BS ISO/CIE 8995-1:2025

BSI Standards Publication

Light and lighting — Lighting of work places

Part 1: Indoor

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National foreword

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Part 1: Indoor

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 274, *Light and lighting*, in cooperation with the International Commission on Illumination (CIE).

This first edition of ISO/CIE 8995-1 cancels and replaces ISO 8995-1:2002, which has been technically revised

The main changes are as follows:

— prior document reference numbers (CIE S 008:2002, ISO 8995-1:2002) replaced with a combined reference number, ISO/CIE 8995-1;

— scope revised;

— Annex A, Annex B, Annex C and Annex D added;

— editorially updated.

A list of all parts in the ISO/CIE 8995 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Good lighting will create a visual environment that enables people to see, to move about safely and to perform visual tasks efficiently, accurately, and safely without causing undue visual fatigue and discomfort. The illumination can be provided by daylight, electric light sources, or a combination of both.

Good lighting requires equal attention to the quantity and quality of the lighting. While the provision of sufficient illuminance on the task is necessary, in many instances the visibility depends on the way in which the light is delivered, the colour characteristics of the light source and surfaces together with the level of glare from the system. In this document, opportunity was taken to specify for various work places and task types, not just the illuminance, but also the limiting of discomfort glare and minimum colour rendering index of the source. Parameters to create comfortable visual conditions are proposed in the body of this document. The recommended values are considered to represent a reasonable balance, having regard to the requirements for safe, healthy, and efficient work performance. The values can be achieved with practical energy efficient solutions.

There are also visual ergonomic parameters such as perceptual ability and the characteristics and attributes of the task, which determine the quality of the operator's visual skills, and hence performance levels. In some cases, enhancement of these influencing factors can improve performance without the need to raise illuminance. This can be achieved, for example by improving the contrast of the task attributes, enlarging the task by the use of up to date visual aids (e.g. glasses) and by the provision of special lighting systems with local directional lighting capability.

Adequate and appropriate lighting enables people to perform visual tasks efficiently and accurately including tasks performed over a prolonged time period or of a repetitive nature. The degree of visibility and comfort required in a wide range of work places is governed by the type and duration of the activity. The lighting also affects circadian rhythms and mood as well as improving performance and well-being.

The final designed, installed and operated lighting system should provide efficient and effective good quality lighting for the user needs tailored to their visual capacity, e.g. visual capacity of elderly users in work places.

It is important that all clauses of this document are followed although the target values for lighting criteria and specific requirements, depending of each type of task/activity, are tabulated in the schedule of lighting requirements (see Clause 7).

This document reflects the generally recognized best practice at the time of publication.

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Light and lighting — Lighting of work places —

Part 1:
Indoor

1 Scope

This document specifies lighting requirements for humans in indoor work places, which meet the needs for visual comfort, performance and safety of people having normal, or corrected to normal visual capacity and response to light.

This document specifies requirements for lighting solutions for typical indoor work places and their associated areas in terms of quantity and quality of illumination. The illumination can be provided by daylight, electric light sources, or a combination of both.

This document gives recommendations for good lighting to fulfil the needs of integrative lighting.

This document neither provides specific solutions nor recommendations for atmosphere or aesthetics created by lighting. It does not restrict the designers' freedom from exploring new techniques nor restrict the use of innovative equipment.

This document is not applicable for emergency lighting. For emergency lighting, see ISO 30061.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3864-1, *Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings*

ISO 9680, *Dentistry — Operating lights*

ISO/CIE TS 22012, *Light and lighting — Maintenance factor determination — Way of working*

CIE S 017, *ILV: International Lighting Vocabulary*

CIE S 026, *CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light*

CIE 58, *Lighting for sports halls*

CIE 62, *Lighting for swimming pools*

IEC 60601-2-41, *Medical electrical equipment - Part 2-41: Particular requirements for the basic safety and essential performance of surgical luminaires and luminaires for diagnosis*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

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— IEC Electropedia: available at https://www.electropedia.org/

CIE maintains a terminology database for use in standardization at the following address:

— e-ILV: available at https://cie.co.at/e-ilv

3.1
activity area
partial area in the work place in which more than one visual task is carried out

Note 1 to entry: Visual tasks can be different in type and/or position.

Note 2 to entry: A room can contain one or more activity areas.

Note 3 to entry: The spatial orientation needs to be specified by the designer.

Note 4 to entry: An activity area is not to be considered as aggregation of a number of distinct task areas across a larger area.

3.2
immediate surrounding area
zone of at least 0,5 m width surrounding the task area within the field of vision

3.3
background area
horizontal area at floor level adjacent to the *immediate surrounding area* (3.2) within the limits of space

3.4
work place
designated area in which work activities are carried out

4 Symbols and abbreviations

$\bar{E}_{\mathrm{m,wall}}$	maintained average illuminance on walls[1)]
$\bar{E}_{\mathrm{m,ceiling}}$	maintained average illuminance on ceiling[1)]
U_{o}	illuminance uniformity
$\bar{E}_{\mathrm{m}}$	maintained average illuminance[1)]
α	shielding angle
C-plane angle	elevation angle
γ	vertical photometric angle
DGP	Daylight Glare Probability
L	luminance
R_{UG}	CIE Unified Glare Rating (UGR)
R_{UGL}	R_{UG} limit value
$\bar{E}_{\mathrm{c}}$	average cylindrical illuminance[2)]
$\bar{E}_{\mathrm{m,c}}$	maintained average cylindrical illuminance[1)]

1) According to CIE S 017, $\bar{E}_{\mathrm{m}}$ is the value below which the average illuminance on a specified area shall not fall.

2) Approximated by the average of the four main directions

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T_{cp}	correlated colour temperature
R_a	general colour rendering index
R_i	special colour rendering index
TLM	temporal light modulation
$P_{st,LM}$	IEC short-term light modulation/ temporal light modulation indicator
SVM	Stroboscopic Visibility Measure
DSE	display screen equipment
f_m	maintenance factor
$\bar{E}_i$	initial illuminance
$\bar{L}_{m,wall}$	maintained average luminance of the walls
$\bar{L}_{m,ceiling}$	maintained average luminance of the ceiling
ρ_{wall}	luminous reflectance of the wall
$\rho_{ceiling}$	luminous reflectance of the ceiling

5 Lighting design criteria

5.1 General

For good lighting practice, it is essential that, along with the required illuminances, additional qualitative and quantitative needs are satisfied.

Lighting requirements are determined by the satisfaction of three basic human needs:

— visual performance, in which the workers are able to perform their visual tasks, even under difficult circumstances and during longer periods;

— visual comfort, in which the workers experience physical and mental comfort; evidence shows that this state contributes to improved work motivation, work quality, and reduced absenteeism;

— safety.

The principal parameters that describe the luminous environment with respect to daylighting and electric lighting are:

— luminance distribution;

— illuminance and illuminance uniformity;

— glare;

— directionality of light;

— lighting in the interior space;

— colour rendering and colour appearance of the light;

— temporal light modulation.

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These criteria are further detailed in Clause 5 and Clause 6, requirements and recommendations are given in Clause 7.

NOTE In addition to the lighting, there are other visual ergonomic parameters which influence visual performance, such as:

— the intrinsic task properties (size, shape, position, colour and reflectance properties of detail and background);

— normal visual capacity and response to light of the person (visual acuity, depth perception, colour perception) (see CIE 227);

— for the visually impaired, for example those who are sensitive to glare or have visual field defects, adaptation and decreased contrast and colour vision where dimming, protection against glare and colour rendering are especially important factors to consider, see CIE 227.

5.2 Luminance distribution

5.2.1 General

The luminance distribution is a crucial factor to determine a proper luminous environment. It affects task visibility and shall be properly controlled.

An appropriate adaptation luminance is needed to optimize:

— visual acuity (sharpness of vision);

— contrast sensitivity (discrimination of small relative luminance differences);

— efficiency of the ocular functions (such as accommodation, convergence, pupillary contraction, eye movements, etc.).

The luminance distribution in the visual field also affects visual comfort. The following shall be avoided for the reasons given:

— excessive luminances and luminance contrasts which can cause discomfort glare and reduced task visibility;

— excessive luminance variation which can cause fatigue because of constant re-adaptation of the eyes.

Attention shall also be given to adaptation in moving from zone to zone within a building.

To create a well-balanced luminance distribution, the luminance values of all surfaces shall be taken into consideration. They are determined by the reflectance and the illuminance on the surfaces. To avoid gloom and to raise adaptation levels and comfort of people in buildings, it is highly desirable to have bright interior surfaces. Room brightness is considered by specifying average illuminance values on walls and ceiling (see Clause 7) and by recommending typical reflectance values (5.2.3).

The lighting designer shall consider and select the appropriate illuminance/luminance values for the interior surfaces based on the guidance in 5.2.2, 5.2.3 and 5.2.4.

NOTE To simplify calculation procedures, this document does not consider the spectral reflectance values but only the average reflectances of the surfaces themselves and considers these perfectly Lambertian surfaces, except for the cases that deal with the surfaces with non-isotropic diffuse reflections.

