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Principles of visual ergonomics — The lighting of indoor work systems

Principes d'ergonomie visuelle — L'éclairage des systèmes de travail intérieurs

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Contents

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8995 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, in collaboration with the International Commission on Illumination (CIE).

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Principles of visual ergonomics — The lighting of indoor work systems

0 Introduction

The aim of visual ergonomics is

— to optimize the perception of visual information used during the course of work;

— to maintain an appropriate level of performance;

— to guarantee maximum safety;

— to provide acceptable visual comfort.

These objectives are achieved in practice by designing the visual environment to take account of a person's capabilities.

Figure 1 shows the parameters that influence a worker's performance in a given visual environment. Parameters such as perceptual ability and the characteristics of the task[1]) to be completed determine the quality of the operator's visual skills. Lighting and work space factors provide the more "environmental" determinants of visual performance. All influence the nature of the visual information available and hence the worker's consequent levels of task performance. Consequently, it may be possible to compensate for a defect in one of the factors by an enhancement of one or more of the others. For example it may be possible to provide adequate visual information by improving the contrast of the task attributes and other task or operator variables, yet have lower overall illumination levels if there is a limit to the illuminance which can be provided.

Considerations such as these imply that the application of visual ergonomics may increase the number of design options available. Consequently, visual ergonomics can be used to provide a range of options, from general guidelines to more detailed information concerning a parameter that needs to be modified to provide an acceptable visual environment.

The ranges of glare limitation (see annex A) and recommended illuminances (see annex B) are taken from existing national standards, codes and regulations. They are intended as examples and guidance for designing the visual environment of work systems especially in those cases where no national codes or legal rules exist.

1) Task is also taken to mean task attributes.

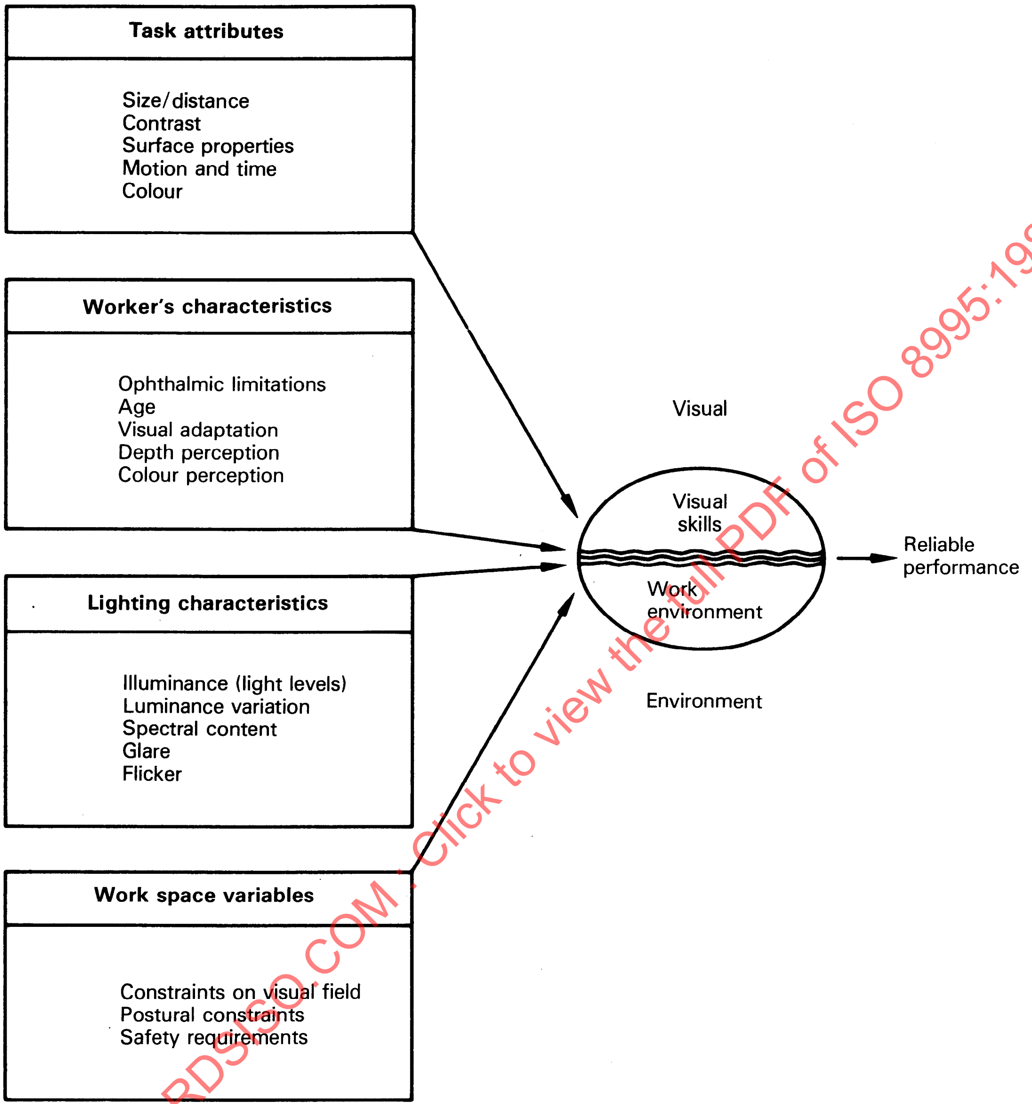


Figure 1 — Major parameters influencing a worker's performance in the visual environment

1 Scope and field of application

This International Standard lays down the principles of visual ergonomics and identifies the parameters that influence visual performance. It also presents the criteria that have to be satisfied in order to achieve an acceptable visual environment.

