BS 8206-2:2008

BRITISH STANDARD

Lighting for buildings –

Part 2: Code of practice for daylighting

ICS 91.060.50; 91.160.10

British Standards

Publishing and copyright information

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 48, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 8206 is published by BSI and came into effect on 30 September 2008. It was prepared by Subcommittee CPL/34/10, *Light and lighting*, under the authority of Technical Committee CPL/34, *Lamps and related equipment*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 8206 supersedes BS 8206-2:1992, which is withdrawn.

Information about this document

This part of BS 8206 represents a full revision of the standard. This revision has been prepared to take account of the publication of BS EN 12464-1 and BS EN 15193. In particular, some of the manual calculations that appeared in the 1992 edition have been omitted and a new annex on climate-based daylight modelling has been added. There is also a new clause on daylighting and health.

Annex B in the 1992 edition gave what was termed "service illuminances" for tasks. Task lighting is now specified in BS EN 12464-1 and this annex, therefore, has been deleted.

The standard describes good practice in daylighting design and presents criteria intended to enhance the well-being and satisfaction of people in buildings, recognizing that the aims of good lighting go beyond achieving minimum illumination for task performance. Simple graphical and numerical methods are given for testing whether the criteria are satisfied, but these are not exclusive and computer methods may be used in practice. Sunlight and skylight data are given.

The aim of the standard is to give guidance to architects, engineers, builders and others who carry out lighting design. It is recognized that lighting is only one of many matters that influence fenestration. These include other aspects of environmental performance (such as noise, thermal equilibrium and the control of energy use) fire hazards, constructional requirements, the external appearance and the surroundings of the site. The best design for a building does not necessarily incorporate the ideal solution for any individual function. For this reason, careful judgement needs to be exercised when using the criteria given in the standard for other purposes, particularly town planning control.

NOTE Figure 2 in this standard is reproduced from the CIBSE Lighting Guide LG10 Daylighting and window design *[1] by permission of the Chartered Institution of Building Services Engineers.*

Use of this document

As a code of practice, this part of BS 8206 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of BS 8206 is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This part of BS 8206 gives recommendations regarding design for daylight in buildings. It includes recommendations on the design of electric lighting when used in conjunction with daylight.

NOTE Data for daylight and sunlight calculations are given in Annex A.

2 Terms and definitions

For the purposes of this part of BS 8206, the following terms and definitions apply.

2.1 daylight
visible part of global solar radiation [BS EN 12665:2002]

NOTE Daylight consists of a combination of sunlight (see ***2.10.1****) and skylight (see* ***2.11.1****).*

2.2 window
construction for closing a vertical or near-vertical opening in a wall or pitched roof, which will admit light and may provide ventilation [BS 6100-1:2004, **5.3.5**]

2.3 rooflight
construction for closing an opening in a flat roof or low pitched roof, intended primarily for lighting and consisting of a frame and glazing [BS 6100-1:2004, **5.3.13**]

2.4 transom
horizontal member dividing an opening or frame of a window or door [BS 6100-1:2004, **5.3.24**]

2.5 obstruction
anything outside a building which prevents a direct view of the sky from a given reference point

2.6 no-sky line
outline on a given surface of the area from which no sky can be seen

2.7 working plane
horizontal, vertical or inclined plane in which a visual task lies [BS 6100-7:2008, **52002**]

NOTE If no information is available, considered to be horizontal and 0.7 m above the floor for offices; horizontal and 0.85 m above the floor for industry and in dwellings.

2.8 window reference point
point in the centre of a window or rooflight opening on the plane of the inside surface of the window wall or roof

NOTE This is used in determining sunlight penetration and average daylight factor.

2.9 supplementary electric lighting
electric lighting used continuously in combination with daylighting

2.10 sunlight

2.10.1 sunlight
that part of the light from the sun that reaches the earth's surface as parallel rays after selective attenuation by the atmosphere

2.10.2 probable sunlight hours
long-term average of the total number of hours during the year in which direct sunlight reaches the unobstructed ground

NOTE A period of "probable sunlight hours" is the mean total time of sunlight when cloud is taken into account.

2.10.3 solar altitude
angle between a line passing through the centre of the solar disc and a horizontal plane on the earth's surface [BS 6100-7:2008, **59006**]

NOTE This is illustrated in Figure 1.

2.10.4 solar azimuth
horizontal angle between a vertical plane passing through the centre of the solar disc and a vertical north–south plane

NOTE 1 Solar azimuth is measured clockwise from due north.

NOTE 2 This is illustrated in Figure 1.

2.11 skylight

2.11.1 skylight
that part of the light from the sun that reaches the earth's surface as a result of scattering in the atmosphere

2.11.2 standard overcast sky
completely overcast sky for which the luminance L_γ at an angle of elevation γ above the horizon is expressed as a function of the luminance L_z at the zenith by the formula:

$$L_\gamma = \frac{L_z(1 + 2 \sin \gamma)}{3}$$

*NOTE This formula for overcast sky luminance distribution is presented as an alternative formula in BS ISO 15469:2004, Clause **6**.*
BS ISO 15469:2004 also contains fifteen other formulae for different types of sky.

2.11.3 daylight factor
ratio of illuminance at a point on a given plane due to light received from a sky of known or assumed luminance distribution, to illuminance on a horizontal plane due to an unobstructed hemisphere of this sky [BS 6100-7:2008, **59011**]

NOTE 1 For the purposes of the calculation of daylight factor in this standard, it is assumed that the sky has the luminance distribution of the standard overcast sky.

NOTE 2 Direct and reflected sunlight are excluded from all values of illuminance.

NOTE 3 The point in an interior for which the daylight factor is calculated is known as the "room reference point".

2.11.4 average daylight factor

ratio of total daylight flux incident on a reference area to total area of reference area, expressed as a percentage of outdoor illuminance on a horizontal plane due to an unobstructed hemisphere of sky of assumed or known luminance distribution [BS 6100-7:2008, **59012**]

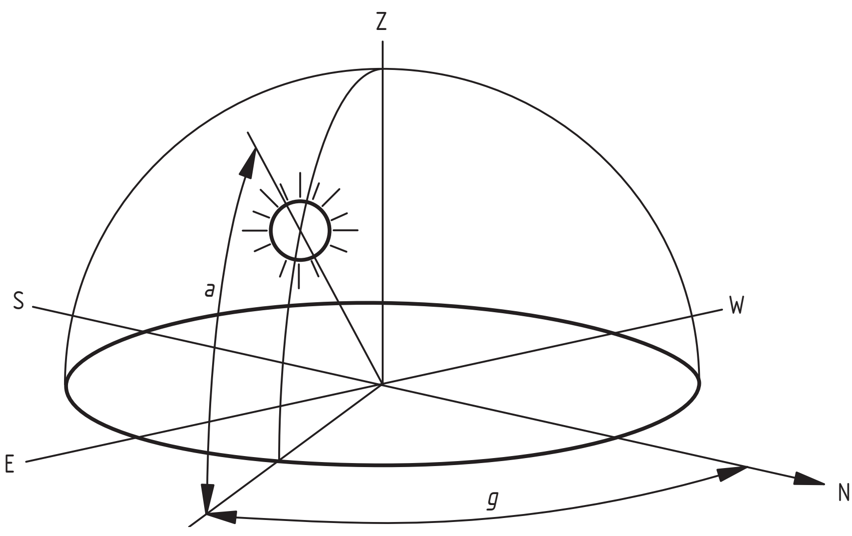
NOTE 1 For the purposes of this standard, it is assumed that the average daylight factor is the mean daylight factor over a horizontal working plane, unless stated otherwise.

NOTE 2 Direct and reflected sunlight are excluded from all values of illuminance.

2.11.5 vertical sky component

ratio, expressed as a percentage, of that part of illuminance, at a point on a given vertical plane, that is received directly from a standard overcast sky (see **2.11.2**), to illuminance on a horizontal plane due to an unobstructed hemisphere of this sky

Figure 1 **Solar altitude and solar azimuth**



Key

Z Zenith

a Solar altitude

g Solar azimuth

Section 2: Aims and criteria for design

3 The contribution of daylight

3.1 General

Daylighting gives to a building a unique variety and interest. An interior which looks gloomy, or which does not have a view to the outside when this could reasonably be expected, will be considered unsatisfactory by its users. The recommendations of this part of BS 8206 recognize that a principal aim of the designer is to produce interiors which are comfortable and give pleasure to their occupants.

Recommendations are made in this section about three separate uses of windows, which are:

a) for view;

b) to enhance the overall appearance of interiors, using sunlight (the direct beam) and skylight (diffuse daylight);

c) for lighting of visual tasks.

It is important to consider the primary function to be served by each window or rooflight in a building, because the criteria differ. Two of the functions, the overall illumination of the interior and the task lighting, may be fulfilled also by electric lighting, which has different qualities. For many buildings, the best design uses daylighting and electric lighting together, with appropriate lighting control, during daytime hours.

3.2 Daylight and health

3.2.1 Regulation of the circadian system

The role of the circadian system (which controls daily and seasonal body rhythms) is to link the functions of the body (e.g. the sleep/wake cycle, and changes in core body temperature and in hormone secretion) with the external day/night cycle. Disruption to this system from lack of light can cause problems such as depression and poor sleep quality which could lead to more serious problems. Therefore, it is important that occupants of buildings, particularly those of limited mobility in, for example, hospitals and nursing homes, and people who might be unable to go outside much, are given access to high levels of daylight, particularly in the mornings, to assist the entrainment of circadian rhythms. Therefore, buildings used by such people should have spaces with high levels of daylight, such as conservatories, which are readily accessible to them.

3.2.2 Mood

Mood can be modified by lighting. Daylighting is dynamic and variable and is strongly favoured by building occupants. Adequate access to daylight can have a positive impact on mood especially in situations where people are static for long periods of time, for example, in a hospital ward.

3.2.3 Seasonal affective disorder (SAD)

A small percentage of people suffer a seasonal mood disorder known as seasonal affective disorder (SAD) with a further number suffering a mild form known as sub-syndromal SAD (S-SAD). Symptoms include depression, lack of energy, increased need for sleep and increased appetite and weight gain, occurring in the winter when there is little daylight. Such symptoms can be reduced by exposure to daylight.

3.2.4 Ultraviolet (UV) radiation

The ultraviolet (UV) radiation in sunlight can be damaging to the skin. However, with people spending many daylight hours behind glass in buildings, there is the danger of insufficient exposure to UV radiation to maintain healthy levels of vitamin D. A vitamin D deficiency leads to rickets in children and softening of the bones in adults.

Exposure to sunlight, even through glass, can kill many types of viruses and bacteria and so can be of great value in winter when there is a high incidence of respiratory infections.

4 Windows and view

4.1 Principle

Unless an activity requires the exclusion of daylight, a view out-of-doors should be provided irrespective of its quality.

All occupants of a building should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus. Even a limited view to the outside can be valuable. If an external view cannot be provided, occupants should have an internal view possessing some of the qualities of a view out-of-doors, for example, into an atrium.

4.2 Analysis of view

In planning the position of windows, the following factors are important.

a) Most people prefer a view of a natural scene: trees, grass, plants and open space.

b) In densely built-up areas, a view of the natural scene may not be available. When only buildings, sky and street can be seen, it is especially desirable that the view be dynamic, i.e. including the activities of people outside and the changing weather, but even a static view is usually better than none.

c) A specific close view may be essential, particularly for security and supervision of the space around dwellings.

d) There is often a need for privacy. This varies with the building type and with the expectations of the users. The view into a building should be considered when the view outwards is determined.

Most unrestricted views have three "layers", as follows:

1) upper (distant), being the sky and its boundary with the natural or man-made scene;
2) middle, being the natural or man-made objects themselves;
3) lower (close), being the nearby ground.

Views which incorporate all three "layers" are the most completely satisfying.

4.3 Size and proportion of windows

The size and proportion of windows should depend on the type of view, the size of the internal space, and the position and mobility of occupants. A variety of window shapes and sizes is illustrated in Figure 2. Some circumstances may suggest a tall window which allows occupants anywhere to enjoy the full vertical span of the view. A narrow horizontal window will only offer a similar prospect to those close to it; a narrow vertical window is also restrictive yet will admit a deeper penetration of daylight. For a given area of window, the more exaggerated the horizontal or vertical proportions, the more restricted will be the position of occupants who can experience the views. A view of the immediate foreground will be experienced normally only by those close to the window.

