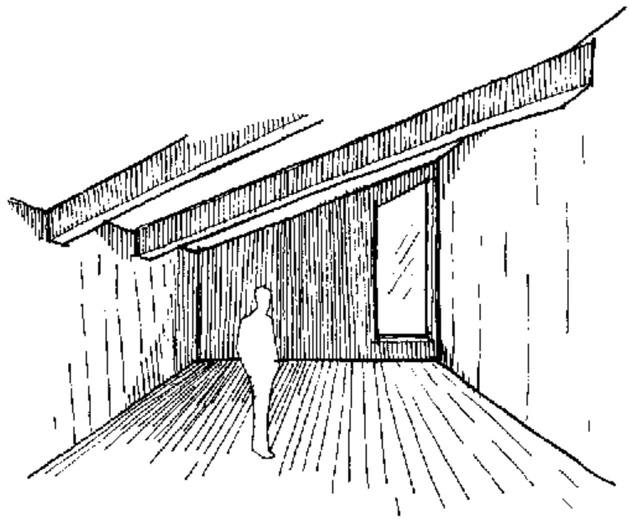


Bilateral lighting

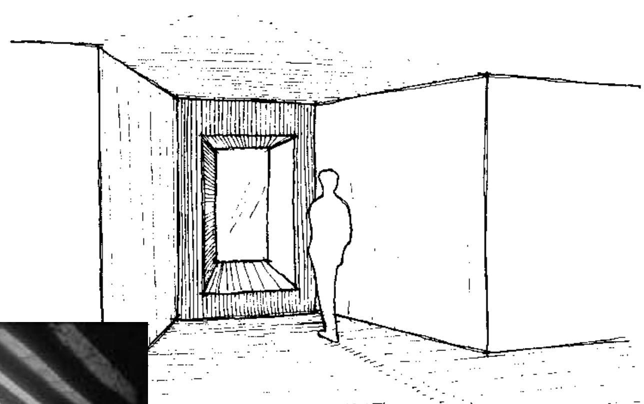
Place windows high on a wall



- *Use adjacent walls as reflectors*

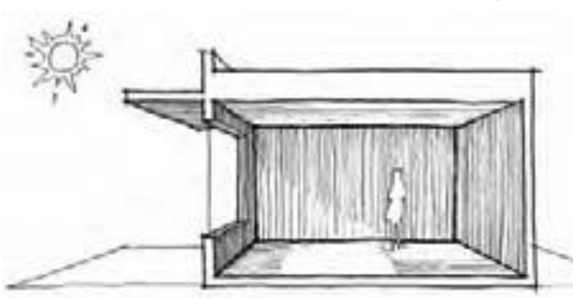


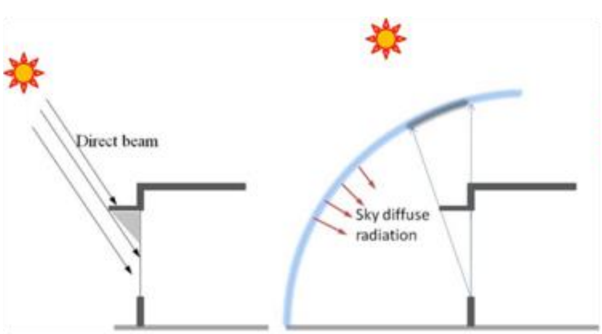
- *Splay the walls of an aperture*

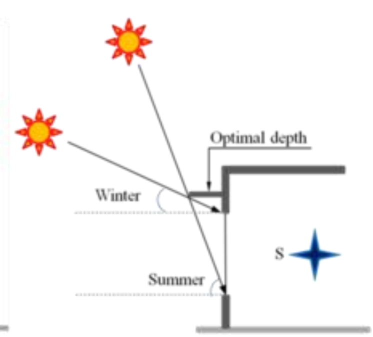


- *Provide daylight filters*

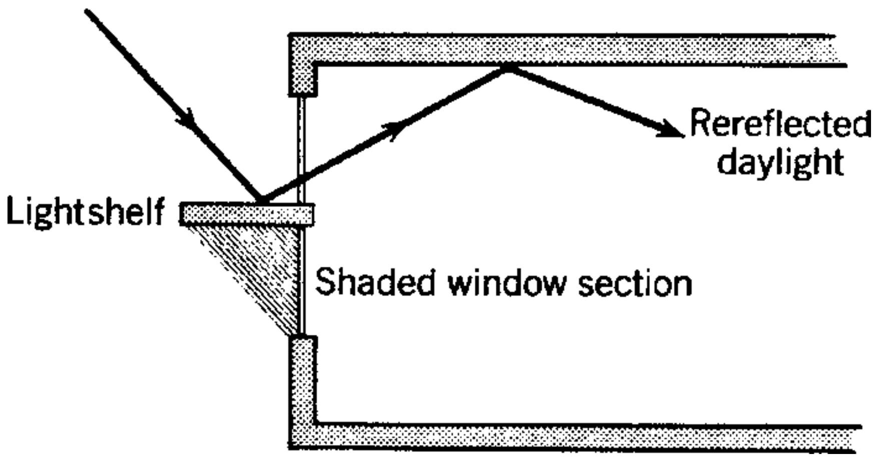
- *Provide summer shading*





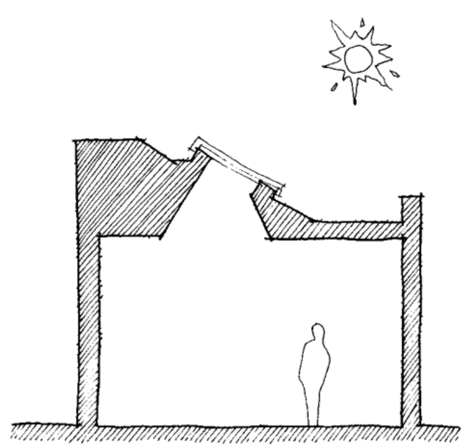


Provide lightshelf

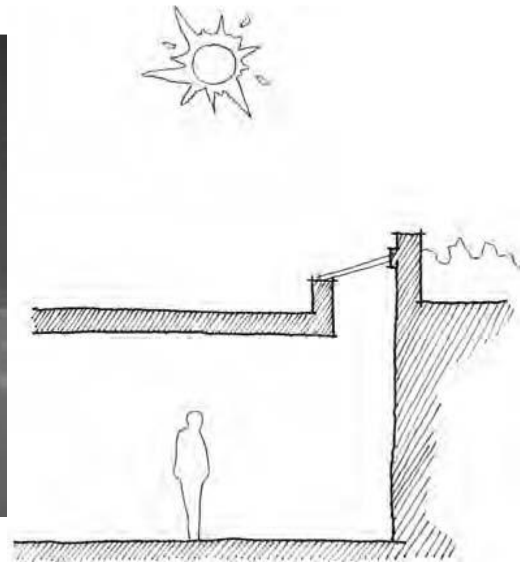


Aperture strategies – top lighting

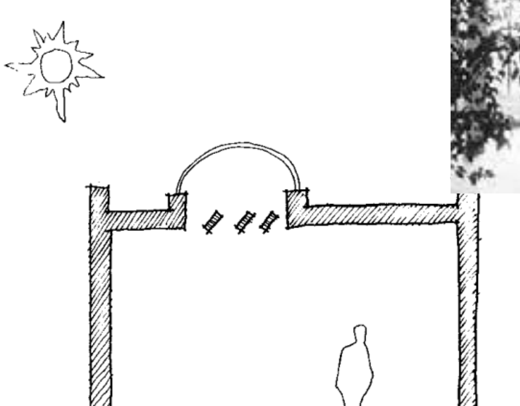
Splay the "walls" of an aperture



Place top lights high in the space



Use interior devices to block, baffle, or diffuse light



Choose the Glazing types

- Clear glazing
- Tinted glazing
- Low E glazing
- Reflective glazing
- Selective glazing

Daylight factor calculation

$$DF = \frac{E_i \text{ indoor illuminance, at a given point}}{E_H \text{ outdoor illuminance}} \quad *100\%$$

- Interior illuminance (*Ei)*
- *outdoor horizontal illuminance (Eh)*

* The daylight factor concept is applicable only where the sky illuminance distribution is known or can reasonably be estimated.