5.2.2 Average luminance of surfaces

When isotropic diffuse reflection can be assumed, the luminance of a certain point on the surface is proportional to the product of the illuminance on that point multiplied by the reflectance of the surface. That means that the reflectance of and the illuminance on the surfaces is a simplified substitution of luminance requirement.

NOTE 1 When the surfaces do not have isotropic diffuse reflection, the same luminous environment is not necessarily assured from the different points of view even if it meets the illuminance requirements.

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When calculating the luminance distribution by using lighting simulation programs, the lighting designer shall consider and select the appropriate minimum requirements of the average luminance of the interior surfaces based as below.

a) When isotropic diffuse reflection can be assumed.

— The lighting designer can set view positions for calculating luminance distribution anywhere.

b) When isotropic diffuse reflection cannot be assumed.

— The lighting designer shall choose several representative view positions in the space depending on the tasks and/or activities being performed and calculate the average luminance values of walls and ceiling from these positions. It is desirable to meet the minimum requirements for the average luminance of walls and ceiling from all these positions.

The average luminance of walls and ceiling from all these positions depending on the tasks and/or activities being performed in the space shall meet the minimum requirements. The minimum requirements for the average luminance can be calculated from the recommended minimum illuminance (Clause 7) multiplied by the recommended value of the reflectance in the wavelength between 380 nm to 780 nm for the calculation purpose (see 5.2.3).

The average maintained luminance on the walls is calculated using Formula (1):

$$\bar{L}_{\mathrm{m,wall}} = \frac{\bar{E}_{\mathrm{m,wall}} \cdot \rho_{\mathrm{wall}}}{\pi} \tag{1}$$

where

$\bar{E}_{\mathrm{m,wall}}$ is the average maintained illuminance on the walls given in Table 9 to Table 62;

ρ_{wall} is the reflectance of the walls (see 5.2.3 for recommended reflectances in the wavelength between 380 nm to 780 nm for the calculation purpose).

The average maintained luminance of the ceilings is calculated using Formula (2):

$$\bar{L}_{\mathrm{m,ceiling}} = \frac{\bar{E}_{\mathrm{m,ceiling}} \cdot \rho_{\mathrm{ceiling}}}{\pi} \tag{2}$$

where

$\bar{E}_{\mathrm{m,ceiling}}$ is the average maintained illuminance on the ceilings given in Table 9 to Table 62;

ρ_{ceiling} is the reflectance of the ceilings (see 5.2.3 for recommended reflectances in the wavelength between 380 nm to 780 nm for the calculation purpose)

NOTE 2 The choice of view positions is at the discretion of the lighting designer, therefore, this method can be considered as an auxiliary one in the lighting design process.

5.2.3 Reflectance of surfaces

For choice of materials and coatings, recommended diffuse reflectances in the wavelength between 380 nm to 780 nm for the calculation purpose are:

— ceiling: 0,7 to 0,9;

— walls: 0,5 to 0,8;

— floor: 0,2 to 0,6.

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The diffuse reflectance in the wavelength between 380 nm to 780 nm of major objects (such as furniture and machinery) are normally in the range of 0,2 to 0,7.

NOTE Clear interior glass has a typical reflectance of 0,1.

5.2.4 Illuminance on surfaces

Illuminances on walls and ceiling together with surface reflectances (see 5.2.3) contribute to luminances and are indicators for perceived room brightness.

Clause 7 provides minimum requirements for the maintained illuminance on walls ($\bar{E}_{\mathrm{m,wall}}$) and ceiling ($\bar{E}_{\mathrm{m,ceiling}}$) depending on the tasks and/or activities being performed in the space.

NOTE Additional guidance can be found in Clause 6.

5.3 Illuminance

5.3.1 General

Areas to be lit are task areas and activity areas, the immediate surrounding area and background area, walls, ceiling, and objects in the space.

The illuminance and its distribution on the task area and on its immediate surrounding area have a great impact on how quickly, safely, and comfortably a person perceives and carries out the visual task.

All values of illuminances given in this document are maintained illuminances specified to fulfil visual comfort and performance needs of people having normal or corrected to normal visual capacity and response to light.

Designing for higher or lower illuminances in combination with controls allows the lighting installation to be tailored to the specific context (i.e., differences in activities or personal characteristics). This can be done using the context modifiers (see Table 1 and Table 2). Higher or lower illuminances shall be used when relevant, e.g., only parts of the day. For calculation and measurement of illuminance averages and uniformities, the grid specification in 5.5 shall be used.

5.3.2 Scale of illuminance

A factor of approximately 1,5 represents the smallest significant difference in subjective effect of illuminance. In normal lighting conditions, approximately 20 lx of horizontal illuminance is required to just discern features of the human face and is the lowest value taken for the scale of illuminances. The recommended steps of illuminance (in lx) are given considering a perceptual difference.

20 - 30 - 50 - 75 - 100 - 150 - 200 - 300 - 500 - 750 - 1 000 - 1 500 - 2 000 - 3 000 - 5 000 - 7 500 - 10 000

5.3.3 Illuminances on the task area or activity area

The maintained illuminance value shall at least meet the requirement as given in Clause 7 ($\bar{E}_{\mathrm{m,required}}$) and shall take into account the following factors:

— psycho-physiological aspects, such as visual comfort and well-being;

— requirements for visual tasks;

— visual ergonomics;

— visual capabilities of the workers;

— practical experience;

— contribution to functional safety;

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— economy.

The values given in Clause 7 are maintained illuminances evaluated over the task area or activity area on the reference surface which can be horizontal, vertical or inclined.

However, it is required to increase the maintained illuminance (by one or two steps in the scale of illuminance (see 5.3.2)), depending on the context modifiers given in Table 1 if the assumptions differ from the normal visual conditions. The context modifiers apply when the actual conditions differ from the assumptions that were made when defining the recommended values.

As an example, an increase of one step is recommended if one or two of the conditions listed in Table 1 apply and an increase of two steps is recommended if more than two of these conditions apply. For examples, see Annex C.

A modified value which considers common context modifiers is given in Clause 7 ($\bar{E}_{\mathrm{m,modified}}$). This modified value shall not be seen as an upper limit. It shall not be applied in the case where general lighting is used, in which an entire space is uniformly lit without giving special consideration to individual visual tasks.

Table 1 — Context modifiers for increase of required maintained illuminance

visual work is critical;
errors are costly to rectify;
accuracy, higher productivity or increased concentration is of great importance;
task details are of unusually small size or low contrast;
the task is undertaken for an unusually long time;
the task area or activity area has a low daylight provision;
the visual capacity of the worker is reduced, e.g., due to age.

NOTE 1 When only general lighting is applied in a space, additional care is needed to ensure the lighting installation can be still contextualized (see 6.2.4).

NOTE 2 Retinal illuminance declines with age due to reduced pupil size and increased spectral absorption of the crystalline lens. It is reasonable for lighting practitioners to increase the illuminance in task area and not in background area to compensate for the decrease in retinal illuminance in the elderly while avoiding intraocular light scattering. More information can be found in CIE 227:2017.

NOTE 3 Daylight provision is considered in 6.5.

NOTE 4 For visually impaired people special requirements can be necessary with regard to illuminances and contrasts.

The values of required $\bar{E}_{\mathrm{m}}$ given in 7.3 are minimum values for normal working conditions.

Decreasing illuminance by one step may be considered when conditions from Table 2 apply.

Table 2 — Context modifiers for decrease of required maintained illuminance

task details are of an unusually large size or high contrast;
the task is undertaken for an unusually short time.

Dimming control may be used to achieve lower levels than $\bar{E}_{\mathrm{m,required}}$ in Clause 7. Using dimming will accommodate for possible future change in working conditions.

The size and position of the task area or the activity area shall be stated and documented by the lighting designers in the designing documents, see Figure 1.

For work stations where the size and/or location of the task area or activity area(s) is/are unknown either:

— the whole area is treated as the task area;

— the whole area is uniformly ($U_{\mathrm{o}} \geq 0{,}40$) lit to an illuminance level specified by the designer.

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If the task area becomes known, the lighting scheme shall be re-designed to provide the required or modified illuminances.

If the type of the task is not known, then the designer has to make assumptions about the likely tasks and state task requirements.

If the whole area is lit to a given illuminance value, then it is recommended that the lighting is controlled in appropriate zones.

When multiple tasks take place in the area, requirements for all of these tasks shall be met. Usually this is done by designing according to the task with the most onerous requirements.

This applies also to an activity area.

5.3.4 Illuminance on the immediate surrounding area

Large spatial variations in illuminance around the task area or activity area can lead to visual stress and discomfort.

The illuminance on the immediate surrounding area shall be related to the illuminance on the task area or activity area and shall provide a well-balanced luminance distribution in the visual field. The immediate surrounding area is a band with a width of at least 0,5 m around the task area within the visual field.

The illuminance on the immediate surrounding area may be lower than the illuminance on the task area but shall be not less than the values given in Table 3.

In addition to the illuminance on the task and activity area, the lighting shall provide adequate adaptation luminance in accordance with 5.2.

The size and position of the immediate surrounding area shall be stated and documented by the lighting designers in the designing documents.

