

## 16 - Natural Lighting

### Introduction

- Physiologically and psychologically it is important to admit daylight into buildings. Daylight is a far more efficient (though non-uniform) source of illumination than artificial lighting.

Source	Efficacy lumens/watt
Tungsten filament	10-15
Fluorescent	45-60
Sodium High Pressure	80-90
Daylight	100-130

- Daylight provides a more pleasant atmosphere inside a building and is a superior quality of light to artificial lighting and is often necessary for specialised tasks such as colour matching.
- Daylight also provides the body with its only means of producing vitamin D.
- Daylight has been shown to counteract the effects of seasonal affective disorder (SAD).

### Fenestration

Daylight is admitted to buildings via windows and skylights, both of which affect all aspects of the environmental performance of the building. The collective term for windows in buildings is *fenestration*.

Fenestration is vital to the functioning of the building, admitting light and heat from the sun as well as ventilating air. Hence fenestration impacts directly upon the comfort of the occupants: fresh air, radiant temperature, air temperature and air movement.

The quality and availability of the daylight inside a building is governed by several factors:

- The nature and brightness of the sky.
- The size shape and position of the windows.
- Reflections from internal surfaces.
- Reflections and obstructions outside the room.

### **Natural Light Sources**

- All natural light emanates from the sun, the light entering buildings either being direct light from the sun or diffuse light. Diffuse light has no uniform direction.
- The illuminance provided by a bright sunny sky may be as much as 100,000 lux, though light of this intensity often causes glare and overheating.
- In the UK much of the light entering buildings is diffuse, either having passed through clouds (overcast sky), being reflected from the surfaces of other buildings or reflected from the ground.
- The nature and brightness of the sky affects the quality of light inside a building so in order to design for daylight inside a building it is necessary to have a mathematical model to describe the sky.
- In general the standard sky model used in lighting design represents an overcast sky - unsurprisingly this is the most common sky occurring in the UK. The model is the uniform standard sky.

### **Uniform Standard Sky**

This is an overcast sky that has the same luminance in every direction. To the observer on the ground the uniform standard sky makes a hemispherical surface of equal brightness around the point of observation.

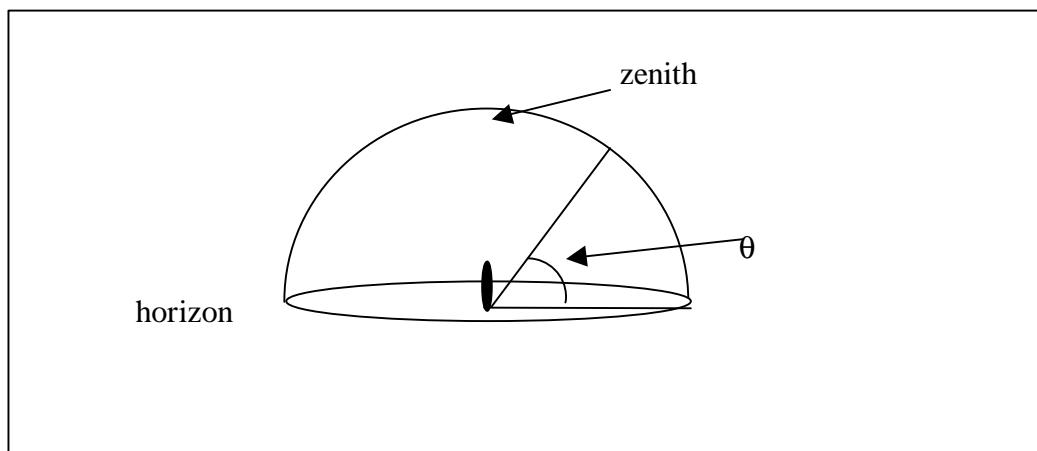
The illuminance at a point on the ground provided by an unobstructed uniform sky varies with the hour of the day. A value of 5000 lux is taken as the design value for the UK, representing the light from a heavily overcast sky. This illuminance value is exceeded around 85% of working hours during the year in the UK.

## CIE Sky

The CIE standard sky is a model of an overcast sky in which the illuminance steadily rises above the horizon. This sky was defined by the Commission Internationale d'Eclairage (CIE). The luminance at any altitude angle  $q$  above the horizon is given by:

$$L_q = 0.33L_z(1 + 2 \sin q)$$

where  $L_z$  is the luminance of the sky at the zenith.