Daylight in a building consists of three components

1. Sky component (SC)
2. Externally reflected component (ERC)
3. Internally reflected components (IRC)

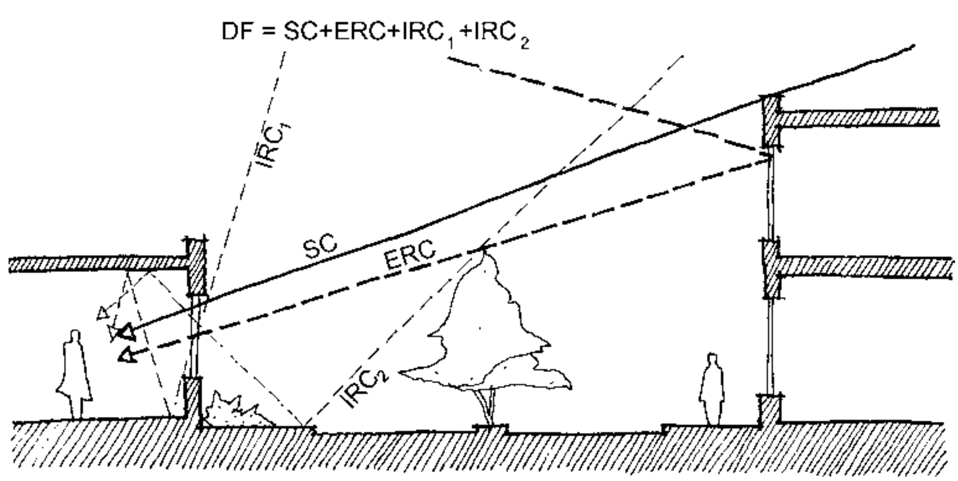
Daylight factor = SC + ERC + IRC.

- SC = incident skylight − window losses
- ERC = SC × RD × RF

Were sky obstructed (RD) and the *reflectance factor (RF)*

Thus, if 25% of the sky is obstructed by a building with a 20% RF, we have

ERC = SC × 0.25 × 0.20



Internally reflected component (IRC)

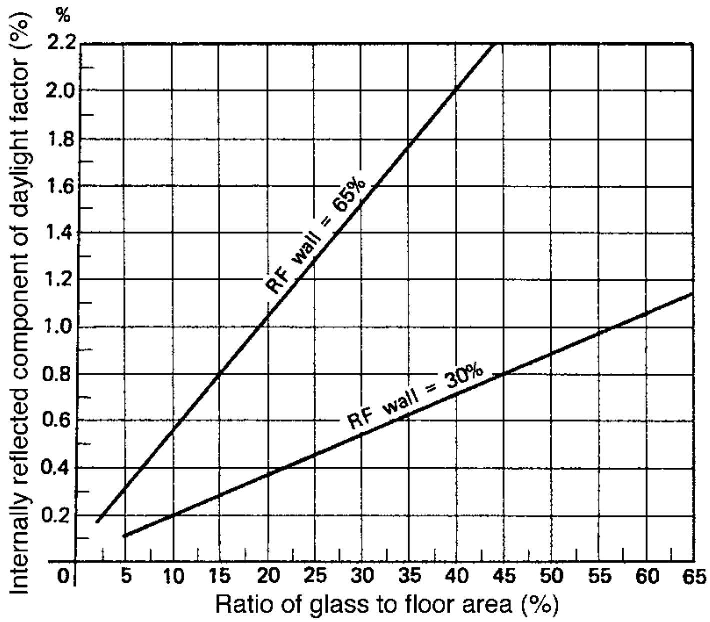


TABLE 14.1 Effect of Wall Reflectance Factor on the Proportion of IRC in the DF

	30% Wall Reflectance		*60% Wall Reflectance*	
Distance from Window in ft (m)	**Total DF**	$\frac{IRC}{DF}$ **(%)**	**Total DF**	$\frac{IRC}{DF}$ **(%)**
0	30	1	31	3.5
5 (1.5)	16	1.9	17	6.5
10 (3.0)	5.5	5.5	6.3	16.9
15 (4.5)	2.1	14.3	2.9	37.9
20 (6.0)	1.3	23	2.1	52.4

Room data:
Room 24 × 28 ft (7.3 × 8.5 m) 70% ceiling reflectance
Window on 28-ft wall—one side only; 20% floor reflectance
Window area = 20% of floor area

TABLE 14.2 Recommended Daylight Factors

Task	DF[a]
Ordinary seeing tasks, such as reading, filing, and easy office work	1.5–2.5%
Moderately difficult tasks, such as prolonged reading, stenographic work, normal machine tool work	2.5–4.0%
Difficult, prolonged tasks, such as drafting, proofreading poor copy, fine machine work, and fine inspection	4.0–8.0%

Source: Millet and Bedrick (1980).