Table 3 — Relationship of illuminances on immediate surrounding to the illuminance on the task area or activity area

Illuminance on the task area or activity area $\bar{E}_m$ lx	Illuminance on immediate surrounding areas lx
≥ 750	500
500	300
300	200
200	150
≤ 150	equal to task area

5.3.5 Illuminance on the background area

In indoor work places, particularly those devoid of daylight, a large area outside the immediate surrounding area needs to be illuminated. The background area shall be illuminated with a maintained illuminance of at least 1/3 of the value of the immediate surrounding area. The background area shall be at least 3 m wide.

The size and position of the background area shall be stated and documented by the lighting designers in the designing documents.

Figure 1 illustrates the minimum dimension of the background area in relation to task and immediate surrounding area.

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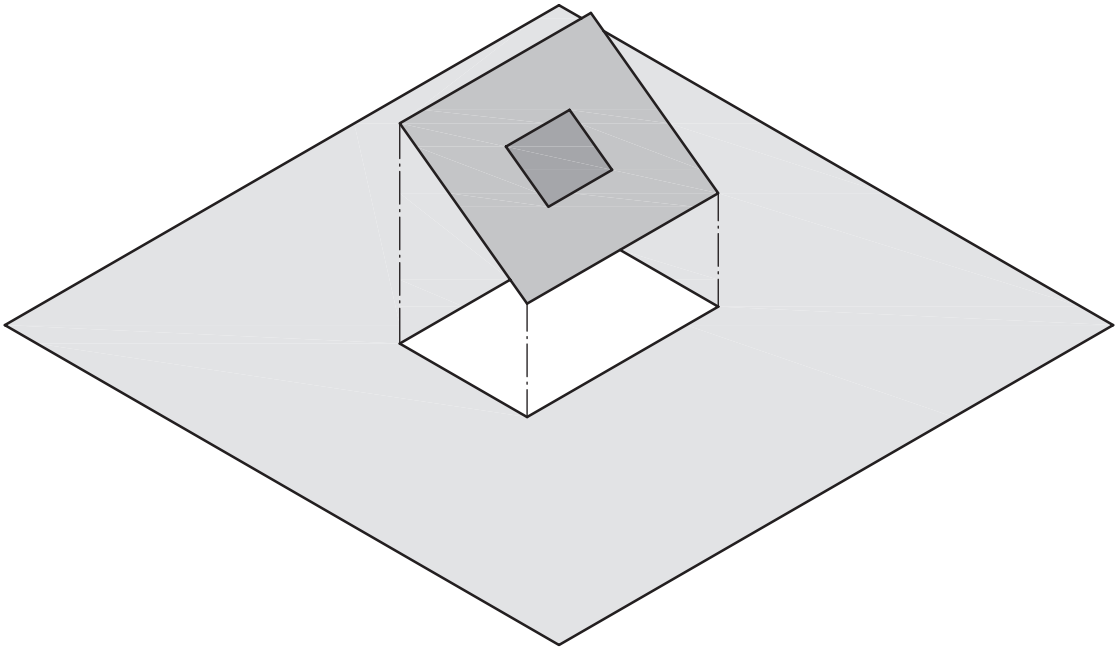

Key

task area or activity area (not true to scale) in a specified size and position (see 5.3.3)

immediate surrounding area (band with a width of at least 0,5 m around the task area or activity area within the visual field)

background area (band with a width of at least 3 m adjacent to the immediate surrounding area or up to the limits of the space for smaller rooms) horizontal on floor level

Figure 1 — Minimum dimensions of immediate surrounding area and background area in relation to task area and activity area (figure is not true to scale)

5.3.6 Illuminance uniformity

In the task area or activity area, the illuminance uniformity (U_0) shall be not less than the minimum uniformity values given in the tables in 7.3.

Uniformity in the immediate surrounding area shall be $U_0 \geq 0{,}40$.

On the background area, the walls and the ceiling the uniformity shall be $U_0 \geq 0{,}10$.

These uniformities shall only be applied to the area illuminated either only by electric light sources or by the combination of daylight and electric light sources.

Illuminance uniformities when daylight is available can be assured by adaptive lighting. Additional benefits of daylight can compensate for the lack of uniformity. More information can be found in 6.5.

5.4 ipRGC-influenced responses to light – Melanopic Equivalent Daylight Illuminance

Light influences human health and well-being through its effects on the circadian system (which regulates, for instance, sleep-wake behaviour) as well as by influencing perception and neuroendocrine, neurobehavioral and cognitive functions. These effects can be strongly mediated by the intrinsically photosensitive retinal ganglion cells (ipRGCs) and therefore the CIE has defined these as ipRGC-influenced responses to light (IIL responses) [CIE S 026]. Appropriate stimulation of the ipRGCs is one of the aims of high-quality integrative lighting. B.5.2 highlights several areas for which the evidence related to the effects of integrative lighting is well established.

When setting targets for IIL effects (see ISO/CIE TR 21783 for more information and Annex B for practical recommendations), all light and lighting quantities related to IIL effects shall be calculated in accordance

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with CIE S 026 and employ the CIE standard illuminant D_{65} (daylight illuminant of ~6 500 K) as a reference to compare to. In the context of this document the following quantities shall be used.

— The stimulation of the ipRGCs shall be quantified using the melanopic Equivalent Daylight Illuminance (melanopic EDI or mel EDI, see CIE S 026).

— The melanopic efficacy of the luminous radiation from a light source or lighting installation, shall be quantified using the melanopic Daylight Efficacy Ratio (melanopic DER or mel DER, see CIE S 026).

For a comprehensive evaluation of the effects of light on the circadian system, details shall be provided on, for instance, the light exposure's timing, duration, and observing field (for a typical user).

NOTE 1 Although some writers use the abbreviations M-EDI or M-DER to refer to melanopic EDI or melanopic DER, this is inadvisable in view of potential confusion with the M-cone related quantities of CIE S 026.

In order to calculate the melanopic EDI resulting from a light source, the photopic illuminance as produced by the light source on the eye of the occupant (see next paragraph) shall be multiplied with the melanopic DER of the light source, see C.1 for an example.

Alternatively, the melanopic EDI is to be obtained as an output of a calculation in which the luminous flux of the light source/luminaire is corrected to reflect the melanopic DER of the light source/luminaire.

The melanopic EDI can also be calculated according to CIE S 026 when starting from a direct measurement of the spectral irradiance as produced by the light source/luminaire on the eye.

NOTE 2 The surface reflectances can influence the conditions that users experience and the resulting illuminances, including melanopic EDI. The actual melanopic EDI can be calculated from measured spectral irradiances at the eye location of the occupant.

The melanopic EDI at the eye location of the occupant shall be determined from the calculated or measured illuminance (or spectral irradiance) on the eye. The illuminance (or spectral irradiance) on the eye shall be determined as follows, by calculations during design or by measurements after commissioning (see Annex D):

— Where the occupant position is known: vertical illuminance at eye height shall be determined at each occupant position with the direction of the detector based on the dominant view direction/direction of gaze. Eye height differs per application, and shall be defined assuming the eye height of a typical occupant in the target area (e.g. 1,2 m for sitting occupants or 1,6 m for standing occupants). Each point shall meet the minimum specified target value or should meet an average cylindrical illuminance in combination with a uniformity target ($\bar{E}_{c,min}/\bar{E}_c$) defined over all work locations.

— In cases where the occupant position is unknown or variable: cylindrical illuminance at eye height shall be determined in the full space, applying the illuminance grid as defined in 5.5. Eye height differs per application, and shall be defined assuming the eye height of a typical occupant in the target area (e.g. 1,2 m for sitting occupants or 1,6 m for standing occupants). Both shall be determined if the eye height is unknown or variable. Following the principles outlined in 5.3.5, a band near the wall may be excluded unless occupants are expected to be in this zone for a significant amount of time (i.e. > 2 h a day). The target can be set either as a minimum value to reach for all calculation points, or as an average cylindrical illuminance in combination with a uniformity target ($\bar{E}_{c,min}/\bar{E}_c$).

— Targets for ipRGC influenced responses can be achieved using both daylight and electric lighting, keeping in mind the variable nature of daylight. In addition, in case daylight dependent control of the lighting installation is employed, the control should take into account both cylindrical and task illuminance targets.

5.5 Illuminance grid

Grid systems shall be created to indicate the points at which the illuminance and melanopic EDI values are calculated and verified for the requirements regarding the task area(s) and activity area(s), immediate surrounding area(s), background area(s), ceiling, walls and cylindrical illuminance.

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Grid cells approximating a square are preferred. If the cell is rectangular, then the ratio of the short dimension to the long dimension of a grid cell shall be kept between 0,5 and 1. The maximum grid size shall be:

$$p = 0{,}2 \times 5^{\log_{10}(d)} \tag{3}$$

where

d is the longer dimension of the calculation area (m), however if the ratio of the longer to the shorter side is 2 or more then d becomes the shorter dimension of the area;

p is the maximum grid cell size (m).

$p \leq 10$ m

The number of points in the relevant dimension is given by the nearest whole number of d/p.

The resulting spacing between the grid points is used to calculate the nearest whole number of grid points in the other dimension. This will give a ratio of length to width of a grid cell close to 1.