The luminance of the sky at the zenith of the CIE sky is three times brighter than at the horizon. This is a good representation of the sky over North Western Europe.

## Daylight Factors

The daylight inside a room is only a small fraction of that available from the sky and reflections. The quantity of daylight inside a room varies with the brightness distribution of the sky and is often described in terms of a daylight factor.

### Definition

Daylight factor (DF) is defined as the ratio of the actual illuminance at a point in a room (lux) and the illuminance available from an identical unobstructed sky.

$$DF = \frac{E_i}{E_o} \times 100$$

So for example, if the daylight factor inside a room is 2% and the illuminance of the sky is 8000 lux then the illuminance at the point inside the room is:

$$0.02 \times 8000 = 160 \text{ lux.}$$

The Daylight Factor and the light inside a room is made up of three separate components:

- **The sky component** – light arriving at a point in a room coming directly from the sky
- **The externally reflected component** – light arriving at a point in a room reflecting into it from an external obstruction
- **The internally reflected component** – light arriving at a point in a room having been reflected from an internal surface.

These three components can be recorded and added to give the overall daylight factor.

### Daylight Factor Contours

The daylight factor inside a room will vary according to position. Daylight factors are often given as working plane contours. Tall windows provide deeper daylight penetration, while multiple windows provide more even daylight distribution.

### Recommended Daylight Factors

Recommended Daylight Factors are as follows:

Location	Average Daylight Factor (%)	Minimum Daylight Factor (%)	Working Plane
General Office	5	2	desks
Classroom	5	2	desks
Entrance Hall	2	0.6	working plane
Library	5	1.5	tables
Drawing Office	5	2.5	boards
Sports Halls	5	3.5	floor

## **Assessment of Daylight Factors**

Inside an existing building daylight factors can be measured directly using a photometer which gives a direct reading of the daylight factor.

In the design stage, daylight factors can be predicted using:

- Design tables;
- Waldram diagram;
- Computer programs;
- Scale models;
- Daylight factor protractors.

### **BRE Daylight Factor Protractor**

A daylight protractor contains two semi-circular scales on transparent overlays (see McMullan). These are used in conjunction with scale drawings of the room being assessed to determine the daylight factor of a room. Different protractor types are available for different window types.

The calculation of the sky component (daylight factor) is as follows:

1. Take section and plan drawing of the room. Mark reference points where you want to measure daylight factor. Choose a protractor suitable for the window type.
2. Draw “sight lines” from the reference point to the top and bottom edges of the sky visible from that point. Place the primary scale of the protractor over the section aligned on the reference point. Read the sky component from the protractor for the top and bottom sight lines and subtract to obtain the uncorrected sky factor.
3. Obtain the top and bottom angles of elevation from the sight lines and protractor. Then obtain the average angle of elevation.
4. On the plan draw sight lines from the same reference point to the vertical edges of the window. Place the auxiliary scale of the protractor on the drawing and obtain the correction factors for each side of the window, add to obtain the total correction factor
5. The sky component (daylight factor) is equal to the uncorrected value times the correction factor.

## **Combined Lighting**

Although natural light is more pleasant to work in than artificial light, the levels of available daylight vary throughout the day and also throughout the year. Also the illumination levels provided by daylight are uneven – high illumination near windows, poor illumination towards the rear of the room.

A compromise is to combine artificial lighting with daylight. This system is known as PSALI .

### **PSALI**

PSALI – Permanent Supplementary Artificial Lighting of Interiors.

PSALI is a system of combined artificial lighting and daylighting, where the two are blended together to provide an even illumination. Parts of the room are permanently lit by artificial light.

PSALI retains most of the psychological advantages of artificial lighting, but can illuminate deeper plan rooms than could be lit with daylight alone.

The principle of PSALI is to provide illumination that appears to be of good daylight character even though most of the working illumination may be from artificial light.

The distribution of light provided by PSALI means that illumination increases gradually towards the windows. The supplementary illumination provided by PSALI can be found by choosing a design lighting level and subtracting the contribution of daylight.

The lamps used for PSALI should match natural light in colour appearance (Colour Corrected Temperature, CCT). Fluorescent tubes with a CCT of 4000-6500K are often used for PSALI, often with recessed fitting.

PSALI is also used to control the switching of lights on and off as daylight levels go up and down. In bright light all illumination may be provided by daylight. At night all lighting is artificial. Light-level switching of luminaires is known as *photo-electric switching*.