[a]Use the smaller DF values for southern latitudes with plentiful winter daylight.

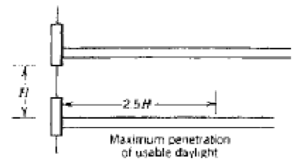
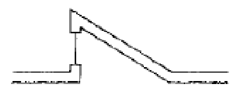
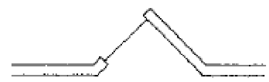
$$\frac{Df_{min}}{DF_{avg}} \geq 0.3$$

Daylight calculation

1st method

The 2.5H Guideline

TABLE 14.4 Daylight Factor Design Estimates for Overcast Sky Conditions

PART A. **SIDELIGHTING**[a, b]	
$DF_{av} = 0.2\left(\frac{\text{window area}}{\text{floor area}}\right)$ $DF_{min} = 0.1\left(\frac{\text{window area}}{\text{floor area}}\right)$	
PART B. **TOPLIGHTING**[c]	
Vertical monitors: $DF_{av} = 0.2\left(\frac{\text{skylight glazing area}}{\text{floor area}}\right)$	
North-facing sawtooth: $DF_{av} = 0.33\left(\frac{\text{skylight glazing area}}{\text{floor area}}\right)$	
Horizontal skylights: $DF_{av} = 0.35\left(\frac{\text{skylight glazing area}}{\text{floor area}}\right)$	

2.5 times the head height of the window above the work plane—assuming clear glazing, overcast skies, no major obstructions, and a total window width that is approximately half that of the exterior perimeter wall

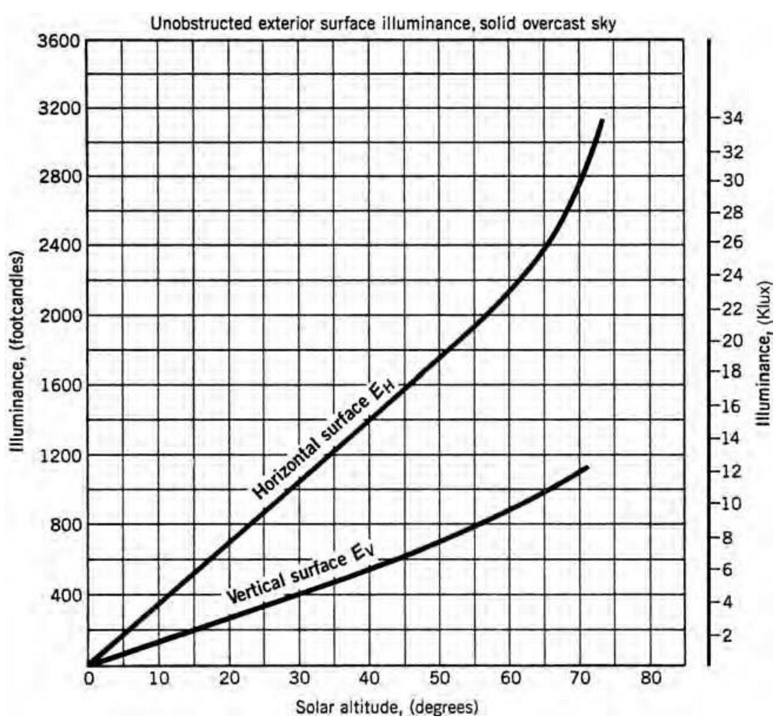
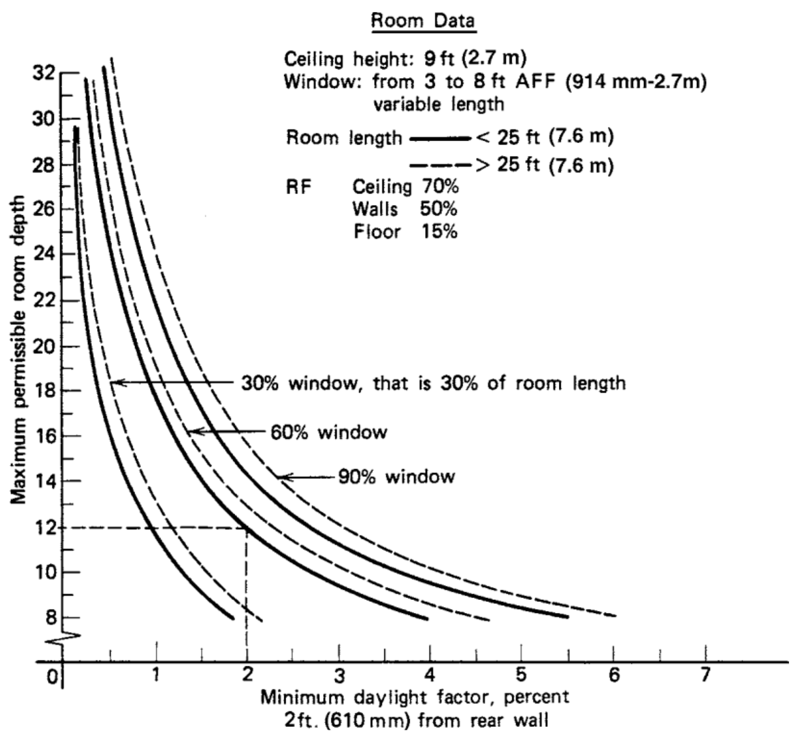