NOTE 1 Formula (3) (coming from CIE x005) has been derived under the assumption that p is proportional to log(d), where:

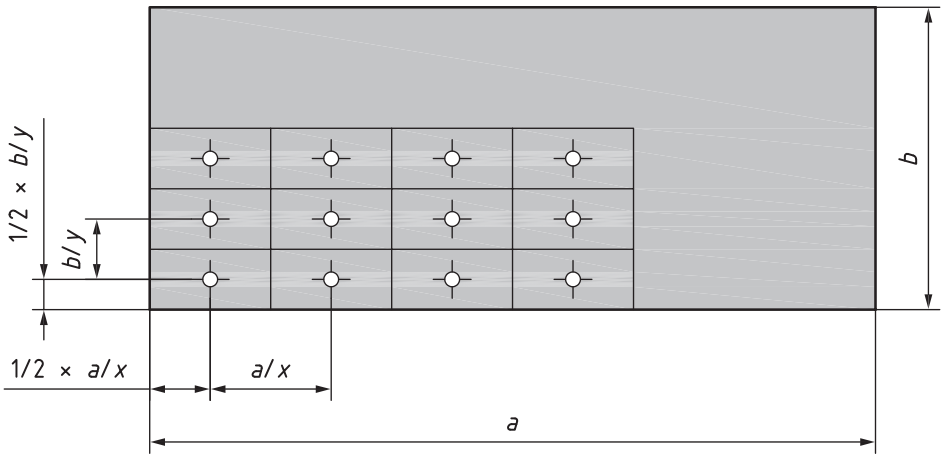
p = 0,2 m for d = 1 m;

p = 1 m for d = 10 m;

p = 5 m for d = 100 m.

NOTE 2 For daylight, the factor 0,2 in Formula (3) is replaced by 0,5.

The illuminance values are calculated and measured at the centre point of grid rectangles. A typical grid is shown in Figure 2.



Key

a dimension of the longer side of the calculation area/verification area (typically d in Formula 3)

b dimension of the shorter side of the calculation area/verification area

x number of points along the longer side

y number of points along the shorter side

Figure 2 — Typical grid

To avoid high impact on uniformity from calculation points near the wall, a band next to the wall can be excluded from the calculation except when the task area is in or extends into this border area. The width of

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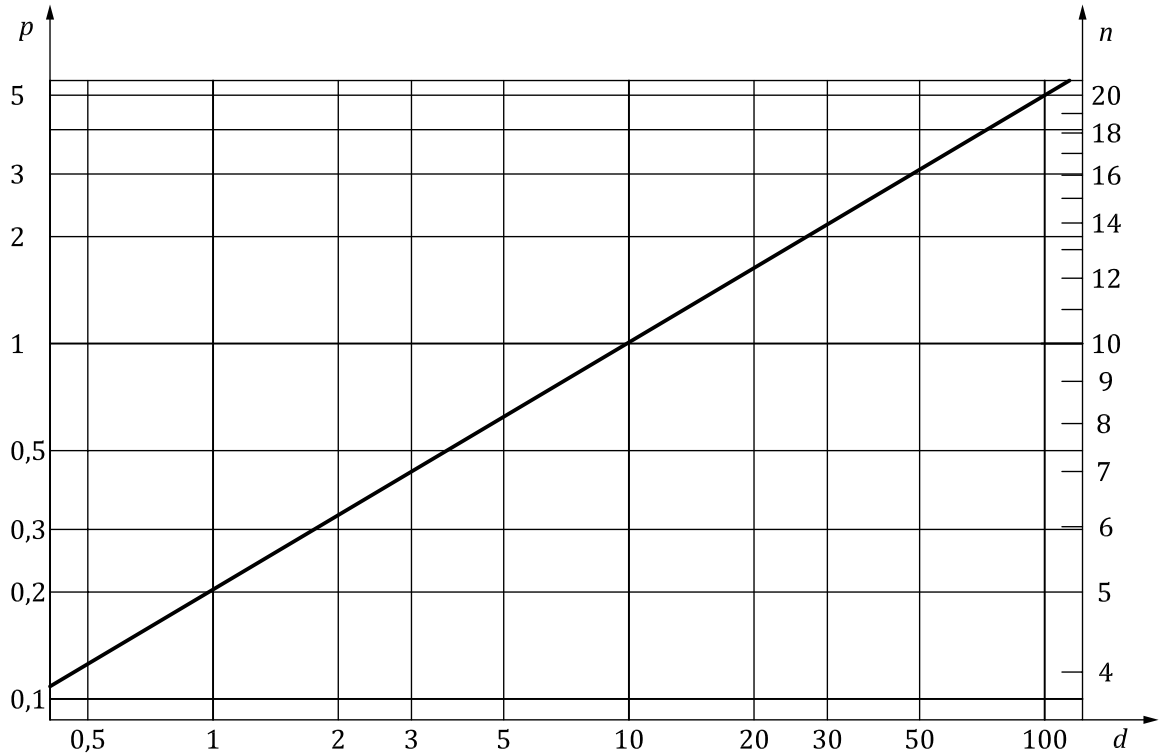
this band is specified as 15 % of the smallest dimension of the area under consideration or 0,5 m, whichever of the two is smaller.

The grid cell size as function of calculation/measurement area dimension is shown in Figure 3.



Key

d longer dimension of the calculation area (m), however if the ratio of the longer to the shorter side is 2 or more then *d* becomes the shorter dimension of the area

p maximum grid cell size (m)

n number of points in relevant dimension

Figure 3 — Grid cell size as function of calculation/measurement area dimension

Calculation points/grids for walls from the floor upwards to the ceiling, and ceiling should follow the same procedure as described above.

The grid point spacing should be chosen such that it does not coincide with the luminaire spacing. Several grid points shall be provided at even intervals between the fixtures, at least including the centre point in the luminaire spacing.

5.6 Glare

5.6.1 General

Glare is a condition of vision in which there is discomfort or a reduction in the ability to see details of objects, caused by an unsuitable distribution or range of luminance, or by extreme luminance contrasts.

It can be caused by bright areas within the visual field, such as lit surfaces, bright parts of the luminaires, daylight openings (e.g. windows and/or roof lights)(see 6.5). Glare shall be limited to avoid errors, fatigue and accidents. Glare can be experienced either as discomfort glare or as disability glare. However, disability glare is less of a critical issue indoor than it is outdoor.

Glare caused by reflections in specular surfaces is usually known as veiling reflections or reflected glare.

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This document employs the following two methods to limit and to predict glare:

a) By preventing direct view of high-luminance elements through shielding the view of the light source, or by limiting the luminance of luminous surfaces.

b) For electric light, by predicting possible discomfort using the CIE Unified Glare Rating.

NOTE Special care is needed to avoid glare when the direction of view is significantly above the horizontal viewing direction, e.g. cases where a regular aspect of the work is looking high up/into the luminaires such as the storage racks, etc.

5.6.2 Limiting luminaire luminance

Bright sources of light can cause glare and can impair the visibility of objects. View of bright sources of light by the occupants in a room shall be avoided, for example by suitable shielding of light sources or suitable shading from bright light through daylight openings.

For luminaires where the light source is directly visible, the minimum shielding angles (see Figure 4) in the visual field given in Table 4 shall be applied for the specified light source luminance.

For luminaires where a direct view of the light source is obscured via optics, the maximum average luminaire luminance for the values of vertical photometric angle given in Table 5 shall be applied (see Figure 4).

The values given in Table 4 and Table 5 do not apply to luminaires with an upward component only, which are mounted above normal eye level, or to luminaires with a downward component only, which are mounted below normal eye level.

Table 4 — Minimum shielding angles at specified light source luminance

Light source luminance kcd m^{-2}	Minimum shielding angle α
20 to < 50	15°
50 to < 500	20°
≥ 500	30°

Table 5 — Maximum average luminance of a luminous optical element at specified vertical photometric angles

Vertical photometric angle γ	Average luminance limits of a luminous optical element kcd m^{-2}
75° ≤ γ < 90°	≤ 20
70° ≤ γ < 75°	≤ 50
60° ≤ γ < 70°	≤ 500

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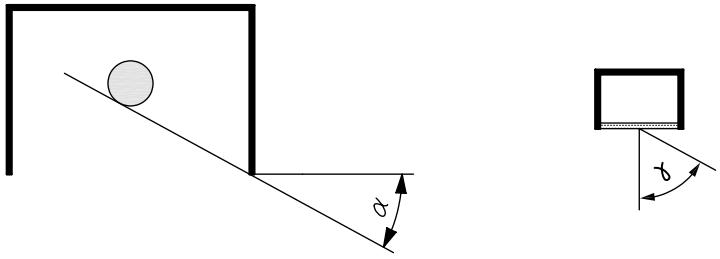

Key

α shielding angle

γ vertical photometric angle

NOTE Left figure shows a cross section of a conventional luminaire with a separate light source. Right picture shows a cross section of a luminous part of the optical element, e.g. a part of a LED luminaire.