Unless a view of the sky is to be deliberately excluded (and the penetration of daylight severely limited) window heads should be above standing eye height. Sills, normally, should be below the eye level of people seated. Transoms should not obstruct significant parts of the view from normal standing or sitting positions. Special consideration should be given to window heights in buildings such as nurseries, schools, hospitals and care homes. Guidance on sill heights in hospitals is given in NHS Health Technical Memorandum 55 [2].

The most limited views occur in a deep room when windows are confined to one wall only. Table 1 gives guidance on minimum window area for a satisfactory view when fenestration is restricted to one wall; higher proportions are recommended. The table gives total glazed area of the room as a percentage of the internal window wall area. When there are windows in two or more walls, the total area of glazing should not be less than the area that would be recommended if the windows were restricted to any one wall. The openings should be distributed to give views from all occupied areas of the room.

Table 1 **Minimum glazed areas for view when windows are restricted to one wall**

Depth of room from outside wall (max.) m	**Percentage of window wall as seen from inside** (min.) %
<8	20
⩾8 ⩽11	25
>11 ⩽14	30
>14	35

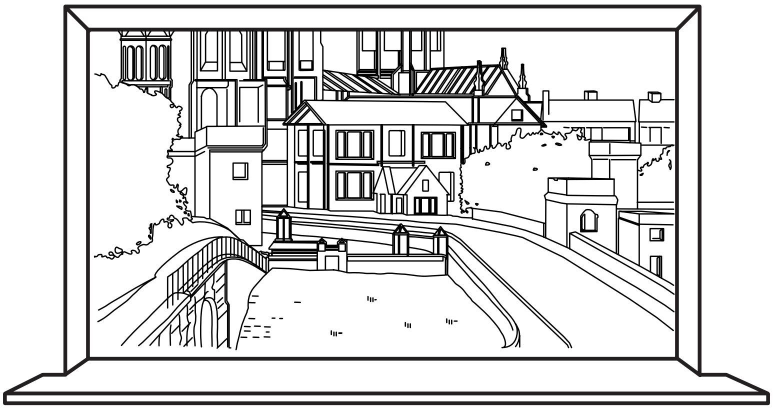
NOTE Windows which are primarily designed for view may not provide adequate task illumination.

When windows are confined to one wall only, it is recommended that the total width of the windows should be at least 35% of the length of the wall.

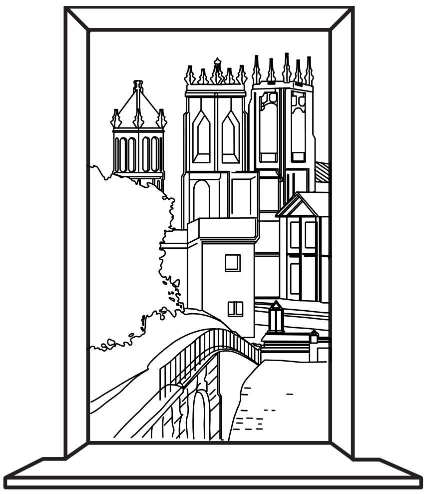
Figure 2 **Views from windows of different shapes and sizes**

Reproduced from CIBSE Lighting Guide LG10: *Daylighting and window design* [1], by permission of the Chartered Institution of Building Services Engineers.

a) Large window providing a view containing all three layers.



b) Smaller window of horizontal proportions providing a view with some sky visible.



c) Smaller window of vertical proportions showing all three layers, but with a restricted view.

5 Daylight and room brightness

5.1 General

The value of daylight goes beyond the illumination of tasks. A daylit room varies in brightness with time, colours are rendered well and architectural form and surface texture can be enhanced by the direction of illumination. Above all, windows give information to the people in a building about their surroundings. Weather and the time of day can be inferred from the changing light.

The user's perception of the character of a daylit interior (often described in terms like "bright and well-lit", or "gloomy") is related to the brightness of all the visible surfaces. This overall luminance depends on the quantity of light admitted and the reflectance of interior surfaces. The reflected light within the room can be as important as the direct illumination.

Sunlight and skylight are both important in general room lighting, but they differ greatly in their qualities. The criteria for each should be satisfied. Sunlight gives patches of high illuminance and strong contrasts; adequate skylight ensures that there is not excessive contrast between one area of the room and another, or between the interior and the view outside. The methods for evaluation of daylight discussed in **5.2** to **5.8** are significant simplifications. In practice, daylight provided by a real sky varies continuously both in amount and distribution. To correctly represent this situation, new climate-based methods are being developed. Climate-based daylight modelling is discussed in Annex B.

If the total glazed area cannot be made large enough for adequate general daylight, supplementary electric lighting is needed to enhance the general room brightness in addition to any need there may be for task illumination (see **7.2**).

5.2 Sunlight: principle

Sunlight should be admitted unless it is likely to cause thermal or visual discomfort to the users, or deterioration of materials.

Provided that the entry of sunlight is properly controlled, it is generally welcome in most buildings in the UK. Dissatisfaction can arise as much from the permanent exclusion of sunlight as from its excess. However, uncontrolled sunlight is unacceptable in most types of building. Good control is particularly important in working interiors and other rooms where the occupants are unable to move around freely. Generally, sunlight should not fall on visual tasks or directly on people at work. It should, on the other hand, be used to enhance the overall brightness of interiors with patches of high illuminance.

Considerations of sunlight should influence the form of the building from the early stages of design, because incorrect decisions about the orientation of rooms or the geometrical shape of the building may preclude the admission of sunlight or cause excessive overshadowing of surroundings. The orientation of windows should take into account the periods of occupancy and any preferences for sunlight at particular times of day. The provision of sunlight is important in dwellings, particularly during winter months. Sunlight is especially valued in habitable rooms used for long periods during the day and in buildings, such as those for the elderly, where the occupants have little direct contact with the outside. In some cases, it is important that there should be direct sunlight on external surfaces seen from a window.

NOTE 1 Sunlight entering a room can have a significant effect on thermal comfort and on the energy consumption of the building. In winter it can be an important contribution to the heating; but excessive solar gain causes serious discomfort and, in air-conditioned buildings, unnecessary use of energy in cooling. Sunlight as a source of thermal energy is considered in BS 8207 and in BS 8211-1.

*NOTE 2 Control of admission of sunlight is covered in **8.1**.*

5.3 Sunlight duration

Interiors in which the occupants have a reasonable expectation of direct sunlight should receive at least 25% of probable sunlight hours (see **2.10.2**). At least 5% of probable sunlight hours should be received during the winter months, between 21 September and 21 March. Sunlight is taken to enter an interior when it reaches one or more window reference points. A calculation procedure is given in **12.2**.

The degree of satisfaction is related to the expectation of sunlight. If a room is necessarily north facing or if the building is in a densely-built urban area, the absence of sunlight is more acceptable than when its exclusion seems arbitrary. It is the duration of sunlight in an interior, rather than its intensity or the size of the sunny patch, which correlates best with the occupants' satisfaction.

5.4 Skylight: principle

The general illumination from skylight should be such that there is not excessive contrast between the interior and the view outside.

The interior of a room will appear gloomy not only if the total quantity of light entering is too small but also if its distribution is poor. In addition, high contrast between the surfaces surrounding windows (or rooflights) and the sky can cause glare.

5.5 Average daylight factor

The average daylight factor (see **2.11.4**) is used as the measure of general illumination from skylight. It is considered good practice to ensure that rooms in dwellings and in most other buildings have a predominantly daylit appearance. In order to achieve this the average daylight factor should be at least 2%.

If the average daylight factor in a space is at least 5% then electric lighting is not normally needed during the daytime, provided the uniformity is satisfactory (see **5.7**). If the average daylight factor in a space is between 2% and 5% supplementary electric lighting is usually required.

*NOTE Excessive daylight can cause visual discomfort and be associated with overheating (see **5.2**).*

5.6 Minimum values of average daylight factor in dwellings

Even if a predominantly daylit appearance is not achievable in a dwelling, it is recommended that the average daylight factor should be at least the relevant value as given in Table 2.

Table 2 **Minimum average daylight factor**

Room type	**Minimum average daylight factor** %
Bedrooms	1
Living rooms	1.5
Kitchens	2

Where one room serves more than one purpose, the minimum average daylight factor should be that for the room type with the highest value. For example, in a space which combines a living room and a kitchen the minimum average daylight factor should be 2%.

5.7 Uniformity of daylight

Surface reflectances and the disposition of glazing should be such that inter-reflected light in the space is strong and widespread.

The uniformity of daylight is considered to be unsatisfactory if:

a) a significant part of the working plane (normally more than 20%) lies behind the no-sky line; or

b) in a room lit by windows in one wall only, the depth of the room is too large in comparison with the height and the width of the windows. (A procedure for calculating this is given in **13.3**.)

In the case of rooflights, unsatisfactory variation in general lighting occurs when the distance between adjacent openings is large in comparison with the ceiling height. The maximum acceptable ratio between rooflight spacing and ceiling height depends on the type of rooflight. Detailed information is given in CIBSE Lighting guide LG10 [1]. In interiors lit primarily by rooflights, the reflectances of the floor and ceiling should be as high as possible.

5.8 Contrast between the interior and the view outside

Glare from windows can arise from excessive contrast between the luminance of the visible sky and the luminance of the interior surfaces within the field of view. The window walls, the window reveals, and the interior surfaces adjacent to rooflights should be of high reflectance (white or light-coloured). Walls generally should not be glossy.

In addition, glare from the sky and bright external surfaces can be reduced by:

a) providing additional illumination on the window wall from other windows;

b) reducing the luminance of the sky as seen from the interior with translucent blinds, curtains or tinted/solar-control glazing, if adequate illumination can be provided by other sources;

   *NOTE 1 Translucent blinds can give a perception of glare if sunlight falls on them (see **8.1**).*

c) splaying window reveals, to give a larger area of intermediate brightness between the exterior view and the window wall.

The aim should be to achieve a subtle gradation of luminance from the darker parts of the room to the visible sky.

Glare from direct sunlight, or from sunlight reflected in glossy external surfaces, should be controlled with shading devices (see Clause **8**).

The use of tinted glazing will reduce the amount of daylight entering and can affect colour perception. External colours might appear distorted, especially when the view outside is seen simultaneously through different types of glass. The perception of internal colours can be altered, unknown to the viewer, when the main source of light is a window of tinted glazing. Care should be taken in the use of tinted glazing materials when safety or task performance requires good colour recognition.

NOTE 2 Some heavily tinted glazings can affect the view out of a building. It has been found that if the transmittance of the glass falls below 25% a significant proportion of the people using the building find the view out unacceptable.

6 Daylight for task lighting

6.1 General

When there are visual tasks to be carried out, the principles of lighting design using daylight are the same as those for electric lighting: it is necessary both to achieve a given level of illumination and to take account of the circumstances that determine its quality.

Daylight has the following characteristics as a task illuminant.

a) A constant illuminance on the task cannot be maintained. When the sky becomes brighter, the interior illuminance increases; and, although control is possible with louvres, blinds and other methods, fluctuations cannot be avoided. Conversely, in poor weather and at the ends of the working day, daylighting needs to be supplemented with electric lighting.

b) The direction of light from windows, which act as large diffuse light sources to the side of a worker, gives good three-dimensional modelling. Rooflights, which give a greater downward component, have a modelling effect similar to that from large ceiling-mounted luminaires.

c) The spectral distribution of daylight varies significantly during the course of a day, but the colour rendering is usually considered to be excellent.

6.2 Quantity of daylight

6.2.1 Illuminance

Task illuminance requirements are specified in BS EN 12464-1. A procedure for calculating daylight illuminance is given in Clause **14**.

6.2.2 Uniformity

Over the task area of an individual worker, the uniformity in illuminance should be that specified in BS EN 12464-1:2002, **4.3.3**. An appropriate criterion indicated in that clause is that the minimum illuminance on a particular task area should not fall below 0.7 times the average illuminance on that task area. It is also important that the area immediately surrounding a task has illuminances not less than those recommended in BS EN 12464-1:2002, Table 1.