TABLE 14.3 Horizontal Illuminances (E_H) from Overcast Sky, at Selected Times, in Columbus, Ohio, and Seattle, Washington, Corresponding to the Recommended DF

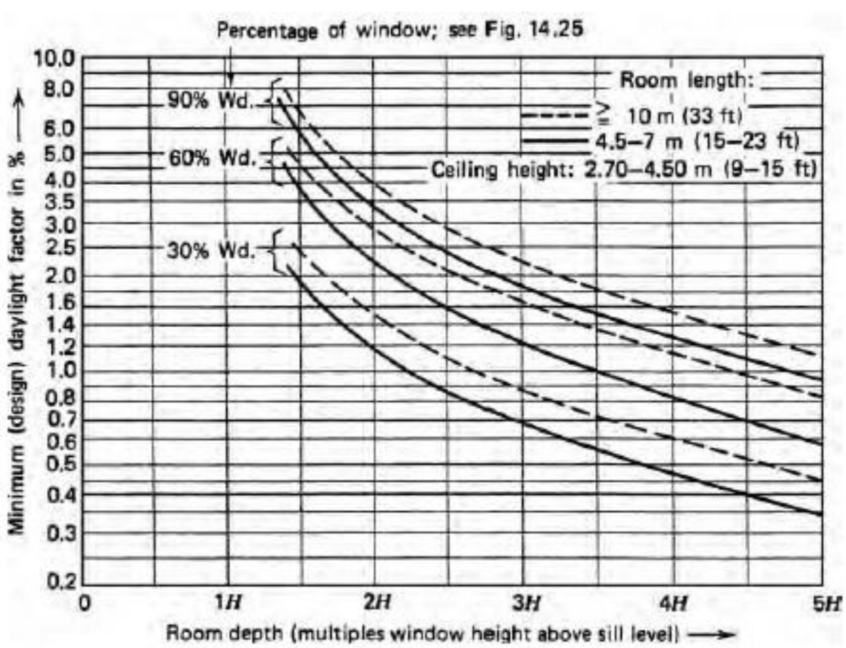
Location	10 AM Solar Altitude[a]	Available Daylight, E_H fc (lux)[b]	DF Recommendation (%)[c]	Illuminance fc (lux) Calculation from DF	Illuminance fc (lux)[d] Recommendation
Columbus 40° N latitude	June 21 60°	2100 (22,500)	1.5–2.5	31–52 (338–563)	28–47 (300–500)
			2.5–4	52–84 (563–900)	47–70 (500–750)
			4–8	84–167 (900–1800)	70–93 (750–1000)
	Mar./Sept. 21 41°	1400 (15,500)	1.5–2.5	21–35 (225–375)	28–47 (300–500)
			2.5–4	35–56 (375–600)	47–70 (500–750)
			4–8	56–112 (600–1200)	70–93 (750–1000)
	Dec. 21 21°	700 (7500)	1.5–2.5	11–18 (113–188)	28–47 (300–500)
			2.5–4	18–28 (188–300)	47–70 (500–750)
			4–8	28–56 (300–600)	70–93 (750–1000)
Seattle 48° N latitude	June 21 56°	1950 (21,000)	1.5–2.5	29–49 (315–525)	28–47 (300–500)
			2.5–4	49–78 (525–840)	47–70 (500–750)
			4–8	78–156 (840–1680)	70–93 (750–1000)
	Mar./Sept. 21 36°	1220 (13,000)	1.5–2.5	18–30 (195–325)	28–47 (300–500)
			2.5–4	30–48 (325–520)	47–70 (500–750)
			4–8	48–97 (520–1040)	70–93 (750–1000)
	Dec. 21 14°	500 (5400)	1.5–2.5	8–13 (81–135)	28–47 (300–500)
			2.5–4	13–20 (135–216)	47–70 (500–750)
			4–8	20–49 (216–532)	70–93 (750–1000)