Figure 4 — Shielding angle α and vertical photometric angle γ

5.6.3 Discomfort glare

5.6.3.1 Discomfort glare from daylight

In areas with daylight access, glare from daylight openings can occur, either by direct sunlight entering and/or when the luminance in the field of view seen through daylight openings is often very high compared with the occupants' adaptation luminance level at a given time. Discomfort glare from daylight shall be avoided.

NOTE To assess the occurrence of discomfort glare from daylight openings, EN 14501 and EN 17037 provide recommended levels for glare protection by the daylight glare probability (DGP).

5.6.3.2 Discomfort glare from electric light – application of UGR tabular method

To select a luminaire suitable for the lighting installation of a given space the rating of discomfort glare caused directly from the luminaires shall be determined using the CIE Unified Glare Rating (UGR) tabular method.

NOTE 1 The UGR tabular method is detailed in CIE 117 and in CIE 190.

NOTE 2 The UGR methodology is intended to support the selection of luminaires which are appropriate for the given application using an average value. For point-based calculation refer to 5.6.3.3.

This R_{UG} (formerly: UGR) value determined using the UGR tabular method shall not exceed the R_{UG} limit value (R_{UGL}) given in Clause 7.

All assumptions made concerning luminaire, room dimensions, room surface reflectance's and spacing to height ratio in the determination of the R_{UG} shall be stated in the scheme documentation.

The tabular method is based on applying Formula (4) to a set of standard conditions (observer position, room dimensions and reflection factors).

$$R_{UG} = 8 \log_{10}\left(\frac{0{,}25}{L_b} \sum \frac{L^2\ \omega}{p^2}\right) \tag{4}$$

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where

R_{UG} is the value of the Unified Glare Rating (UGR);

L_b is the background luminance in cd m^{-2}, calculated as $E_{ind} \cdot \pi^{-1}$, in which E_{ind} is the vertical indirect illuminance at the observer's eye;

L is the luminance in cd m^{-2} of the luminous parts of each luminaire in the direction of the observer's eye;

ω is the solid angle in steradian of the luminous parts of each luminaire at the observer's eye;

p is the Guth position index for each individual luminaire which relates to its displacement from the line of sight.

NOTE 3 For more information on discomfort caused by glare from luminaires with a non-uniform source luminance, refer to CIE 232.

NOTE 4 The limiting values R_{UGL} form a series whose steps indicate noticeable changes in glare. For indoor work places, this series of R_{UGL} is: 16, 19, 22, 25, 28 where a low value means “little likelihood of discomfort glare” and a high value means “significant possibility of discomfort glare”.

NOTE 5 For a tabular UGR value, in some cases, a variation of R_{UG} is given based on different luminaire spacing. This variation of UGR within the room can be determined using the comprehensive tables for different observer positions, as detailed in CIE 117. A high variation indicates that even small changes in the observer position can result in larger changes in glare. The compliance of the indoor lighting does not take into account these variations in the CIE Unified Glare Rating (UGR) tabular method.

The boundary conditions for the determination of the R_{UG} value by the tabular method include having one type of luminaire only in a rectangular space, a regular luminaire grid, same installation height and same orientation (C-plane and γ angles). This limits the application of the methodology to some extent but does not exclude its use. To maximize the applicability of the tabular method, A.2 covers recommended practices when the above boundary conditions are not met.

The UGR method is not suitable for evaluating disability glare.

The UGR tabular method shall also not be applied to following luminaires:

— wall washers;

— totally indirect;

— spots with adjustable directionality;

— very small or very large luminous surfaces (see A.2.1).

5.6.3.3 Determination by UGR formula

If it is deemed impossible to use the tabular method (taking into account the recommended practices as provided in Annex A), or it is required to investigate the glare at specific points in detail, R_{UG} values can be determined by using the UGR Formula (4) from 5.6.3.2 at specific points where the observer’s viewing direction is known.

National practice and regulations use the UGR formula in different ways but in general it should be applied with caution as direct use of UGR calculations at a point within a room is outside of the scope and applicability of the method used to produce the limiting criteria.

These values can serve to compare different lighting solutions in a relative manner.

Account should be taken of possible variations in observer position and viewing direction, up to the expected displacement/rotation of the head of a person.

All assumptions made concerning the calculation shall be stated in the lighting scheme documentation.

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5.6.4 Veiling reflections and reflected glare

High luminance reflections in the visual task area can alter task visibility, usually detrimentally. Veiling reflections and reflected glare shall be avoided or minimised by the following measures:

— arrangement of work stations with respect to luminaires and daylight openings;

— surface finish (matt surfaces);

— luminance restriction of luminaires and daylight openings;

— high reflectance and well-lit ceiling and bright walls.

5.7 Visual appearance of objects and people within the interior space

5.7.1 General

The visual appearance of objects and people in interiors is affected by the following lighting conditions: shadows, cylindrical illuminance, directional lighting, and modelling. These lighting conditions shall be adequately controlled.

5.7.2 Shadows

Direct light from light sources produces shadows on objects or faces and creates shadows on a background surface when intercepted by an opaque object. Shadows can be described using two main characteristics: the gradient of the edge of the shadow (i.e. are the shadows very harsh or very soft) and the contrast between the shadow and its immediate surroundings (i.e. are the shadows very dark or less dark). These characteristics depend on the lighting installation and the overall indoor conditions. Soft and light shadows shall be aimed for in work areas to create a pleasant and natural environment. Annex B.3.3 provides additional information on shadow characteristics.

5.7.3 Cylindrical illuminance requirement in the activity space

Good visual communication and recognition of objects within a space require that the volume of space in which people work or move shall be illuminated. This is satisfied by providing adequate average cylindrical illuminance, $\bar{E}_c$ in the space. The required maintained average cylindrical illuminances ($\bar{E}_{m,c}$) to be determined on a horizontal plane in the room and space are given in Clause 7. The uniformity of the mean cylindrical illuminance shall be $U_o \geq 0{,}10$. The cylindrical illuminance shall be calculated for the space including the task area or activity area and its immediate surrounding area. The height of the horizontal calculation plane shall be defined assuming the eye height of a typical occupant in the target area (e.g. 1,2 m for seated people and 1,6 m for standing people above the floor).

NOTE As an approximation for the cylindrical illuminance, the average value of four vertical illuminances measured on either side of two orthogonal planes can be used.

5.7.4 Directional lighting of visual tasks areas

With directional lighting, the light is incident predominantly from a particular direction onto the work plane or onto an object. Lighting from a specific direction can reveal the three-dimensional texture of a surface or the details within a visual task area. Lighting direction shall be adequate to increase the visibility of visual targets in the task area and to make the task easier to perform.

5.7.5 Modelling

The general appearance of an interior is enhanced when its structural features, the people and objects within it are lit so that form and texture are revealed clearly and pleasingly. Modelling describes the perceived general appearance of objects and people. Both shadow characteristics (see 5.7.2) are decisive for the appearance of people and objects. The presence of directional lighting also influences the shadow

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characteristics and different modelling effects can arise according to the features and position of the directional light source. Lighting direction shall be appropriate also for good modelling.

5.8 Colour aspects

5.8.1 General

The colour quality attributes of a near-white electric light source or daylight entering a space are characterized by:

— the colour appearance of the light;

— its colour rendition properties.

These two attributes shall be considered separately in 5.8.2 and 5.8.3, with the aim to cover white light used in spaces, where tasks and/or activities can be affected with reference to relevant requirements given in Clause 7.

NOTE The design documentation can specify where lighting solutions are given only for decorative ambience lighting and with no potential impact to the performance of workers.

5.8.2 Colour appearance of the light source

The colour appearance (white-tone) of a light source is related to the chromaticity of the light emitted. Light source colour appearance is characterized by the correlated colour temperature (CCT) T_{cp} and expressed in Kelvin (K), see Table 6.

NOTE 1 CIE 015 describes additional metrics that describe the colour appearance of light sources.

Table 6 — Light source colour appearance / correlated colour temperature categories

Colour appearance	Correlated colour temperature T_{cp}
warm	below 3 500 K
neutral	3 500 K to 5 000 K
cool	above 5 000 K

The choice of colour appearance of the light is a matter of psychology (including preference), aesthetical and architectural considerations. The choice can vary depending on illuminance level, colours of the room and furniture, surrounding climate and the application. Additionally, colour temperature variations can be applied to achieve integrative lighting goals. Careful consideration is necessary, especially in the case of night shift work.

NOTE 2 Sources can be either static in nature (i.e. featuring only one single correlated colour temperature T_{cp}) or feature some form of dynamic behaviour in which the colour temperature can be adjusted. The latter types of systems are often referred to as 'Tuneable white', 'Colour tuneable' or 'Incandescent-like dimmable'.

NOTE 3 The correlated colour temperature T_{cp} provides an indication for the "white-tone" of a light source, but appearance differences between sources of the same T_{cp} can still occur due to differences in the emission spectrum. The distance to the Planckian locus or n-step $u'v'$ circles (see CIE TN 001) can be used to study this effect.

Unless otherwise specified in Clause 7, CCT selection is based on the previously mentioned aspects.

5.8.3 Colour rendering

For task areas and activity areas, colours shall be rendered with sufficient fidelity to support visual performance, the feeling of comfort and well-being, and accurate rendering of colours in the environment, of objects and of human skin.