6.3 Quality of daylight

6.3.1 General

The considerations of lighting described in BS EN 12464-1 and in the Society of Light and Lighting (SLL) publication *The code for lighting* [3] apply both to daylit interiors and to those with electric lighting. The quantity of illumination is not the sole criterion of good task lighting.

There are two aspects of task daylighting which need particular attention: glare and specular reflection.

6.3.2 Glare

Windows may fill a greater part of a worker's field of view than electric light fittings. Distraction, a poor luminance balance between task and background, and discomfort glare can all occur if the visual task is viewed directly against the bright sky. Although a view outside should be provided, it is usually better if the glazing is at the side of workers, rather than directly facing them.

There is no standard procedure for calculating discomfort glare from skylight. Sky luminance can be very high, and the size of the apparent source is large; so by the criteria adopted for electric lighting most windows cause glare. It should be reduced by ensuring that the sky is not in the immediate field of view with the task, and by following the recommendations given in **5.8**.

Highly reflective sunlit external surfaces are more likely to add vitality to a scene than constitute an objectionable glare source. This stimulus will be welcomed in all but the most demanding visual situations. However, glare from the sun, viewed directly or specularly reflected, can be unacceptable in a working environment. If the sun or its mirrored image is likely to lie within 45° of the direction of view, then shading devices should be used (see **8.1**). Low transmittance glazing is unlikely to attenuate the beam sufficiently to eliminate glare; diffusing glazing materials, in scattering the beam, may cause the window or rooflight itself to become an unacceptably bright source of light.

6.3.3 Specular reflection

The visibility of tasks can be seriously impaired by bright reflections of the sky in glossy surfaces. With windows, troublesome reflections occur predominantly in vertical surfaces. With rooflights, horizontal task areas are the most seriously affected. However, openings of either type can affect surfaces of all orientations if the geometry is incorrect. Special attention should be given to the avoidance of reflections of windows in display screens, chalkboards, and pictures in galleries, and it is preferable that these surfaces do not face a window directly.

Section 3: Further design issues

7 Electric lighting used in conjunction with daylight

7.1 Functions of supplementary electric lighting design

Electric lighting has two distinct functions in a daylit building, which are:

a) to enhance the overall appearance of the room, by improving the distribution of illuminance and by reducing the luminance contrast between the interior and the view outside;

b) to achieve satisfactory illuminance on visual tasks.

These two functions correspond with the recommendations about room brightness and task illumination in daylight, described in Clause **5** and Clause **6**. The electric lighting should be designed for both functions.

7.2 Lighting quality

7.2.1 Balance of daylight and electric light

Unless the purpose of the windows is only to provide a view, daylight should appear to the users to be dominant in the interior. This is normally achieved when the average daylight factor is 2% or more, even though the horizontal illuminance from electric lighting may be greater than the daylight illuminance in parts of an interior.

The design of electric lighting should be such that occupants are aware of the natural gradation of daylight across interior surfaces and of changes in the light outside.

7.2.2 Modelling

The sideways component of light from windows is important in the enhancement of modelling. It is apparent in the articulation of mouldings and in the highlights and shadows of three-dimensional features. The electric lighting should be designed with the daylighting to achieve optimum modelling, reinforcing the directionality where the natural illumination is too diffuse, and providing infill lighting where windows alone would give harsh modelling.

7.2.3 Contrast between interior and exterior

When the general level of inter-reflected light is low, or the surfaces surrounding a window or rooflight are of low reflectance, there will be high luminance contrast with the view outside. The brighter the view, the higher should be the luminance of the room surfaces which frame the view. Often the best solution is to increase the reflectance of the surfaces surrounding a window rather than use electric lighting.

7.2.4 Colour appearance of lamps

The sky varies in colour with time and in azimuth and altitude. These variations are considerable and no electric lamp matches continuously the colour appearance of daylight. For instance, the appearance of a lamp with a colour temperature close to that of light from a clear sky at midday may seem excessively blue as evening approaches. Sunlight reflected into a room from vegetation or brightly coloured surfaces outside can have a noticeable hue and can affect the colour appearance of lamps.

Apparent discrepancies between the colour of electric light and of daylight may be reduced by:

a) using lamps of cool or intermediate class correlated colour temperature (see BS EN 12464-1:2002, Table 3);

b) screening lamps from the view of occupants (see BS EN 12464-1:2002).

7.2.5 Sequences of spaces

Individual spaces can be satisfactory with low levels of daylighting and correspondingly low illuminances from supplementary electric lighting or, alternatively, with high levels of both. However, adjacent rooms usually should not contrast harshly with each other either in brightness or in the colour of the illuminant. The building should be planned to avoid passing directly from a brilliantly sunlit space into one with a low level of combined lighting. A transitional space will help the eye to adapt in comfort from one to the other.

7.3 Task lighting

7.3.1 Illuminance

The total illuminance from daylight and electric light should satisfy the illuminance criteria for the visual task (see **6.2.1**). Care should be taken that a task is not viewed against the sky or a very bright area of the room. If this is unavoidable, its illuminance should be such that there is a satisfactory brightness contrast between task and surroundings, depending upon the nature of the task.

7.3.2 Direction and modelling

Electric lighting should be designed so that good modelling assists task performance. The directionality of daylighting is usually an advantage but in some cases it is necessary to use electric lighting to increase the luminance of surfaces in shadow.

7.3.3 Colour

When discrimination of surface colour is essential for task performance, the choice of lamp should be that recommended for the task under entirely electric lighting. It may be necessary for the user to ascertain whether the task is illuminated primarily with electric light or with daylight.

7.4 Change in lighting at dusk

An interior with some supplementary lighting yet which is primarily daylit will change in character when, late in the day, the electric lighting becomes predominant. As dusk approaches, additional electric illumination is often needed, both to increase task illuminance near the windows and to improve the general brightness of the room, but not for the purpose of reducing sky glare.

Electric lighting controls are described in Clause **9**. Consideration should be given to the separation of daytime and night-time lighting. It may be necessary to install some electric lighting that is switched on at dusk and some that is switched off.

NOTE Information on security lighting is given in BS 8220.

8 Sunlight shading

8.1 General

It is essential that the admission of sunlight be controlled in all work spaces and other interiors where the thermal or visual consequences might lead to personal discomfort or cause materials to undergo unacceptable deterioration. In general, the best control of sunlight penetration is achieved by careful planning of the orientation and disposition of rooms and their windows. (See Clause **10** for a description of the factors which affect degradation of materials.)

All fenestration in positions where sunlight could cause discomfort or damage should be provided with shading. For some interiors it is acceptable if sunlight is restricted during the warmer months by shading the apertures with elements such as balconies or overhanging roofs, or by fixed louvres or screens. It may be possible to arrange fixed shading devices or install daylight redirecting systems so that daylight is redistributed to better effect, but fixed devices generally reduce the skylight admitted and glazed areas may need to be increased. The effectiveness of fixed shading devices will depend on window orientation.

Traditional low transmittance “solar” glazing will diminish light as well as solar gain. However, new types of coated glazing can give a high daylight transmittance with a lower solar gain. This might be the best method of reducing summer cooling loads where large areas of glass are needed for view or appearance.

Retractable and adjustable shading is often appropriate to the low solar altitudes of the UK. It is important that the system should be easily maintained and, if manually controlled, easily operated. This is best achieved when shading systems are fitted internally, although shading devices on the outside of the glazing are thermally more effective as heat from the intercepted radiation is more readily dissipated into the external air. Adjustable external systems should be robust, or retract when necessary if vulnerable to wind damage. Shading devices may interrupt the view and restrict natural ventilation. Translucent blinds with a high transmittance may be perceived as sources of glare when illuminated by direct sunlight. This potential problem can be ameliorated by the use of blinds with a transmittance of less than 10%.

Although shading by trees is an attractive alternative to the use of blinds, exclusive reliance on foliage to shade fenestration is unlikely to be satisfactory for working interiors. Furthermore, a tree in leaf will diminish the light available from the sky obscured to between 0.1 and 0.3 of the unobstructed value. In winter the bare branches of a deciduous tree are likely to reduce the skylight to between 0.5 and 0.8 of the unobstructed value from the part of the sky enclosed within the tree's outline. These values are approximate only. They vary with the species and with different members of the same species. They vary also with the path length of the light through the foliage and therefore, in multiple planting, with the depth and composition of the stand.

8.2 Overshadowing

8.2.1 Loss of daylight to existing buildings

Guidance regarding the loss of light to existing buildings following construction of a proposed new development nearby is given in the BRE Report *Site layout planning for daylight and sunlight: a guide to good practice* [4]. To assess the impact on the amount of diffuse daylight entering existing buildings, the Report recommends using the vertical sky component, and gives methods for its calculation. The maximum value of the vertical sky component is almost 40% for a completely unobstructed vertical wall. The vertical sky component on a window is a good measure of the amount of daylight entering it.

The BRE Report [4] sets out two guidelines regarding the vertical sky component.

a) If the vertical sky component at the centre of the existing window would exceed 27% with the new development in place, then enough skylight would still be reaching the existing window.

b) If the vertical sky component with the new development in place would be both less than 27% and less than 0.8 times its former value, then the area lit by the window would be likely to appear more gloomy, and electric lighting would be needed for more of the time.

The vertical sky component is one of the factors on which the average daylight factor in an existing interior depends. A reduction in vertical sky component to 0.8 times its former value, corresponds to a reduction in the average daylight factor in the room served by the window to between 0.85 times and 0.92 times its former value when the original vertical sky component was >27% or 5%, respectively.

The BRE Report [4] also gives guidance on the impact of a proposed new development on the uniformity of daylight in existing buildings, as measured by the position of the no-sky line (see **5.7**). If, following construction of a new development, the no-sky line were to move so that the area of the existing room which does receive direct skylight was reduced to less than 0.8 times its former value then this would be noticeable to the occupants, and more of the room would appear poorly lit. This would also be true if the no-sky line were to encroach on key areas like kitchen sinks and worktops.

8.2.2 Loss of sunlight to existing buildings

To find out whether an existing building would still receive enough sunlight, the guidance in **5.3** can be used. The BRE Report *Site layout planning for daylight and sunlight: a guide to good practice* [4] suggests that all main living rooms of dwellings, and conservatories, should be checked if they have a window facing within 90° of due south. Kitchens and bedrooms are less important, although care should be taken not to block too much sun. In non-domestic buildings any spaces which are deemed to have a special requirement for sunlight should be checked; they will normally face within 90° of due south anyway.

If, following the new development, the existing room could receive more than 25% of probable sunlight hours (see **5.3**) including at least 5% of probable sunlight hours in the winter months, between 21 September and 21 March, then the room would still receive enough sunlight.

Any reduction in sunlight access below this level should be kept to a minimum. If the probable sunlight hours were both less than this and less than 0.8 times their former value, either over the whole year or just in the winter months (21 September to 21 March) then the occupants of the existing building would notice the loss of sunlight. The room could appear colder and less cheerful and pleasant.

8.2.3 Overshadowing of an open space by a proposed development

The overshadowing of an open space by a proposed development could seriously limit the usefulness of the space for external activities in fine weather, or lead to the persistence of frost and snow in winter and the creation of areas unsuited to the growth of plants. Examination of the duration and extent of site shadowing is therefore recommended at the planning stage. Guidance on this issue is given in the BRE Report *Site layout planning for daylight and sunlight: a guide to good practice* [4].

9 Energy efficiency

9.1 Energy consumption in lighting

Within the UK, lighting accounts for around 5% of the total primary energy consumed. However, in some types of building, such as office blocks, 10% to 30% of the primary energy (a fair reflection of energy cost) is used by lighting.

In such buildings the exploitation of daylight can do much to reduce this energy cost. In Royal Institute of British Architects (RIBA) case studies of buildings classified as "energy efficient" (published under the title *Buildings, the key to energy conservation* [5]) it was found that in general the shallow plan, daylit, naturally ventilated buildings had around half of the primary energy consumption (in MJ/m^2/year) of the deep plan, air-conditioned buildings with extensive artificial lighting.

Another study by the BRE indicated potential energy savings averaging 20% to 40% in offices and factories if daylighting is used effectively (see BRE report *Daylighting as a passive solar energy option: an assessment of its potential in non-domestic buildings* [6]). To achieve such savings, not only should daylight be admitted to the building but suitable controls should be installed to ensure the displacement of energy used for electric lighting.