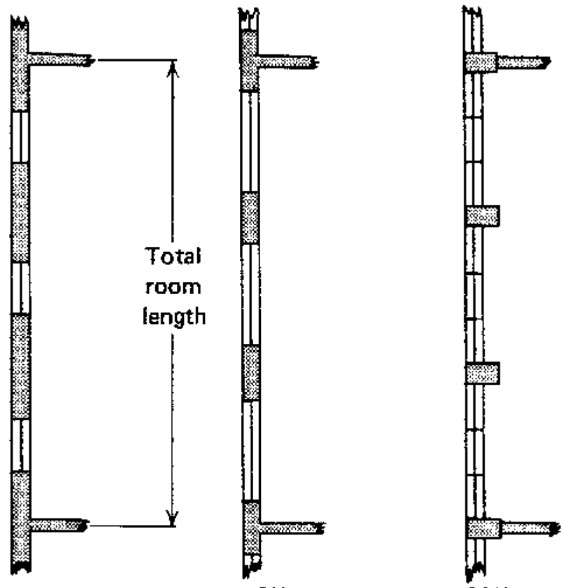
Daylight calculation

2nd method (CIE)


Room Data
Ceiling height: 9 ft (2.7 m)
Window: from 3 to 8 ft AFF (914 mm-2.7m)
variable length
Room length —— < 25 ft (7.6 m)
– – – > 25 ft (7.6 m)
RF Ceiling 70%
Walls 50%
Floor 15%
Maximum permissible room depth
30% window, that is 30% of room length
60% window
90% window
Minimum daylight factor, percent
2 ft. (610 mm) from rear wall