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To provide an objective indication of the colour rendering properties of a light source the general colour rendering index R_a (see CIE 13.3) is used. The maximum value of R_a is 100. The minimum R_a value for distinct types of task areas and activity areas within a space are given in Clause 7. Safety colours shall always be identifiable in accordance with ISO 3864-1.

For the evaluation of specific object colours or human skin tone, the appropriate special colour rendering index (R_i) should be considered.

Luminaires which emit coloured light (e.g. for a decorative purpose), are not considered 'near white' and cannot be assessed with the general colour rendering index R_a. However, these luminaires can influence the colour rendering on task areas or in activity areas. In such cases, additional care is needed to ensure that colour rendering requirements on the task areas and/or activity areas are met.

NOTE 1 The colour appearance and colour rendering properties of the observed lighting in a space are affected by the spectral reflectance properties of all surfaces.

NOTE 2 Because the verification for R_a (see 8.4) is just a check against manufacturer data, it is self-evident that criteria for colour rendering is meant for functional lighting only and it is not relevant for e.g. coloured light sources, when their operation are for decorative ambience purposes only.

5.9 Temporal light modulation (TLM)

Contemporary lighting systems vary widely in the degree to which their light output contains temporal variations (temporal light modulation, TLM). This is a mostly a function of the electronics used to control the light source or lighting system. Whereas legacy technologies were similar in their TLM characteristics regardless of the manufacturer (e.g., all magnetically ballasted fluorescent tube systems operated at twice the mains frequency), LED lighting systems can differ widely one from another. The scientific community and industry continue to investigate how best to characterize lighting system TLM. Fundamental characteristics of TLM waveforms are the dominant frequency, the modulation depth, the waveform shape (e.g., sine wave, rectangular wave, or complex forms), and (for rectangular waves and some complex waveforms) duty cycle. Several integrated metrics are in use in different jurisdictions. Among these are the IES Flicker Index (see ANSI/IES LM-83-23), $P_{st,LM}$ (see IEC/TR 61547-1), and the stroboscopic visibility measure (SVM) (see CIE TN 006; IEC/TR 63158).

TLM is known to affect human visual perception, neurobiology, and performance, sometimes in adverse ways (see IEEE 1789-2015). The visual perception effects are collectively known as temporal light artefacts, and include flicker, the stroboscopic effect, and the phantom array (see CIE TN 006). The adverse effects of TLM include headache and eyestrain.

To prevent these adverse effects, lighting systems should be selected such that values of the required metrics (e.g., $P_{st,LM}$, SVM, or IES Flicker Index) should be minimized, e.g., by maximizing the operating frequency, minimizing the modulation depth, using DC electrical supply, or a combination of these. Lighting systems should be designed such that these values remain minimized throughout the entire dimming range. Ongoing research seeks to establish limit values for these metrics for various applications.

5.10 Lighting of work stations with Display Screen Equipment (DSE)

5.10.1 General

The lighting for DSE work stations shall be appropriate for all tasks performed at the work station, e.g. reading from the screen, reading printed text, writing on paper, keyboard work, etc.

For these areas, the lighting criteria and system shall be chosen in accordance with type of task area or activity area, from the schedule in Clause 7.

Reflections in DSE and, in some circumstances, reflections from the keyboard can cause disability and discomfort glare. It is therefore necessary to select, locate and arrange the luminaires to avoid high brightness reflections.

The luminance of the background wall should be balanced to the brightness of the screen.

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The designer shall determine the mounting zones where reflections can be a problem and shall choose equipment and plan mounting positions which will cause no disturbing reflections.

5.10.2 Luminaire luminance limits with downward flux

Light can lower the contrast of the presentation on DSE by:

— diffused veiling reflection caused by the illuminance on the display surface;

— reflected luminances from luminaires and bright surfaces reflecting in the display.

ISO 9241-307 gives recommendations for the visual qualities of displays concerning unwanted reflections.

This subclause describes luminance limits for luminaires which can be reflected in DSE for normal viewing directions.

Table 7 gives the limits of the average luminaire luminance at elevation angles of 65° and above from the downward vertical, radially around the luminaires, for work stations where display screens which are vertical or inclined up to 15° tilt angle are used.

Table 7 — Limits for the average luminance of luminaires, which can be reflected in flat screens

Screen high state luminance	High luminance screen $L > 200$ cd m^{-2}	Medium luminance screen $L \leq 200$ cd m^{-2}
Case A (positive contrast and normal requirements concerning colour and details of the shown information, as used in office, education, etc.)	≤ 3 000 cd m^{-2}	≤ 1 500 cd m^{-2}
Case B (negative contrast and/or higher requirements concerning colour and details of the shown information, as used for CAD, colour inspection, etc.)	≤ 1 500 cd m^{-2}	≤ 1 000 cd m^{-2}
NOTE Screen high state luminance (see ISO 9241-302) describes the maximum luminance of the white part of the screen and this value is available from the manufacturer of the screen.		

If screen types are not known at the lighting design stage, the designer should inform the user about the luminance criteria chosen for the luminaires in the space.

If a high luminance screen is intended to be operated at luminances below 200 cd m^{-2}, the conditions specified for a medium luminance screen shall be considered.

Some tasks, activities or display screen technologies require different lighting treatment (e.g. lower luminance limits, special shading, individual dimming).

In areas of industrial activities and crafts, screens are sometimes protected by additional front glasses. The unwanted reflections on these protection glasses shall be reduced by suitable methods (such as anti-reflection treatment, tilting of the protection glass or by shutters).

6 Lighting design considerations

6.1 General

To apply the lighting design criteria from Clause 5, the following aspects should be taken into account for the lighting design:

— recommended illuminance requirements, see 6.2;

— operation of the lighting system, see 6.2.4;

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— energy efficiency requirements, see 6.4;

— variability of light, see 6.2.4.

Examples for the application of the processes described in 6.2 are given in Annex C.

Verification procedures can be found in Clause 8.

6.2 Illuminance requirements and recommendations

6.2.1 General

To allow for a larger variety in application requirements, Clause 7 provides maintained illuminances $\bar{E}_m$ in steps according to the scale of illuminances in 5.3.2 from required to modified values.

6.2.2 Lighting of the task area or activity area and its immediate surrounding area

The following steps shall be followed in selecting the appropriate lighting criteria for the task area or activity area and immediate surrounding area:

a) Define the task area and activity areas in the space.

b) Determine the appropriate type of task or activity based on the visual tasks executed in that area.

c) Select the "task or activity related requirements" from the tables in 7.3 ($\bar{E}_m$, U_o, R_a, R_{UGL}). For activity areas with multiple tasks the most onerous requirements shall be used for design (see 5.3.3).

d) Select the adequate maintained illuminance $\bar{E}_m$ in steps using the scale of illuminance in 5.3.2 starting from the required value for the actual working condition according to the specific context modifiers as specified in 5.3.3 (Table 1 and Table 2).

e) Select the appropriate illuminance requirements for the immediate surrounding area and background area based upon the $\bar{E}_m$ selection in step d) and Table 3 (see 5.3.4 and 5.3.5).

NOTE 1 The task area or activity area can be horizontal, vertical or inclined, and multiple tasks or activities can take place in the same area (consult 5.3.3 for guidance).

NOTE 2 To balance energy efficiency while ensuring satisfaction during different times of operation adaptive lighting can be used. When the task or activity is not being performed, or an activity of less visual difficulty is being performed, lower light levels can be employed using controlling or switching if appropriate. Further information is contained in CIE 222 and CIE 227.

6.2.3 Lighting of the space

To enhance the visual appearance and brightness impression of the room and space and good visual communication and recognition of objects, the following steps shall be followed:

a) Determine the relevant room surfaces around the workspace (the walls and ceiling). The surfaces to be illuminated are at least those that contribute to the perception of room brightness.

b) Select the requirements for "objects and people" and for "room brightness" from the tables in 7.3 ($\bar{E}_{m,c}$, $\bar{E}_{m,wall}$, $\bar{E}_{m,ceiling}$) based on all selected tasks and activities in 6.2.2, step a) and step b). If different requirements apply select the most onerous requirements to respect all specified tasks and activities within the space.

c) In areas with high distance to the ceiling, a lower ceiling illuminance can be accepted. E.g. in industrial premises or other areas with only direct lighting and lower reflectance than the recommended values in 5.2.3, or areas where illumination of the ceiling is not appropriate.

NOTE For example, in high industrial halls the upper part of the wall and the ceiling can be excluded.

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The R_{UGL} determined by the task or activity requirements needs to be fulfilled by luminaires in the field of view within the space except those luminaire types excluded in 5.6.3.2.

If in step d) of 6.2.2 higher values have been selected for $\bar{E}_m$ on the task area or activity area, the wall, ceiling and cylindrical illuminance values should also be increased by up to the same number of steps (see 5.3.2 for step sizes).