BS EN 15193 gives details of how to estimate the electrical energy saved when using daylight in conjunction with electric lighting.

9.2 Window design and energy efficiency

In the design of windows, daylight is only one of several factors to be considered. Windows can affect the energy balance of the building by increasing both conduction heat loss and solar gain, and to a lesser extent and in certain cases, by infiltration losses. Conduction heat loss is roughly proportional to window area; it can be reduced by using double or triple glazing with or without low emissivity glass. In principle such glazing causes only a small diminution in interior daylight levels (although in some "high performance" windows the small glazing to frame ratio can reduce light penetration substantially). Solar heat gain is generally useful in winter when it reduces space heating requirements; in summer it can result in increased cooling load in air-conditioned buildings. The guidelines on the control of solar gain given in Clause **8** should be followed.

9.3 Passive solar design

The form, fabric and systems of a passive solar building are arranged and integrated to maximize the benefits of ambient energy for heating, lighting and ventilation in order to reduce consumption of conventional fuels. The sensitive use of daylighting, coupled with appropriate lighting controls, can therefore be viewed as an integral part of passive solar design.

Daylighting and solar radiation are complementary in that, when solar gains are at their highest, daylighting can be used to reduce or eliminate casual heat gains from electric lighting. In a passive solar building this effect is important because it will even out swings in heat gain, reducing overheating in summer. Thus the need for good daylighting should be kept in mind at all times, especially if purely thermal elements like trombe walls are being considered. In a domestic setting where lighting energy use is less important, the visual implications of passive solar design need to be recognized; the recommendations given in Section 2 should be followed. This applies especially to north-facing rooms where minimal window areas might otherwise be chosen on thermal grounds.

9.4 Lighting controls

For daylight to make a real contribution to energy efficiency it is not enough that it should just be admitted into the building; appropriate lighting controls are essential. There are four basic forms of lighting control which can be linked to daylight, as follows:

a) manual;

b) timed switch-off with optional manual reset;

c) photoelectric switching on/off;

d) photoelectric dimming.

These can be used in combination with each other. Sensors which determine whether a space is occupied may also be used. BS EN 15193 gives a method of calculating the efficiency of the various types of controls available.

The importance of effective lighting control should not be underestimated. In a conventionally daylit commercial building the choice of controls can make a substantial difference to the energy used for lighting. In addition, lighting controls should meet the needs and expectations of the users of the building. Further details are given in BRE Digest 498 *Selecting lighting controls and daylight use* [7].

10 Conservation of materials inside buildings

10.1 General

Many materials are damaged or faded by exposure to light. This is evident, for example, when furnishing fabrics are examined after a period of use.

Some objects are insensitive to light, some are moderately sensitive and others are so responsive that a few months' exposure to light will produce a change in appearance. The extent to which materials deteriorate under given lighting conditions depends largely on their chemical constitution. Information on the degradation of specific materials is given in the CIBSE Lighting Guide LG8 *Lighting for museums and art galleries* [8].

10.2 Factors affecting degradation

There are three factors affecting degradation, as follows:

a) spectral composition of the light;

b) illuminance;

c) period of exposure.

Radiation at the shorter wavelengths (blue and ultraviolet) usually causes the greatest degradation. The effects of illuminance and exposure time are interrelated as the degradation is approximately a function of their product. For instance, an exposure to 100 lx for 10 h can cause similar degradation as exposure to 1 000 lx for 1 h.

10.3 Improving conservation

10.3.1 Spectral composition

Ordinary window glass and the standard grades of clear or translucent plastics used for glazing rooflights absorb only part of the ultraviolet radiation in daylight. Additional filtering may be necessary. Certain chemicals will absorb almost all ultraviolet radiation without affecting significantly the transmission or colour of the light. These ultraviolet absorbers can be incorporated in most transparent and translucent plastics and a range of UV absorbing films is available for coating windows and rooflights.

10.3.2 Illuminance

Daylight illuminance in interiors can exceed 1 000 lx. For many display materials a limiting level of 200 lx is recommended and only 50 lx is recommended for materials very sensitive to light. These values may conflict with higher levels recommended in BS EN 12464-1 for a satisfactory visual environment and, if conservation is a prime factor, this should be taken into account in design decisions on window areas and methods of daylight control.

10.3.3 Exposure period

If degradation is a problem then the time for which the material is exposed to relatively high illuminances should be limited. Simple precautions, such as pulling the blinds or curtains when the room is unoccupied, will help. However, an awareness of the possible damage due to long exposure to direct sunlight or daylight should influence the positioning and illuminance of any light sensitive material.

11 Statutory and legal requirements affecting the provision of daylight

There are a number of statutory requirements that might impinge on the provision of daylight. The most significant of these are rights to light and Part L of the Building Regulations. Rights to light is a complex area of law, but the basic principle is that if a new building restricts the amount of light that enters an existing building then under certain circumstances it might be considered that owner of the existing building has suffered an injury.

Part L of the Building Regulations is concerned with energy consumption of buildings. The Approved Documents for the Building Regulations [9] refer to daylight several times in connection with reduction of energy used for electric lighting.

In the UK there is no general statutory requirement for a particular daylighting level. However Regulation 8 of the Workplace (Health, Safety and Welfare) Regulations 1992 (as amended) [10] requires that "Every workplace shall have suitable and sufficient lighting" and that this lighting "shall, as far as is reasonably practicable, be by natural light".

Control of glare is a legal requirement in most spaces where people work with display screen equipment, such as computer workstations. The Schedule to Regulation 3 of the Health and Safety (Display Screen Equipment) Regulations 1992 (as amended) [11] requires that "Windows shall be fitted with a suitable system of adjustable covering to attenuate the daylight that falls on the workstation".

Section 4: Methods of calculation

12 Sunlight

12.1 Sunpath diagrams

12.1.1 General

The sunpath diagrams given in Figure A.1 and Figure A.2 illustrate the apparent movement of the sun in London and Edinburgh.

The formulae given in **12.1.2** to **12.1.8** may be used to calculate the sun position with an accuracy of about ±1°.

12.1.2 Day angle

The day angle, τ_d, in radians, is given by the following formula:

$$\tau_d = \frac{2\pi(J-1)}{365}$$

where

J is the day number (J is 1 for 1 January and 365 for 31 December; February is taken to have 28 days).

12.1.3 Solar declination

The solar declination is the angle between the sun's rays arriving at the earth and the earth's equatorial plane.

The solar declination, δ_s, in radians, is given by the following formula:

$$\delta_s = 0.006918 - 0.399912\cos\tau_d + 0.070257\sin\tau_d - 0.006758\cos2\tau_d + 0.000907\sin2\tau_d - 0.002697\cos3\tau_d + 0.001480\sin3\tau_d$$

12.1.4 Equation of time

The equation of time gives the variation between clock time and solar time due to the eccentricity of the earth's orbit around the sun.

The equation of time, ET, in hours, is given by the following formula:

$$\text{ET} = 0.170\sin\left\{\frac{4\pi(J-80)}{373}\right\} - 0.129\sin\left\{\frac{2\pi(J-8)}{355}\right\}$$

where

J is the day number (see **12.1.2**).

NOTE The arguments to the sine functions are in radians.

12.1.5 True solar time

True solar time differs from clock time owing to a number of factors, these being the difference between the site longitude and the longitude of the standard meridian, the equation of time, and the use of summer time.

True solar time, TST, in hours, is given by the following formula:

$$\mathrm{TST} = \mathrm{LT} + \frac{\lambda_s - \lambda}{15} + \mathrm{ET} - \mathrm{TD}$$

where

- LT is local clock time, in hours, from midnight;
- ET is the equation of time, in hours (see **12.1.4**);
- TD is the summer time or daylight saving time, in hours;
- λ is the longitude of the site, in degrees;
- λ_s is the longitude of the standard meridian, in degrees.

12.1.6 Hour angle

The hour angle, ξ, in radians, is given by the following formula:

$$\xi = \frac{\pi}{15}\mathrm{TST}$$

where

- TST is true solar time, in hours (see **12.1.5**).

12.1.7 Solar altitude

The solar altitude, a, in radians, is given by the following formula:

$$a = \sin^{-1}(\sin\varphi\sin\delta_s - \cos\varphi\cos\delta_s\cos\xi)$$

where

- δ_s is the solar declination, in radians (see **12.1.3**);
- φ is the latitude of the site, in radians;
- ξ is the hour angle, in radians (see **12.1.6**).

12.1.8 Solar azimuth

The solar azimuth, g, in radians (from north) is given by the following formulae:

$$g = \cos^{-1}\frac{-\sin\varphi\sin a + \sin\delta_s}{\cos\varphi\cos a}, \quad 0 < \xi \leqslant \pi$$

$$g = 2\pi - \cos^{-1}\frac{-\sin\varphi\sin a + \sin\delta_s}{\cos\varphi\cos a}, \quad \pi < \xi \leqslant 2\pi$$

where

- φ is the latitude of the site, in radians;
- a is the solar altitude, in radians (see **12.1.7**);
- δ_s is the solar declination, in radians (see **12.1.3**);
- ξ is the hour angle, in radians (see **12.1.6**).

12.1.9 Stereographic sunpath diagrams

The concentric circles on a stereographic sunpath diagram represent angles of elevation above the horizon; the scale and compass points around the perimeter represent orientation. Each of the long curved arcs gives the sunpath, the solar altitude and azimuth, for a particular day; the shorter, converging, lines give the time of day.

Figure 3 shows how the outline of a window reveal, seen from the window reference point, can be plotted on the diagram. The window reveal cuts off the view of the sky 59° each side of the window's orientation and at 68° above the horizontal. On the sunpath diagram, the outline of the reveal (heavy line) shows that in mid-December sunlight could reach the window reference point between sunrise and approximately 1 p.m.; in mid-June there is possible sunlight between approximately 6 a.m. and midday, solar time (approximately GMT).

When rectangular obstructions on a stereographic diagram are plotted, vertical edges are represented by straight lines which converge to the centre. A horizontal edge, such as the head of the window reveal, is represented by a curved line. It is normally sufficiently accurate to draw this curve by finding its highest altitude (68° in the example given in Figure 3) and the points of intersection with the horizon, which are 180° apart. Shadow angle protractors are available which may be traced to give the lines of horizontal obstructions.

In Figure 4 an obstructing building is superimposed on the diagram. The longer elevations of this building face north and south. The building lies 40 m due south of the window being studied, its flat roof being 20 m above the window reference point. From the window, the obstruction subtends an angle in plan between 130° and 200° from north, and 27° above the horizon in altitude to the south.

All sunlight in mid-December is now obscured. In January sunlight can reach the window for about half an hour immediately after sunrise. In March the building no longer obscures the sunpath.

12.2 Probable sunlight hours

This clause gives a procedure for calculating the fraction of probable sunlight hours recommended in **5.3**. It uses the probability diagram, which gives the actual distribution of sunlight with respect to solar altitude and azimuth.

Figure A.3 is based on the sunlight statistics for London, although it may be used with reasonable accuracy for assessing sunlight in other parts of Britain. The density of dots is proportional to the probability of the sun shining from a particular area of the sky. There are 100 dots on the diagram, so each dot represents 1% of probable sunlight hours. The dots below the dashed line represent the sunlight occurring during winter months.

In Figure 5 the window reveal and the obscuring building have been superimposed on the diagram. There are 44 dots unobscured, that is 44% of probable sunlight hours, with 11% occurring during the winter months. The recommendation of **5.3** is satisfied. However, it will be seen that a considerable amount of direct sunlight will be received in the room during late morning and around midday in summer. Some form of shading device may be necessary to prevent overheating.