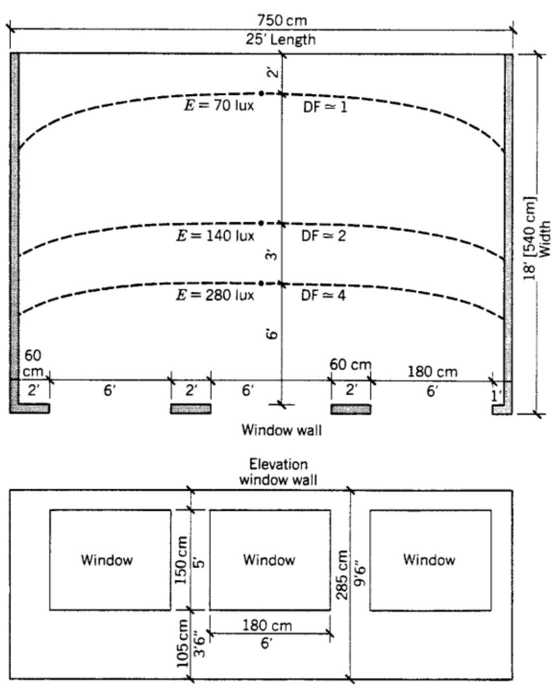
CIE method

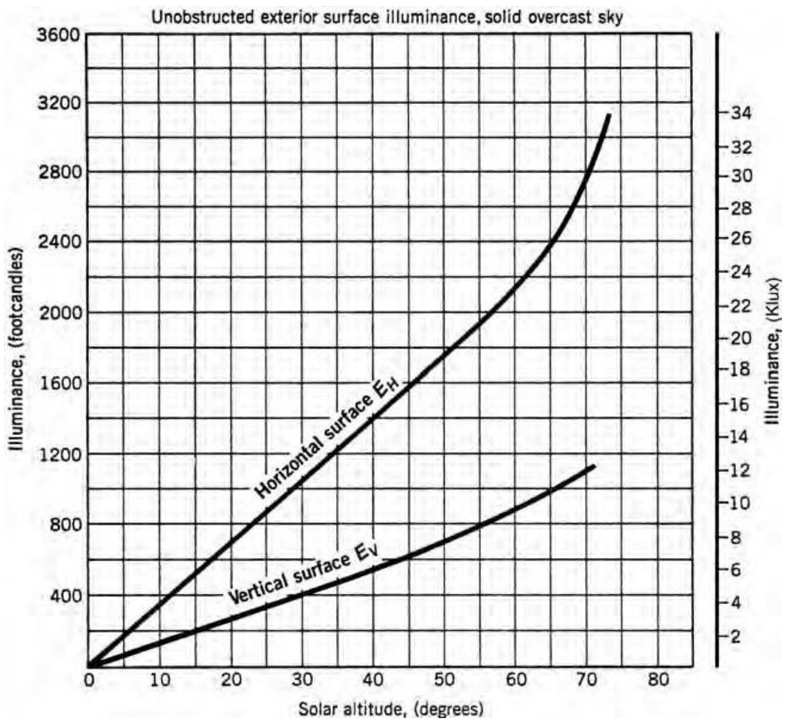

Percentage of window; see Fig. 14.25
90% Wd.
60% Wd.
30% Wd.
Room length:
≧ 10 m (33 ft)
4.5–7 m (15–23 ft)
Ceiling height: 2.70–4.50 m (9–15 ft)
Minimum (design) daylight factor in %
Room depth (multiples window height above sill level)



Plane of window walls showing window width expressed as a percentage of total room length.

(b)





Advantages of the system are:

1. Consideration of obstructions, exterior reflections, and interior reflections.
2. Applicability to a very wide range of side and top fenestration designs.

Limitations of the system are:

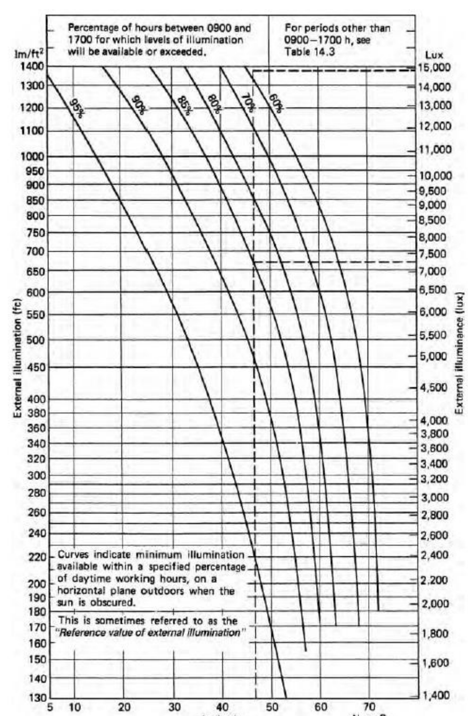
1. Inapplicable to clear sky and direct sun conditions.
2. Inapplicable to other than rectangular rooms.
3. Unusable with sun shading devices or high reflectance ground.
4. Results give points of minimum, twice minimum, and four times minimum daylight only. Other points must be interpolated or extrapolated.
5. Window proportions and position in a wall are fixed.

Daylight calculation

Maintain exterior lighting conditions

CIE continue

Maintained daylight percentage for the working hours



Daylight calculation

4th method (equation method)

Equations

$DF = Sf * TL * \alpha / St * (1- R^2)$

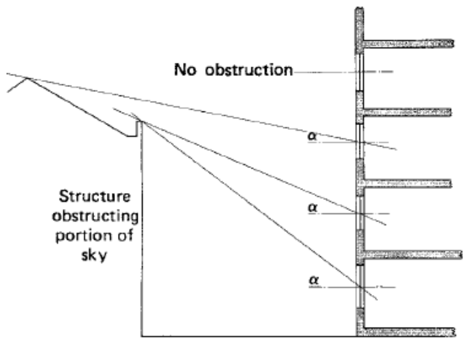
Sf : glass surface area (10% for frame)

TL : light transmittance

α : visible sky angle (90º no obstacle, 60º if the buildings creating shadow about 30º up the ground