6.2.4 Variability and adjustability of light

Light reveals the world through vision; it also influences mood, alertness, and physiological states. The pattern of daily light and dark exposure regulates circadian rhythms (CIE S 026; ISO/CIE TR 21783), and variability of lighting or daylighting also contributes to visual interest and prevents the stress associated with static environmental conditions. Integrative lighting is designed to beneficially affect all of these processes in parallel. Light exposure parameters that influence these processes include the intensity, spectrum, duration, timing, and pattern of light exposure, with individuals' responses depending also on their chronotype, physical health, past light history, and state of health. Integrative lighting objectives can be met with daylighting and electric lighting solutions. The specific solutions will vary by application area and user groups, for example spaces occupied for extended periods or by people with limited mobility.

Integrative lighting ensures:

— the maximum use of available daylight;

— lights are off or dim in unoccupied space;

— suitable lighting for the requirements of each visual task;

— responsiveness to occupant needs and preferences;

— availability of energy-saving control strategies (e.g., load shedding, lumen maintenance).

A lighting installation's brightness and spectrum can be adjusted automatically or manually. The system should allow for sufficient granularity (i.e. sufficient sub-zones in a given zone) to allow for individual or group-based adjustments. Adjustments to a lighting installation can be applied to any part of the space – for example, to the task area, the walls, or the ceiling – to meet task and individual needs, including visual appearance and visual comfort (see Annex B).

Dimming controls allow to increase or decrease the lumen output from a luminaire and can have additional functionality to modify the variation in correlated colour temperature (CCT) or different lighting scenes or according to daylight provision. Controlling can have additional functionality to modify the operation of the luminaire(s) in an installation, for example variation in CCT or different lighting scenes or according to daylight provision. An additional benefit can be facilitating reconfiguration in the case of changes in the use of the space, without rewiring.

Lighting should be adjustable by the user to meet their needs, also known as personal control. Personal control is a lighting control strategy that provides building occupants with the ability to select and adjust workspace lighting to their preferred conditions. The individual user may be able to adjust the light level, the light source spectrum, or the light source direction. Some systems permit differential choices to be made for direct and indirect components from a direct-indirect luminaire. Changing the balance of ambient versus task lighting will also alter the directionality of light in the space. Personal lighting control can also include control over daylight using shading systems. Personal control has been shown to improve occupant satisfaction and motivation, and to have indirect effects on health, well-being, and organizational commitment; it also results in energy savings. The CIE has provided a decision scheme to determine the appropriate control solution for a given circumstance (CIE 222). Where automatic controls are used, local manual over-rides enable individuals to obtain their preferred conditions.

When varying lighting (e.g. using personal control) it is possible that lighting requirements (as stated in the tables in 7.3) are no longer met. However, the values listed in the tables in 7.3 shall remain achievable using only the electric lighting (assuming a worst-case scenario without daylight contribution). Designing a basic lighting installation only fulfilling the minimum criteria can limit the possible benefits of good lighting quality.

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In multi-user spaces, such as an open office, it is recommended to provide users with means to control the lighting installation. Providing individual control can be difficult because choices from one individual can adversely affect another; nonetheless, the system should provide sufficient granularity (e.g., using sub-zones within a given zone) to allow for individual or group-based adjustments while preventing high contrasts between the sub-zones. Depending on the furnishings and lay-out, it can be possible to arrange the lighting and controls such that each occupant has a controllable lighting fixture directly illuminating over their workspace so that they can change the lighting in their workspace without adversely affecting others nearby. Another possible control strategy is to use a system that will determine an average setting among groups of individuals.

Some systems permit occupants to control multiple aspects of the lighting installation. This can include (but is not limited to) intensity, light source colour appearance (CCT), and in the most complex systems, the spectral composition of the light output or its directionality.

The fit between control system and lighting system should take into account the need to avoid introducing unwanted temporal light modulation (see 5.9) and chromatic modulation to the light output. This can require pre-testing the chosen controls and luminaires to verify compatibility before a field installation.

Dynamic daylighting solutions allow occupants to control the sunlight that is coming in through the windows so the sun is not causing too much glare or solar heat gain. The system should be capable of adjustment based on sky conditions (e.g. shades automatically in place during times of direct sunlight coming in and shades automatically removed when there is non-glaring daylight coming in). Automatic control can help to reduce lighting energy use by ensuring the use of daylight when it is available; however, occupants should also have the ability to manually override the automation to set the shading to their preferred level if the automated setting is not to their liking. Dynamic glazing and shading systems can also improve thermal comfort and reduce energy use by excluding diffuse sky radiation in addition to direct solar radiation. See also 6.5 concerning the benefits of daylight.

6.3 Maintenance factor

The lighting scheme shall be designed taking into account an overall maintenance factor (f_m) calculated for the selected lighting equipment, environment and specified maintenance schedule for the task area or activity area in accordance with ISO/CIE TS 22012.

The illuminance requirements for each task as specified in Clause 7 are given as maintained illuminance ($\bar{E}_m$) values. The initial illuminance $\bar{E}_i$ can be calculated from $\bar{E}_m$ as follows:

$$\bar{E}_i = \frac{\bar{E}_m}{f_m} \tag{5}$$

where

$\bar{E}_m$ is the maintained illuminance;

$\bar{E}_i$ is the initial illuminance;

f_m is the maintenance factor.

The designer shall:

— state the f_m and list all assumptions made in the derivation of the value;

— specify lighting equipment suitable for the application environment;

— prepare a maintenance schedule to include e.g. frequency of light source replacement, luminaire and room cleaning intervals.

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The maintenance factor f_m has a large impact on energy efficiency. The assumptions made in the derivation of the f_m shall be both realistically achievable and optimized in a way that leads to a high value.

NOTE 1 Guidance on the determination of the maintenance factor and the energy saving Constant Light Output (CLO) controls functionality can be found in ISO/CIE TS 22012 and further information on the derivation of f_m for electric indoor lighting systems can be found in CIE 97.

NOTE 2 For daylight calculations, reduction of transmittance of daylight openings due to dirt deposition has an influence on daylight supply.

6.4 Energy performance

Lighting should be designed to meet the lighting requirements of a particular task, activity or space in an energy efficient manner. It is important not to compromise the visual aspects of a lighting installation simply to reduce energy consumption. The required minimum illuminance values as set in this document are minimum values and shall be maintained over time (see 6.3 and 7.3).

Energy savings can be made by harvesting daylight, responding to occupancy patterns, responding to request of grid, improving maintenance characteristics of the installation, and making full use of controls.

Daylight can supply all or part of the light needed for visual tasks or activities, and therefore offers potential energy savings. The amount of daylight indoors depends firstly on the availability of daylight outside (i.e. the prevailing weather at the site) and, thereafter, the environment surrounding the building, the components immediately around the daylight opening and the configuration of the interior spaces. With a near vertical daylight opening in the façade, the daylight availability decreases rapidly with the distance from the façade. Supplementary lighting (e.g. additional daylight openings or electric light sources) can be needed to ensure the required illuminance levels at the work station are achieved and to balance the luminance distribution within the room. Controls can be used to ensure appropriate integration between daylighting and electric lighting.

A procedure for the estimation of the energy requirements of a lighting installation is given in ISO/CIE 20086. It gives a methodology for the calculation of a Lighting Energy Numeric Indicator (LENI), representing the energy consumption of lighting within a building over a given time frame. This indicator may be used for single rooms on a comparative basis only, as the benchmark values given in ISO/CIE 20086 are drawn up for some types of room or application areas. ISO/CIE 20086 provides a simplified method for calculating the potential energy savings of daylight.

6.5 Daylight

Daylight should be the predominant light source for buildings during daytime, with electric lighting used to supplement daylight when and where it is needed. Doing so will reduce the energy used for lighting as well as delivering additional benefits for occupants, including improved well-being. See ISO/CIE 10916 for details concerning the calculation of the effect of daylighting on lighting energy use and ISO/CIE 20086 concerning the calculation of lighting energy use in buildings

Daylight can be provided through daylight openings including windows, skylights, or other innovative fenestration technologies such as light guidance systems (e.g., light shelves, louvres, mirror shafts) and light transport systems (e.g., light pipes, core sunlighting systems, light guides).

Additional benefits of daylight in buildings include its high level of colour rendering; the visual interest provided by its variations in intensity, spectrum, and light distribution over the day and season; the potential for contributions of timing, spectrum, and intensity of light exposure to promoting circadian regulation; and benefits on mood, satisfaction and associated organizational productivity outcomes (CIE 158; ISO/CIE TR 21783; ISO/TR 9241-610).

Depending on how the daylight enters the building, the view to the outdoors and information about weather and external events can provide opportunities for psychological restoration in addition to the benefits described above, and are preferred by most people.

Integrating daylight into lighting design is an architectural design challenge. Factors to consider include the latitude, weather, building shape, mass, and orientation, external obstructions (i.e. natural obstructions,

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presence of surrounding buildings), the building structure and interior design, the glazing characteristics, and the content of the external view. Metrics describing daylight include the daylight factor (CIE 016) and climate-based annualized quantities described in EN 17037 and IES LM-83.