NOTE The BRE Report Site layout planning for daylight and sunlight: a guide to good practice *[4], gives an alternative graphical method of calculating probable sunlight hours.*

Figure 3 **Window reveal drawn on a sunpath diagram for London**

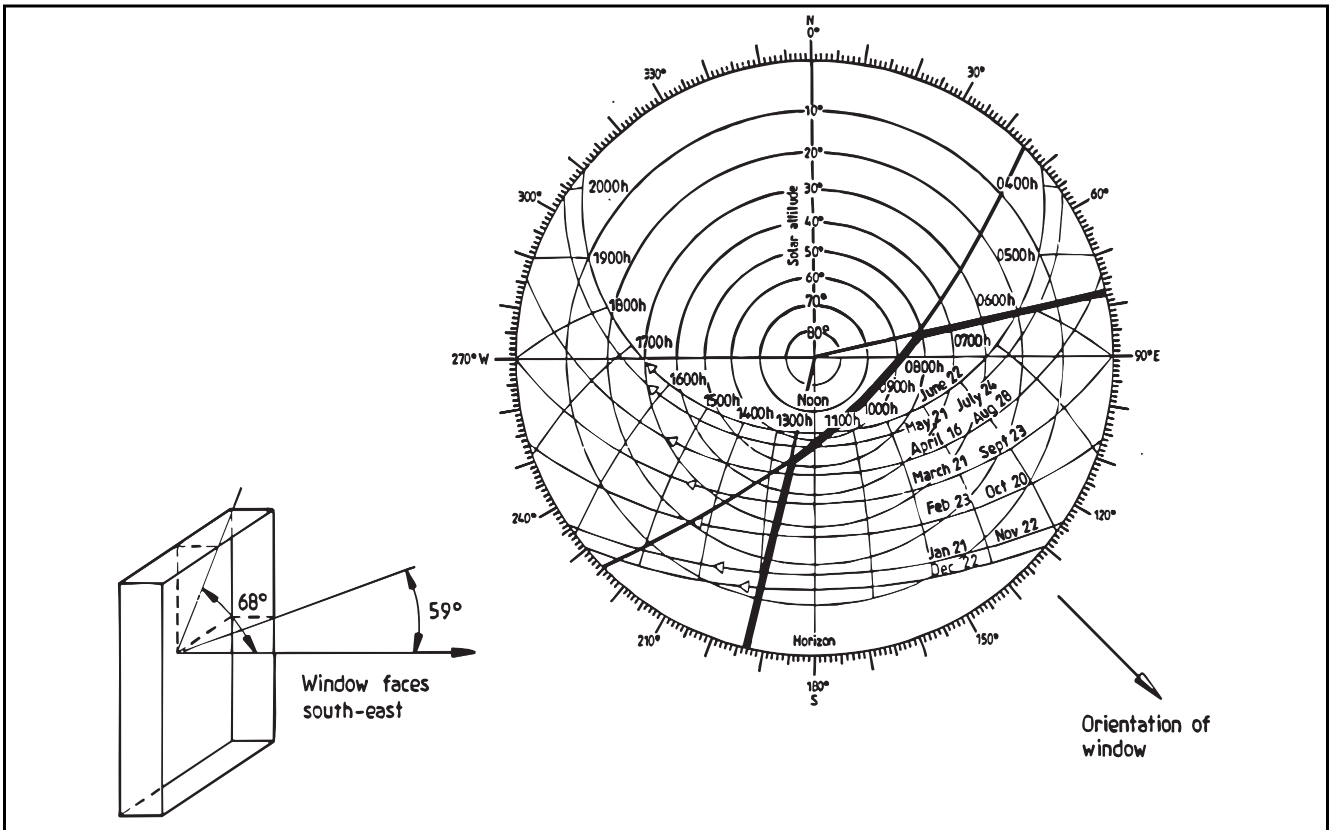


Figure 4 **Obstructing building superimposed on the sunpath diagram**

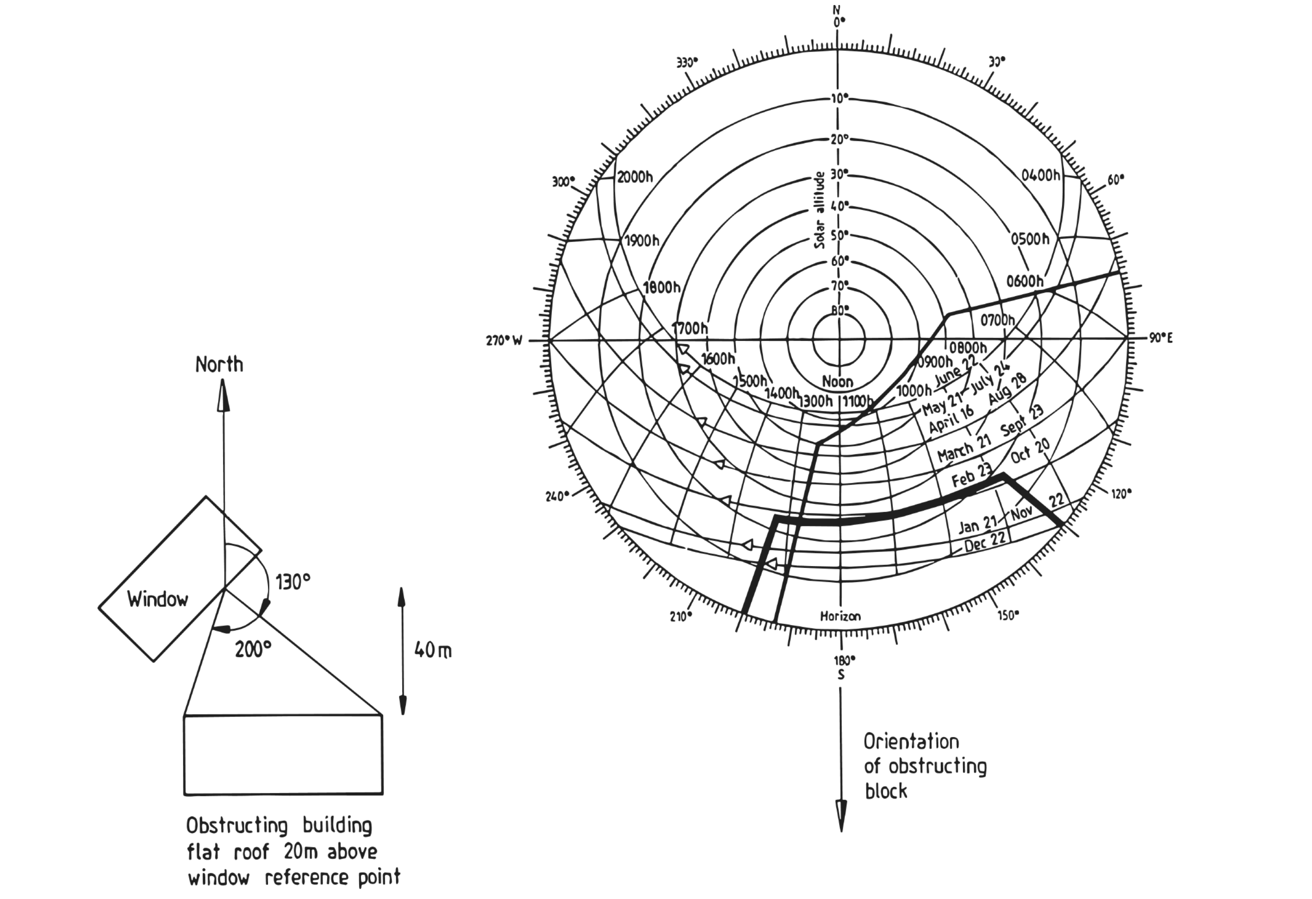
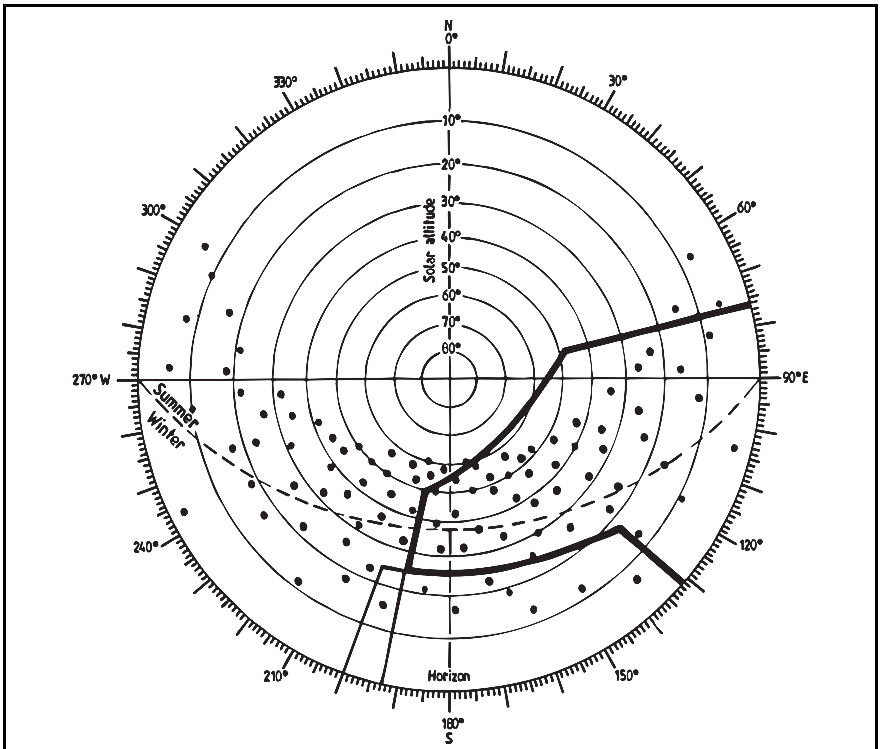


Figure 5 **Use of sunlight probability diagram to determine sunlight reaching window reference point**



12.3 Use of physical models

When the built form or its surroundings is complex, it is usually quicker to examine sunlight patterns in a scale model than to use graphical techniques. Sunlight in a model may be studied either with a heliodon or by using a sundial with an independent light source. A heliodon enables a lamp to be set at a position, in relation to a model, which corresponds to given times of day and year for a particular latitude. A sundial for the appropriate latitude is placed on the model, orientated in relation to the north point of the model, and illuminated with a small light source or with actual sunlight. The shadow trace on the sundial indicates the date and time of the corresponding light falling on the model.

The accuracy of model studies is limited by the possible precision of the model's construction, by divergence of the light beam across the width of the model, and by errors in the computed position of the light source. With a small scale model, it should not be assumed that the occurrence of the shadow pattern observed is more accurate than to the nearest half-hour.

12.4 Use of computer models

Computer-based techniques are now commonly used to predict and investigate patterns of sun and shade falling on and around buildings. The data requirements are computer files in a commonly accepted format that contain a three-dimensional description of the buildings, or suitable plans from which such a description can be created. These descriptions are usually computer aided design (CAD) models. Many commonly used CAD packages allow the user to specify a location for the building and a time of day, from which a shading pattern can be quickly generated. The shading patterns produced by most CAD packages are generally qualitative, i.e. they disclose which surfaces are in sun and shade, but the absolute levels of illumination and various inter-reflection effects are not modelled. Some packages allow the easy creation of animations that can, for example, show the progression of the shadow patterns throughout the course of a selected day. More sophisticated packages can indicate how much of the year a point on a building surface is shaded from receiving direct sun. The greatest level of detail is provided by lighting simulation software that uses so-called physically-based rendering techniques to generate images. These simulations can give information on predicted levels of incident sunlight as well as disclosing the time of day/year when it occurs.

13 Calculation of average daylight factor

13.1 Windows and rooflights with continuous obstructions of uniform height

This clause recommends a procedure for calculating the average daylight factors given as criteria in **5.5** to **5.7**.

When external obstructions can be defined adequately by two horizontal lines, i.e. the upper and lower limits of the visible sky, the average daylight factor on the working plane, D, expressed as a percentage, is:

$$\bar{D} = \frac{TA_w\Theta}{A\left(1 - R^2\right)} \tag{1}$$

where

- T is the diffuse light transmittance of the glazing, including the effects of dirt (see **A.1.2** for typical figures);
- A_w is the net glazed area of the window, in square metres (m^2) (see **15.2**);
- Θ is the angle subtended by the visible sky, in degrees. It is measured in a vertical plane normal to the glass, from the window reference point, as illustrated in Figure 6;
- A is the total area of the ceiling, floor and walls, including windows, in square metres (m^2);
- R is the area-weighted average reflectance of the interior surfaces (A). In initial calculations for rooms with white ceilings and mid-reflectance walls, this may be taken as 0.5. Table A.1 lists reflectances of various materials.