St: total area of internal surfaces + area of glasses

R: average reflection factor of internal surfaces

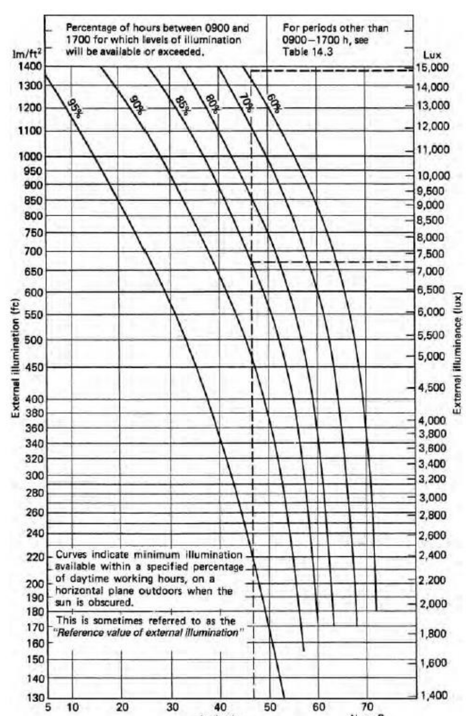


(a)

TABLE 14.7 Transmittance Data of Glass and Plastic Materials

Material	Approximate Transmittance (%)
Polished plate/float glass	80–90
Sheet glass	85–91
Heat-absorbing plate glass	70–80
Heat-absorbing sheet glass	70–85
Tinted polished plate	40–50
Figure glass	70–90
Corrugated glass	80–85
Glass block	60–80
Clear plastic sheet	80–92
Tinted plastic sheet	9–42
Colorless patterned plastic	80–90
White translucent plastic	10–80
Glass-fiber-reinforced plastic	5–80
Double glazed—two lights clear glass	77
Tinted plus clear	37–45
Reflective glass[a]	5–60

- Maintained daylight percentage for the working hours



Daylight calculation

Design corrections

TABLE 14.5 Correction Factors to Be Used in CIE Daylight Calculations

A. CORRECTION FACTOR TO ACCOUNT FOR GLASS TRANSMITTANCE

Diffuse Transmittance of Glass (%)	Correction Factor
80	0.95
70	0.80
60	0.70
50	0.60
40	0.45
30	0.35

B. CORRECTION FACTORS TO ACCOUNT FOR DIRT ACCUMULATION ON GLASS

		Angle of Slope (Measured to the Horizontal)		
Locality	**Class of Industry**	**90–75°**	**60–45°**	**30–0°**
Country or outer-suburban area	Clean	0.9	0.85	0.8
	Dirty	0.7	0.6	0.55
Built-up residential area	Clean	0.8	0.75	0.7
	Dirty	0.6	0.5	0.4
Built-up industrial area	Clean	0.7	0.6	0.55
	Dirty	0.5	0.35	0.25

C. PERCENTAGES TO USE WHEN FIGURE 14.27 CURVES ARE APPLIED TO PERIODS OTHER THAN 09.00–17.00 HOURS

Curve in Figure 14.27	95%	90%	85%	80%	70%	60%
Alternative period			Percentage of alternative period			
07.00–15.00	95	90	85	80	70	60
08.00–16.00	100	100	95	85	70	60
07.00–17.00	95	85	75	65	55	45
06.00–18.00	75	70	65	60	50	40

Source: Daylight, International Recommendations for the Calculation of Natural Daylight (1970).

TABLE 14.8 Typical Light Loss Factors for Daylighting Design

	Light Loss Factor Glazing Position		
Location	**Vertical**	**Sloped**	**Horizontal**
Clean areas	0.9	0.8	0.7
Industrial areas	0.8	0.7	0.6
Very dirty areas	0.7	0.6	0.5

TABLE 14.9 Reflectances of Building Materials and Outside Surfaces

Material	Reflectance (%)
Aluminum	85
Asphalt (free from dirt)	7
Bluestone, sandstone	18
Brick	
Light buff	48
Dark buff	40
Dark red glazed	30
Red	15
Yellow ochre	25
White	75
Cement	27
Chromium	65
Concrete	55
Copper	40
Earth (moist cultivated)	7
Granolite pavement	17
Glass	
Clear	7
Reflective	20–30
Tinted	7
Grass (dark green)	6
Gravel	13
Granite	40
Marble (white)	45
Macadam	18
Marble	45
Paint (white)	
New	75
Old	55
Plaster	
Smooth	80
Rough	40
Stippled	40
Slate (dark clay)	8
Snow	
New	74
Old	64
Vegetation (mean)	25