Because of the necessity to achieve the recommended maintained conditions from Clause 7 with electric lighting alone, the combination of daylight and electric light sources will exceed these conditions. Uniformity requirements do not apply in the daylit zones. Adjustable electric lighting (see 6.2.4), whether manual or automatic, should be provided to achieve desired light levels and energy consumption targets by integrating daylight and electric light sources. Automated controls (e.g., using photosensors) require careful attention to calibration and commissioning (see Annex D and ISO/TS 21274) to ensure that conditions are neither under-lit nor over-lit.

Direct sunlight and high contrasts between the diffuse sky and interior conditions can be glare sources, and direct sunlight can cause overheating. Providing shading, especially to block direct sunlight, will reduce the risk of visual and thermal discomfort. Selection of window shade fabric has a considerable effect on glare, view, and solar heat gain. Perforated fabrics with a dark inside surface help to maintain view, whereas a highly-reflective outside fabric surface helps reject solar heat gain. Automated shading can be used to block direct sunlight when needed, while returning to an open state during other hours to allow more daylight contribution to the space.

6.6 Room brightness

An indication of perceived room brightness in spaces where visual tasks or activities are carried out shall be obtained by a combination of reflectances and illuminances on walls and the ceiling.

Additional indications of perceived room brightness are explained in Annex B.

7 Schedule of specific lighting requirements

7.1 Composition of the tables

The requirements for task areas and activity areas are given in Table 9 to Table 62. The columns are understood as shown in Table 8. This applies to c) to j) in all tables in 7.3. For the application of the tables in 7.3, see Clause 6.

a) Ref. no - the reference number for each task area or activity area.

b) Type of task/activity area - those task areas or activities areas for which specific requirements are given. If the particular task or activity is not listed, the values given for a similar, comparable situation should be adopted. Task areas or activity areas can also be a room, e.g. a corridor or resting room.

c) $\bar{E}_m$ required - the required maintained average illuminance $\bar{E}_m$ on the reference surface (see 5.3) for the interior (area) in which the task or activity from b) is performed.

d) $\bar{E}_m$ modified - the modified maintained average illuminance $\bar{E}_m$ considering common context modifiers when the visual conditions differ from the normal assumptions (see 5.3.3) on the reference surface (see 5.3) for the interior (area) in which the task or activity from b) is performed.

NOTE Lighting control can be required to achieve adequate flexibility for the variety of tasks performed.

e) U_o - the minimum illuminance uniformity U_o on the reference surface for the maintained illuminance $\bar{E}_m$ chosen according to c) or d).

f) R_a - the minimum general colour rendering indices (R_a) (see 5.8.3) for the situation listed in b).

g) R_{UGL} - the UGR limits (Unified Glare Rating limit, R_{UGL}) that are applicable to the situation listed in b) (see 5.6.3.2).

h) $\bar{E}_{m,c}$ - the maintained average cylindrical illuminance $\bar{E}_{m,c}$ for the recognition of objects and people as described in 5.7.3.

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i) $\bar{E}_{m,wall}$ - the maintained average illuminance on walls $\bar{E}_{m,wall}$ as described in 5.2.4.

j) $\bar{E}_{m,ceiling}$ - the maintained average illuminance on ceilings $\bar{E}_{m,ceiling}$ as described in 5.2.4.

k) specific requirements - specific requirements for the situations listed in b).

Table 8 — Assignment of columns to requirements

Task area or activity area design				Room or space design requirements			
Task or activity related requirements					For visual communication and recognition of objects (5.7.3)	Brightness appearance of rooms (5.2.2, 5.2.3, 5.2.4)	
$\bar{E}_m$ lx		7.1 e) U_o	7.1 f) R_a	7.1 g) R_{UGL}	7.1 h) $\bar{E}_{m,c}$ lx	7.1 i) $\bar{E}_{m,wall}$ lx	7.1 j) $\bar{E}_{m,ceiling}$ lx
7.1 c) required[a]	7.1 d) modified[b]				$U_o \geq 0{,}10$		

[a] required: minimum value

[b] modified: considers common context modifiers in 5.3.3

7.2 Schedule of task areas and activity areas

Table 9 to Table 62 give the requirements for the specific types of task area or activity area.

Table 9 — Traffic zones inside buildings

Table 10 — General areas inside buildings – Rest, sanitation and first aid rooms

Table 11 — General areas inside buildings – Control rooms

Table 12 — General areas inside buildings – Store rooms, cold stores

Table 13 — Logistics and warehouses

Table 14 — Industrial activities and crafts – Agriculture

Table 15 — Industrial activities and crafts – Bakeries

Table 16 — Industrial activities and crafts – Cement, cement goods, concrete, bricks

Table 17 — Industrial activities and crafts – Ceramics, tiles, glass, glassware

Table 18 — Industrial activities and crafts – Chemical, plastics and rubber industry

Table 19 — Industrial activities and crafts – Electrical and electronic industry

Table 20 — Industrial activities and crafts – Food stuffs and luxury food industry

Table 21 — Industrial activities and crafts – Foundries and metal casting

Table 22 — Industrial activities and crafts – Hairdressers

Table 23 — Industrial activities and crafts – Jewellery manufacturing

Table 24 — Industrial activities and crafts – Laundries and dry cleaning

Table 25 — Industrial activities and crafts – Leather and leather goods

Table 26 — Industrial activities and crafts – Metal working and processing

Table 27 — Industrial activities and crafts – Paper and paper goods

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Table 28 — Industrial activities and crafts – Power stations

Table 29 — Industrial activities and crafts – Printers

Table 30 — Industrial activities and crafts – Rolling mills, iron and steel works

Table 31 — Industrial activities and crafts – Textile manufacture and processing

Table 32 — Industrial activities and crafts – Vehicle construction and repair

Table 33 — Industrial activities and crafts – Wood working and processing

Table 34 — Offices

Table 35 — Retail premises

Table 36 — Places of public assembly – General areas

Table 37 — Places of public assembly – Restaurants and hotels

Table 38 — Places of public assembly – Theatres, concert halls, cinemas, places for entertainment

Table 39 — Places of public assembly – Trade fairs, exhibition halls

Table 40 — Places of public assembly – Museums

Table 41 — Places of public assembly – Libraries

Table 42 — Places of public assembly – Car parks (indoor)

Table 43 — Educational premises – Nursery school, play school

Table 44 — Educational premises – Educational buildings

Table 45 — Health care premises – Rooms for general use

Table 46 — Health care premises – Staff rooms

Table 47 — Health care premises – Wards, maternity wards

Table 48 — Health care premises – Examination rooms (general)

Table 49 — Health care premises – Eye Examination rooms

Table 50 — Health care premises – Ear Examination rooms

Table 51 — Health care premises – Scanner rooms

Table 52 — Health care premises – Delivery rooms

Table 53 — Health care premises – Treatment rooms (general)

Table 54 — Health care premises – Operating areas

Table 55 — Health care premises – Intensive care unit

Table 56 — Health care premises – Dentists

Table 57 — Health care premises – Laboratories and pharmacies

Table 58 — Health care premises – Decontamination rooms

Table 59 — Health care premises – Autopsy rooms and mortuaries

Table 60 — Transportation areas – Airports

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Table 61 — Transportation areas – Railway installations

Table 62 — Places of worship, e.g. churches, mosques, synagogues and temples

7.3 Lighting requirements for task areas, activity areas, room and space brightness

The requirements for the specific tasks and activities are given by $\bar{E}_{\mathrm{m}}$, U_{o}, R_{a} and R_{UGL}. The requirements for the space in which the task(s) or activities are carried out are given by $\bar{E}_{\mathrm{m,c}}$ for the perception of objects and people within this space and $\bar{E}_{\mathrm{m,wall}}$ and $\bar{E}_{\mathrm{m,ceiling}}$ for room brightness. The latter are used for designing the room and the space including R_{UGL}. Glare (by R_{UGL}) is dedicated to the space in which a task is carried out. The first four columns are used for task area or activity area design and more than one of these areas can occur within one space.

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Table 9 — Traffic zones inside buildings

Ref. no.	Type of task/activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,c}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
9.1	Corridors and circulation areas	100	150	0,40	70	28	50	50	30	Illuminance at floor level. R_a and R_{UGL} similar to adjacent areas. 150 lx if there are vehicles on the route. The lighting of exits and entrances shall provide a transition zone to avoid sudden changes in illuminance between inside and outside by day or night. Care should be taken to avoid glare to drivers and pedestrians.
9.2	Stairs, escalators, travolators	100	150	0,40	70	25	50	50	30	Illuminance at floor level. Requires enhanced contrast on leading edge of the steps.
9.3	Elevators, lifts	100	150	0,40	70	25	50	50	30	Illuminance at floor level. Light in front of elevator, see Ref.no.9.4.
9.4	Area in front of lifts, elevators and escalators	200	300	0,40	70	25	75	75	50	Area up to 1 m in front of lift, elevators and escalators. Illuminance at floor level.
9.5	Loading ramps/bays	150	200	0,40	70	25	50	50	-	
9.6	Building entrance with canopy	30	50	0,40	-	-	-	-	-	
9.7	Gangways: manned	150	200	0,40	70	25	-	50	30	Illuminance at floor level. For storage rack face see Table 13.

[a] required: minimum value

[b] modified: considers common context modifiers in 5.3.3

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