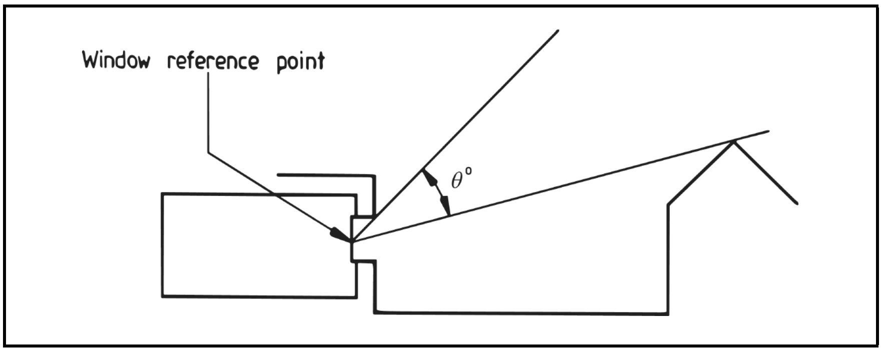
When two or more windows in a room face different obstructions, or differ in transmittance, the average daylight factor should be found separately for each window, and the results summed.

To find the window area above the working plane, in square metres, needed to achieve a given average daylight factor, the equation may be inverted, as follows:

$$A_w = \frac{\bar{D}A\left(1 - R^2\right)}{T\Theta} \tag{2}$$

NOTE The window area below the working plane does not significantly increase the amount of daylight falling onto the working plane. This is because the light from the lower part of the windows has to bounce off at least two room surfaces before it reaches the working plane, and it is also common for there to be obstructions below the working plane. A study has shown that the area of the window below the working plane is only about 15% as effective at letting light onto the working plane as an equivalent area above the working plane.

Figure 6 **Angle of visible sky used in calculating average daylight factor**



13.2 Limitations of the formula

Equations 1 and 2 should not be applied where external obstructions cannot be represented by a single angle of elevation, for example where a window faces into a courtyard. For further information, see the BRE Report *Site layout planning for daylight and sunlight: a guide to good practice* [4] and *Modification of the split-flux formulae for mean daylight factor and internal reflected component with large external obstructions* [12].

BRE information paper IP 15/88 [13] gives additional information on the calculation of average daylight factor under rooflights.

13.3 Room depth

This clause recommends a procedure for calculating the maximum depth of a side-lit room in the case described in **5.7**b).

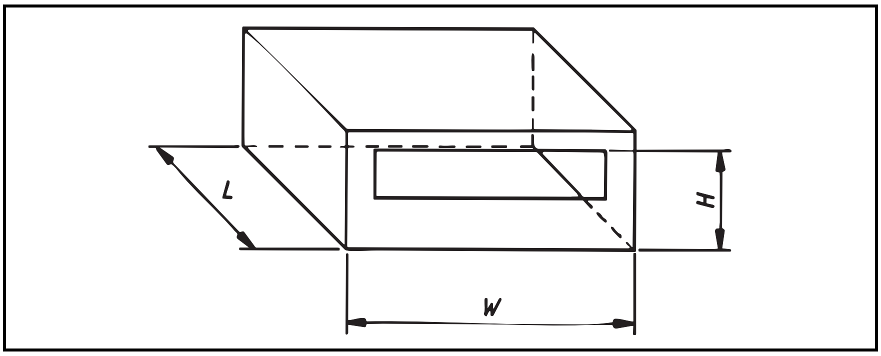
In a room with windows in one wall only, the following inequality should be satisfied:

$$\frac{L}{W} + \frac{L}{H} \leqslant \frac{2}{1 - R_b}$$

where

- L is the depth of the room from window to back wall, in metres (m), as shown in Figure 7;
- W is the width of the room, measured parallel to the window, in metres (m) (see Figure 7);
- H is the height of the window head above floor level, in metres (m) (see Figure 7);
- R_b is the area-weighted average reflectance of the interior surfaces (walls, floor and ceiling) in the half of the room remote from the window.

Figure 7 **Limiting depth of a side-lit room**



14 Calculation of daylight illuminance

This clause recommends a procedure for calculating daylight illuminance in relation to the criteria discussed in **6.2**.

In principle, the daylight illuminance at any point can be found if the sky luminance distribution and the geometry and reflecting characteristics of obstructing surfaces are known. Computer programmes are now available which can carry out this type of calculation. In practice, however, it is usually adequate to use a simple equation to obtain internal illuminance, as follows:

$$E_{in} = \frac{E_h f_o D}{100} \tag{3}$$

where

E_{in} is the internal illuminance, in lux (lx);

E_h is the external unobstructed horizontal illuminance, in lux (lx);

f_o is a window orientation factor. This allows for the effects of window orientation on non-overcast days;

D is the overcast sky daylight factor at a given point, expressed as a percentage.

(Values of E_h and f_o are given in **A.3**.)

As daylight illuminances are always changing, it is rarely appropriate to state a single-figure illuminance value for a daylit interior. In practice, it is usually best to quote the percentage of a year that a given internal illuminance is exceeded. The fraction of the time that E_h exceeds a given illuminance during a working day is given in Figure A.4 and Figure A.5 for London and Edinburgh. Further data are given in CIBSE Guide J [14].

In a few cases, month/hour average illuminances may also be needed. Equation 3 can again be used, this time with the average external illuminances shown in Figure A.6. However, high precision is not possible, because the orientation factor f_o does not account for the variation in orientation effects with time of day.

The daylight factor at a point may be determined by the use of manual calculation methods, the use of software or physical models.

15 Examples of the calculation of window transmittance

15.1 Average daylight factor

In equation 1 (see **13.1**) the value of transmittance, T, is the net transmittance of the glazing. Thus for a vertical window in clear float glass in an industrial location, the value of T is calculated from the equation:

$$T = g \times m$$

where

g is the glass transmission factor (taken from Table A.2);

m is the maintenance factor (calculated in accordance with **A.1.3**).

EXAMPLE:

If the glass transmission factor is 0.8 (as given in Table A.2 for a 6 mm clear glass window) and the maintenance factor for a commercial building with vertical glazing in an urban area is 0.9 (as calculated in accordance with **A.1.3**) then:

$$T = 0.8 \times 0.9 = 0.72$$

15.2 Overall aperture and net glazed area

If daylight factors are calculated from the overall aperture area in the wall or roof, instead of the net glazed area, a further correction factor should be used. It is given by the fraction:

$$\frac{\text{actual glass area}}{\text{overall area of aperture}}$$

If there are any other obstructions, such as curtains or structural supports, the overall transmittance should be reduced in proportion to the area of opening that they obscure.

Annex A (informative) Data for daylight and sunlight calculations

A.1 Values of reflectance and transmittance

A.1.1 Reflectances

The reflectance of a building material in use is affected by weathering, dirt and moisture. The overall reflectance of a surface is also affected by its shape: a deeply corrugated surface reflects less light than a smooth surface of the same material. Glossy surfaces have a slightly higher reflectance than matt materials of the same body colour, but the distribution of reflected light and the appearance of the surface is more significant than the change in total reflectance. Approximate reflectance values are given in Table A.1.

Table A.1 **Approximate values of the reflectance of light**

Material	**Reflectance**
Ground	
Snow (new)	0.8
Sand	0.3
Paving	0.2
Earth (dry)	0.2
Earth (moist)	0.1
Grass	0.1
Green vegetation	0.1
Other external materials	
Brickwork (white glazed)	0.7
Portland stone	0.6
Medium limestone	0.4
Concrete	0.4
Brickwork (London stock)	0.3
Brickwork (red)	0.2
Granite	0.2
Window glass	0.1
Tree foliage	0.1
Materials used internally	
White paper	0.8
Stainless steel	0.4
Cement screed	0.4
Carpet (cream)	0.4
Wood (light veneers)	0.4
Wood (medium colours)	0.2
Wood (dark oak)	0.1
Quarry tiles	0.1
Window glass	0.1
Carpet (deep colours)	0.1

Table A.1 **Approximate values of the reflectance of light** (*continued*)

Material	**Reflectance**
Paint colours (with BS 4800 colour code) [A)]	
White 00E55	0.85
Pale cream 10C31	0.81
Light grey 00A01	0.68
Strong yellow 10E53	0.64
Mid-grey 00A05	0.45
Strong green 14E53	0.22
Strong red 04E53	0.18
Strong blue 18E53	0.15
Dark grey 10A11	0.14
Dark brown 08C89	0.10
Dark red-purple 02C39	0.10
Black 00E53	0.05

A) References given are values for gloss paint. BS 4800 lists approximate Munsell references for paint colours for building purposes, and gives a useful method for deriving reflectances from Munsell references.

A.1.2 Transmittances

With the proliferation of glazing materials, it is no longer possible to recommend particular correction factors for tinted, reflecting or diffusing glazing. Table A.2 gives approximate values, but these should be taken only for guidance. Information about specific materials should be obtained from the manufacturer. Where a manufacturer can only supply the direct transmittance values, the diffuse transmittance values can be estimated by multiplying these by 0.91.

Table A.2 **Mean light transmittance of glazing materials**

Material	**Diffuse light transmittance**
Clear 6 mm glass	0.80
Body-tinted 6 mm glass	
bronze	0.40
grey	0.39
green	0.66
Strongly-reflecting 6 mm glass	0.18
Sealed unit (2 × 6 mm clear glass)	0.65
Sealed unit (6 mm clear glass + 6 mm low-emissivity neutral)	0.63
Sealed unit (6 mm reflecting + 6 mm clear)	0.26
Sealed unit (6 mm strongly-reflecting + 6 mm clear)	0.15
Wired cast glass, 6 mm	0.74

A.1.3 Maintenance factors

The maintenance factor allows for the reduction of daylight transmittance due to dirt.

To determine the maintenance factor for a particular situation it is necessary to first find the value for the percentage loss of light in the particular building type from Table A.3, and then multiply it by the special factors given in Table A.4 and Table A.5 if necessary, and subtract the result from 100%.

Table A.3 **Percentage losses of light in particular types of buildings**

Building type	**Percentage loss of daylight compared with clean glazing**	
	Rural/suburban	**Urban**
Residential: private and communal. Rooms with few occupants, good maintenance	4	8
Commercial, educational. Rooms used by groups of people, office equipment	4	8 to12
Polluted atmosphere. Gymnasia, swimming pools	12 to 24	12 to 24

Table A.4 **Exposure multiplying factors**

Exposure	**Exposure multiplier**		
	Vertical glazing	**Inclined glazing**	**Horizontal glazing**
Normal exposure for location	×1	×2	×3
Exposed to heavy rain	×0.5	×1.5	×3
Exposed to snow	×1	×3	×4

Table A.5 **Special exposure multiplying factors**

Condition	**Multiplying factor**
Vertical glazing sheltered from rain	×3
Weathered or corroded glazing	×3 (no correction for rain exposure)
Leaded glazing	×3

For example, considering vertical leaded glazing in a rural house. The loss of light will be 4% × 1 × 3 = 12%. The maintenance factor will be 100% – 12% = 88% = 0.88.

A.1.4 Correction for frames and glazing bars

If windows have frames and/or glazing bars then it is necessary to allow for the light obstructed by these. Correction factors for frames and glazing bars are given in Table A.6.

Table A.6 **Correction factors for frames and glazing bars**

Type of frame	Correction factor
Metal patent glazing	0.9
Metal frame, large pane	0.8
Wood frame, large pane	0.7
Wood frame, "Georgian" pane	0.6

A.2 Availability of sunlight

Figure A.1, Figure A.2 and Figure A.3 show, respectively, sunpath diagrams for London, and for Edinburgh, and a sunlight probability diagram.

Figure A.1 **Sunpath diagram for London (latitude 51° N)**

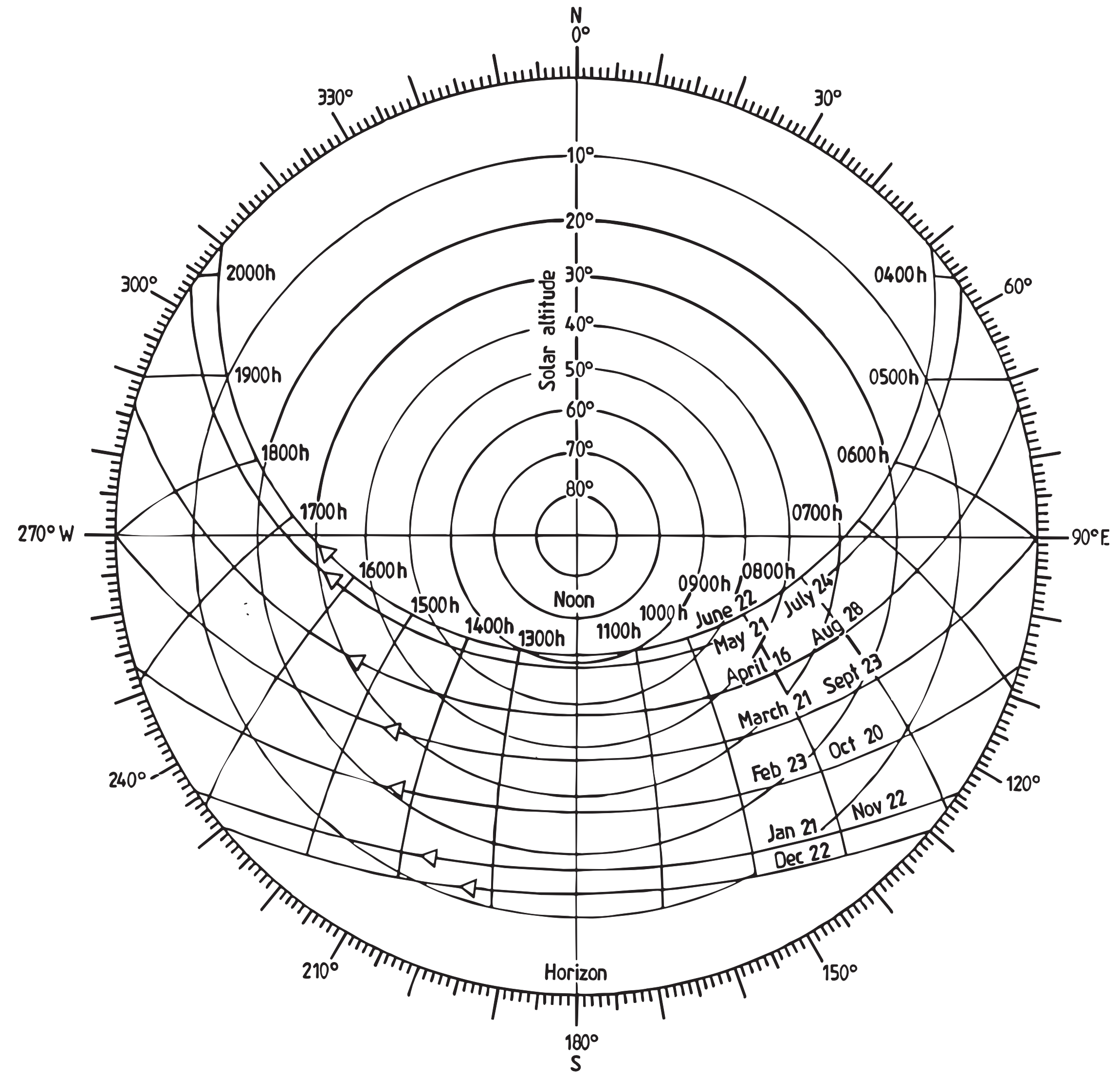


Figure A.2 **Sunpath diagram for Edinburgh (latitude 56° N)**

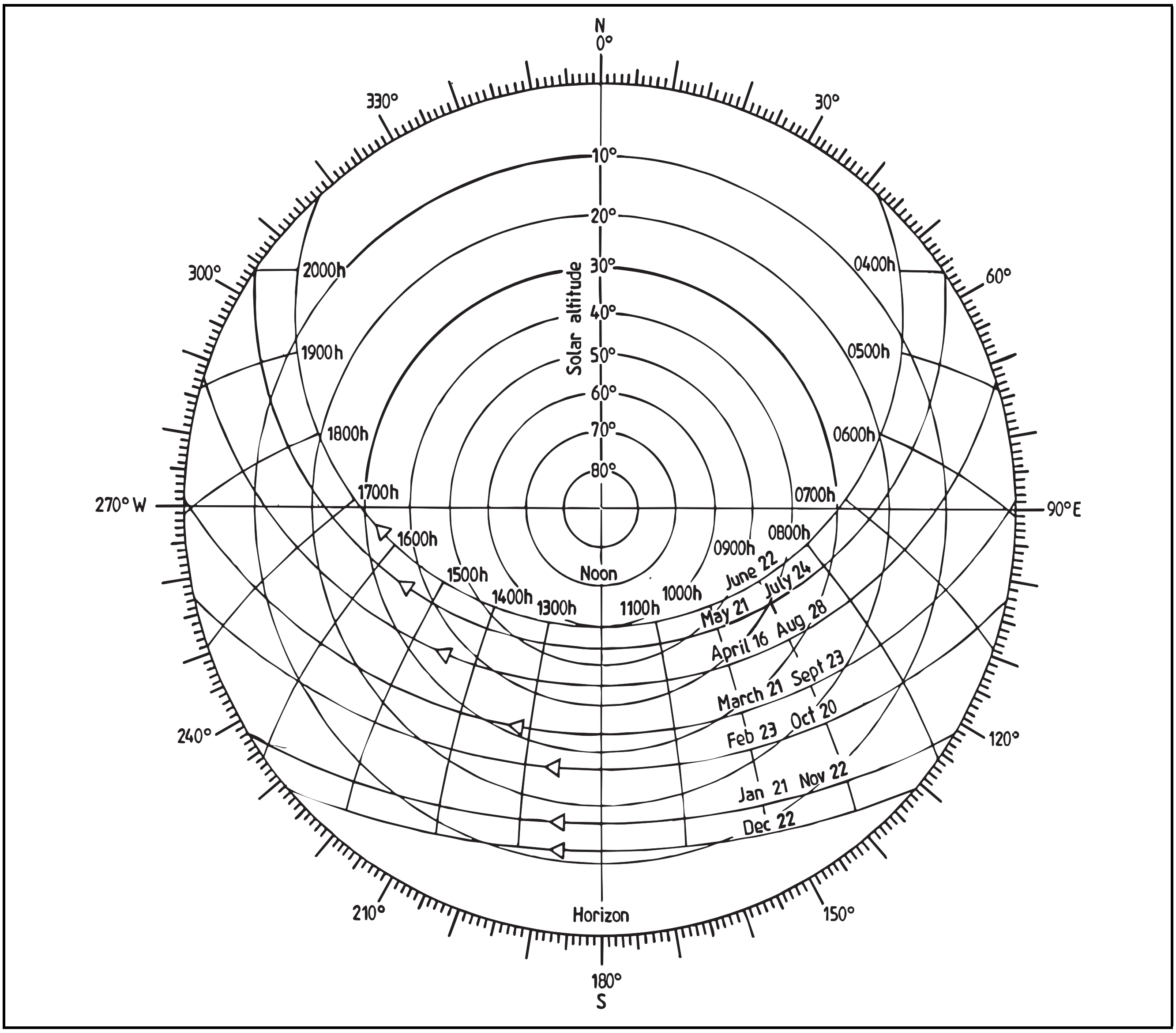
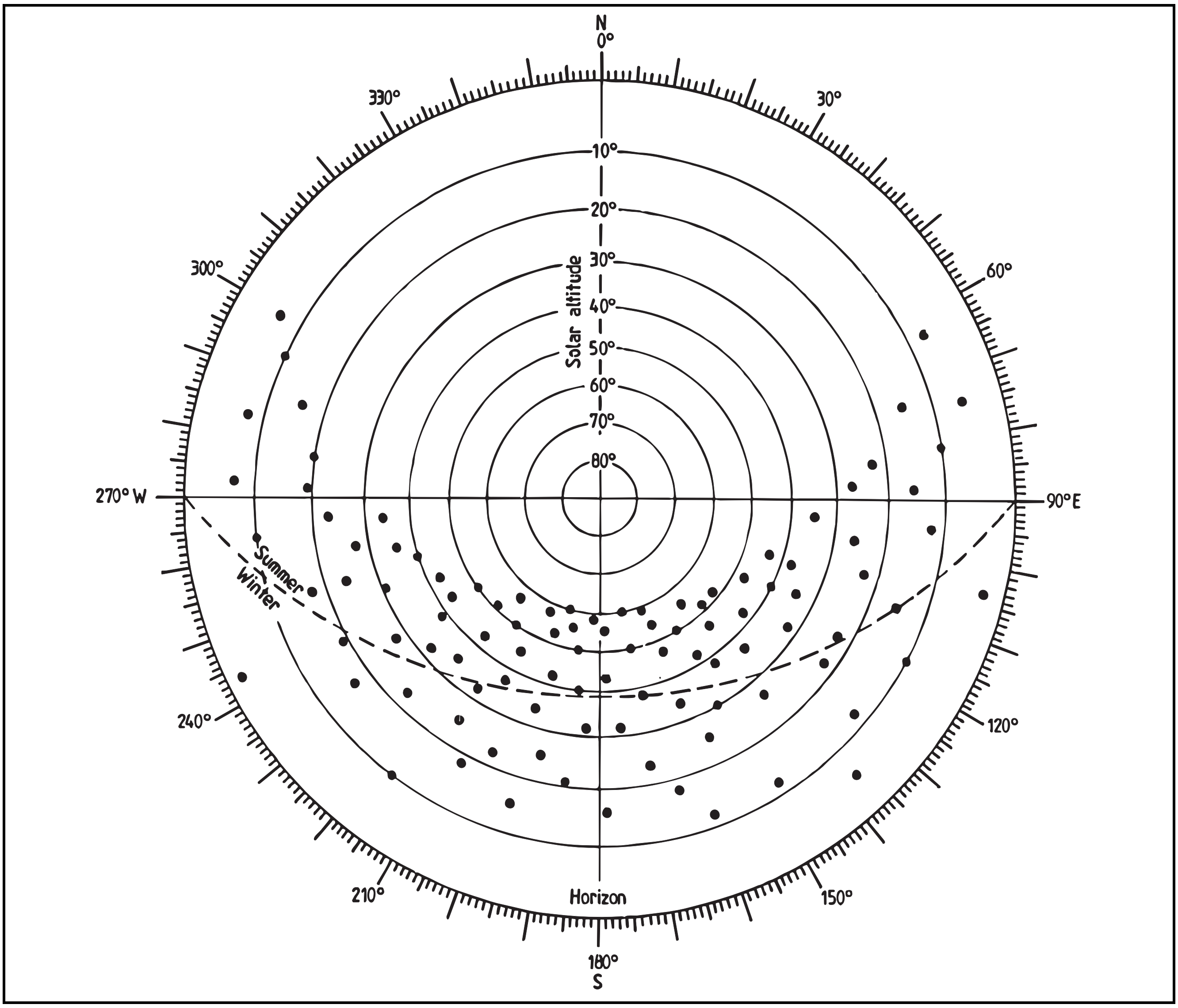


Figure A.3 **Sunlight probability diagram**



A.3 Availability of skylight

Table A.7 gives diffuse orientation factors. Figure A.4 and Figure A.5 illustrate diffuse illuminances for London and Edinburgh. Figure A.6 gives mean horizontal diffuse illuminances at London.

Table A.7 **Diffuse orientation factors for an 09.00 to 17.00 working day** (factor f_o in equation 3 in Clause **14**)

Orientation	**Orientation factor**
North	0.97
East	1.15
South	1.55
West	1.21

Figure A.4 **Diffuse illuminance (E_h) availability for London**
(see Clause **14** for factor E_h in equation 3)

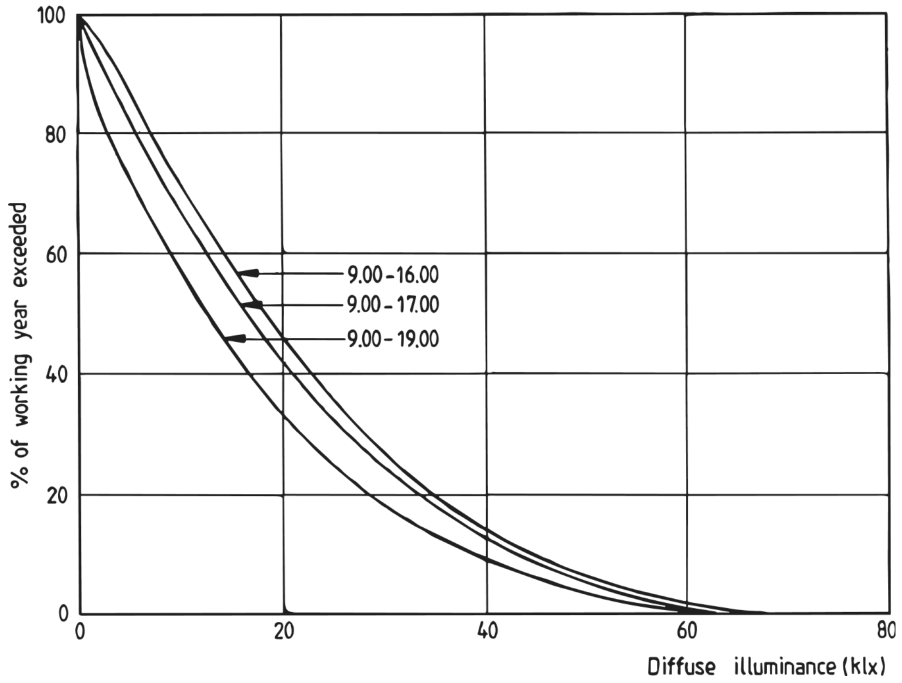


Figure A.5 **Diffuse illuminance (E_h) availability for Edinburgh**
(see Clause **14** for factor E_h in equation 3)

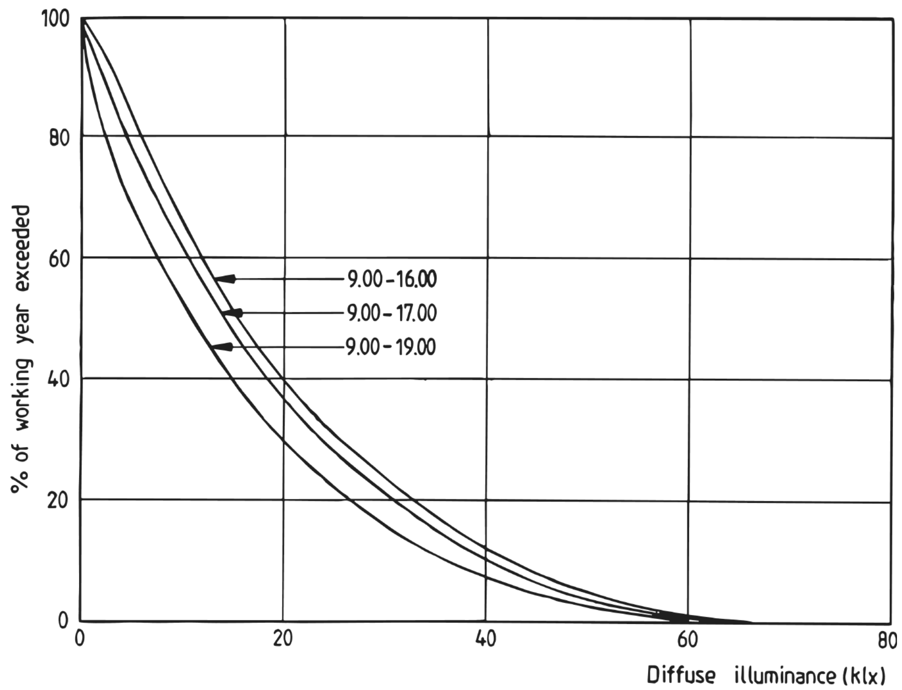
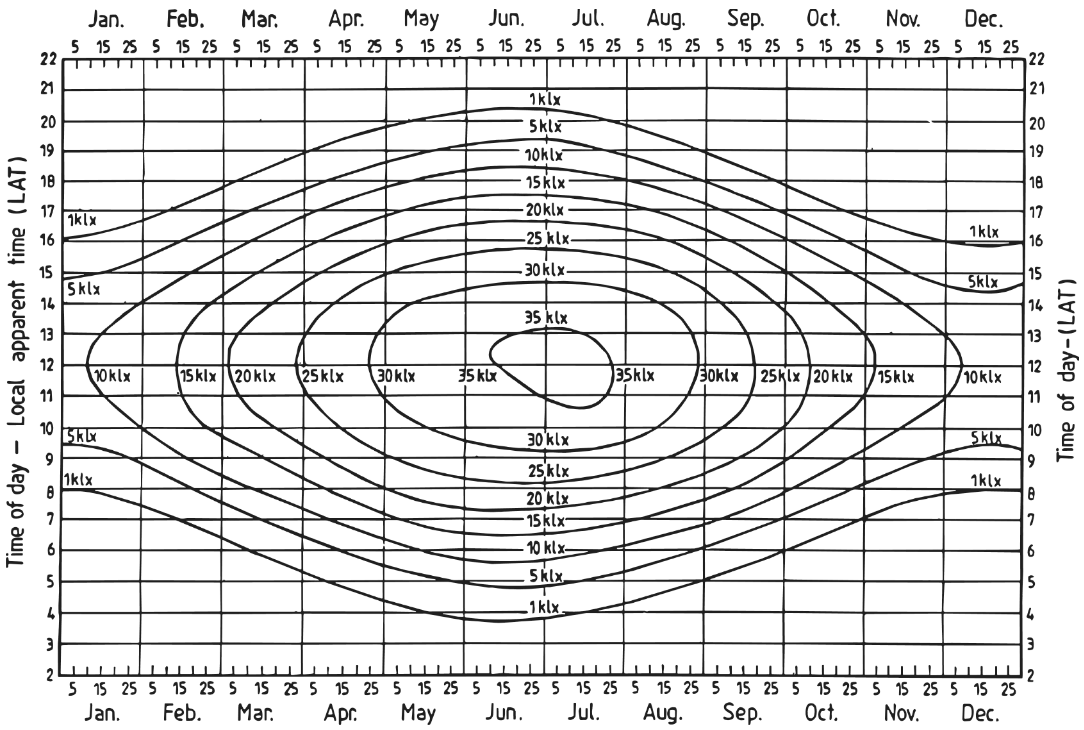


Figure A.6 **Mean horizontal diffuse illuminances at London (Kew)**



Annex B (informative) Climate-based daylight modelling

B.1 General

Climate-based daylight modelling is the prediction of various radiant or luminous quantities (e.g. irradiance, illuminance, radiance and luminance) using sun and sky conditions that are derived from standard meteorological datasets. Climate-based modelling delivers predictions of absolute quantities (e.g. illuminance) that are dependent both on the locale (i.e. geographically-specific climate data are used) and the building orientation (i.e. the illumination effect of the sun and non-overcast sky conditions are included) in addition to the building's composition and configuration. This is in contrast to the daylight factor (see **2.11.3**) which is a relative value of illumination under standard overcast sky conditions. Thus it depends only on the composition (i.e. reflective and transmissive properties) and configuration (i.e. the three-dimensional form) of a building and its surroundings (see Clause **13**). The daylight factor is insensitive to the building's location and compass orientation. Climate-based daylight modelling, therefore, can be said to offer a more realistic measure of likely daylight illumination conditions than that given by a daylight factor study alone.

A climate-based analysis is intended to represent the prevailing conditions over a period of time, rather than be simply a "snapshot" of specific conditions at a particular instant. Because of the seasonal variation of daylight, the evaluation period is normally taken to be an entire year, although sometimes seasonal or monthly analyses may be required. Additionally, analyses may be restricted to those hours in the day that cover the time that a particular building is in use.

B.2 Use of climate data

The pattern of hourly values in a standard climate dataset is unique. Because of the random nature of weather, it will never be repeated in precisely the same way. Therefore any report of climate-based analysis should incorporate a clear statement about the climate database that has been used, and the extent to which the dataset used is typical of long-term average data. The principal sources of basic data for climate-based daylight modelling are the standard climate files which were originally created for use by dynamic thermal modelling programs [15]. These datasets contain averaged hourly values for a full year, i.e. 8 760 values for each parameter. For lighting simulation, the required parameters may be either of the following pairs:

- global horizontal irradiance and either diffuse horizontal irradiance or direct normal irradiance;
- global horizontal illuminance and either diffuse horizontal illuminance or direct normal illuminance.

The user might need to convert irradiances to illuminances using a luminous efficacy model [16]. If measurements of diffuse horizontal irradiance or illuminance are supplied then the user will need to determine the values for direct normal from the specific latitude, longitude and time using the standard equations for sun position (see **12.1**).

Standard climate data for a large number of locations across the world are available for download from several websites. For example, the Chartered Institution of Building Services Engineers (CIBSE) have compiled climate datasets for 14 locations across the UK.[1] Additional daylight specific datasets can be obtained from the International Daylight Measurement Programme website [2] and the European Database of Daylight and Solar Radiation.[3]

B.3 Applications

There are a number of possible ways to use climate-based daylight modelling [17], [18], [19], [20] and [21]. The two principal analysis methods are cumulative and time-series.

A cumulative analysis is the prediction of some cumulative measure of daylight (e.g. total annual illuminance) based on the aggregated luminance (or radiance) effect of (hourly) sky and the sun conditions derived from the climate dataset. It is usually determined over a period of a full year. This could equally be carried out on a seasonal or a monthly basis, i.e. predicting a cumulative measure for each season or month in turn. The cumulative method can be used for predicting the micro-climate and solar access in urban environments, the long-term exposure of art works to daylight, and the seasonal dynamics of daylight and/or shading at the early design stage of a building.

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1) http://www.cibse.org
2) http://idmp.entpe.fr
3) http://www.satel-light.com/core.htm

Time-series analysis involves predicting instantaneous measures (e.g. illuminance) based on all the hourly (or sub-hourly) values in the annual climate dataset. These predictions could be used to evaluate, for example, the overall daylighting potential of a building and the occurrence of excessive illuminances or luminances. These parameters can then be used as inputs to behavioural models for light switching and/or blinds usage, and in assessing the performance of daylight responsive lighting controls.

B.4 Methodology

In principle, climate-based daylight modelling could be carried out using either computer simulation techniques, or scale models in a sky simulator (i.e. physical modelling). To date, however, climate-based daylight modelling has been demonstrated using only computer simulation techniques. A time-series analysis might proceed as follows.

- Obtain basic climate data from a weather tape, usually global and diffuse irradiance.
- Convert the irradiance data to external horizontal illuminances using a luminous efficacy model.
- Generate a sky luminance distribution using a sky model.
- Use the sky luminance distribution to calculate internal illuminances.
- Calculate the illuminance contribution of sunlight.
- Determine the artificial lighting requirements using a lighting control algorithm.
- Calculate the resultant heat gains produced by the lighting (if the lighting simulation is to be part of an integrated building energy analysis program).

This approach would require a full lighting simulation for each of the four thousand or so unique sky and sun configurations that can be derived from all the daylight hours in the annual climate dataset. This can result in lengthy simulation times. A computationally more efficient approach is to use daylight coefficients [22]. The daylight coefficient is defined as the internal illuminance at a point that results from a patch of unit-luminance sky, divided by the solid angle of that patch of sky. In the simulation, it can be computed and cached for each of a defined grid of patches of sky. The internal illuminance for a given sky luminance distribution can then be obtained by multiplying the daylight coefficient for each patch of sky by its luminance and angular size, and then summing all these values. The full simulation of internal reflection is carried out once for each sky patch, rather than for every different sky in the climate dataset [17], [18], [23] and [24]. Prediction of sunlight illuminance may be carried out with a modified approach based on the daylight coefficients. Where analysis has been based on daylight coefficients, the sky grid used should be stated. Sometimes, to improve accuracy, a higher resolution sky grid is used for light coming directly from the sky or sun. If such an approach has been adopted, it should be clearly reported.

To predict cumulative measures of, for example, illuminance, several methods may be used. These include:

a) arithmetic aggregation of the time-series values derived from a daylight coefficient approach; and

b) synthesizing sky and sun descriptions that contain the aggregated luminance (or radiance) of many "instantaneous" sky and sun configurations.

An attraction of the aggregated luminance approach is that, once the cumulative sky and sun conditions have been calculated, the simulations can be carried out using standard daylighting software, thus avoiding the complexities of implementing the daylight coefficient approach. However, using an aggregated luminance approach will tend to "mask" extreme daylight conditions, resulting in predicted illuminances that are indicative of mean conditions. If such an averaging approach has been adopted, it should be clearly explained, along with an assessment of the likely effects on the resulting predictions.

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