This International Standard is applicable to working areas in industrial buildings, offices and hospitals, etc., but not those working areas of low luminance used for such activities as, for example, projection, viewing of transparencies, handling of photosensitive materials. The special requirements specified for interiors where visual display units are used are also beyond the scope of this International Standard. Similarly, visual tasks requiring special analysis such as where optical aids are used, to enhance task detail, are also not covered.

This International Standard is intended primarily for the non-specialist involved in matters concerned with the visual environment. The references in clause 2 provide more detailed information to complement this International Standard.

It is recommended that a specialist be consulted if the information provided in this International Standard is not readily applicable, or if a more precise evaluation is needed because technical difficulties and cost constraints limit the role played by lighting.

2 References

ISO 6385, *Ergonomic principles in the design of work systems.*

CIE Publication No. 13.2, *Method of measuring and specifying colour rendering properties of light sources.*

CIE Publication No. 16, *Daylight — International recommendations for the calculation of natural daylight.*

CIE Publication No. 17, *International lighting vocabulary.*

CIE Publication No. 19/2, *An analytic model for describing the influence of lighting parameters upon visual performance.*

CIE Publication No. 29/2, *Guide on interior lighting.*

CIE Publication No. 55, *Discomfort glare in the interior working environment.*

3 Definitions

For the purposes of this International Standard, the definitions in CIE Publication No. 17 and the following definitions apply.

3.1 Eye and vision

3.1.1 adaptation: The process which takes place as the eye adjusts to the luminance and/or the colour of the visual field or the final state of this process.

3.1.2 accommodation: Adjustment of the focus of the eye, normally spontaneous, for the purpose of attaining maximum visual acuity at various distances.

3.1.3 visual acuity: The capacity for discriminating details in objects or between objects which are very close together.

Quantitatively, it can be expressed by the reciprocal of the angle subtended by the extremities of the detail separation which is just visible at the entrance of the pupil or other point of reference on the eye.

3.1.4 contrast: A term that is used subjectively and objectively.

a) Subjective sense: Subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively. (Hence: brightness contrast, colour contrast, simultaneous contrast, successive contrast.)

b) Objective sense: Quantities usually defined as a luminance ratio (usually for successive contrasts) L_2/L_1, or by the following formula (for surfaces viewed simultaneously):

$$\frac{L_2 - L_1}{L_1}$$

where

L_1 is the dominant or background luminance;

L_2 is the object luminance.

When the areas of different luminance are comparable in size and it is desirable to take an average, the following formula may be used instead:

$$\frac{L_2 - L_1}{0{,}5\,(L_2 + L_1)}$$

3.1.5 brightness: Attribute of the visual sensation associated with the amount of light emitted from a given area.

It is the subjective correlate of luminance.

3.1.6 glare: The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the brightness of the general surroundings to which the eyes are adapted.

3.1.7 reflected glare: Glare resulting from specular reflections from polished or glossy surfaces.

3.1.8 flicker: Visual impression of intermittency, alternation, or variation in presentation of light.

3.1.9 stroboscopic effect: Apparent immobilization or change of motion of an object, when the object is illuminated by a light of appropriate frequency and varying intensity.

3.1.10 visual field: The area or extent of physical space visible to an eye in a given position.

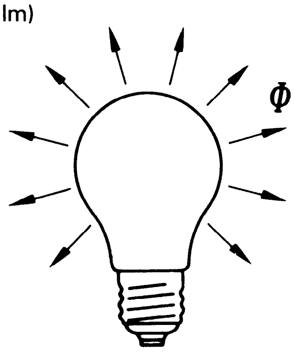
3.1.11 visual environment: The total space which can be seen from a particular location by moving one's head and eyes.

3.2 Quantities and units of light and colour

3.2.1 luminous flux: The light power emitted by a source, or received by a surface. The quantity is derived from radiant flux (power) by evaluating the radiation in accordance with a standardized spectral sensitivity of the eye.

Symbol: Φ

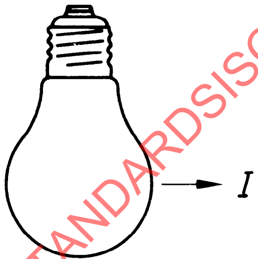
Unit: lumen (lm)



3.2.2 luminous intensity (of a source in a given direction): The luminous flux per unit solid angle in a specific direction. It is the luminous flux on a small surface normal to the direction, divided by the solid angle that the surface subtends at source.

Symbol: I

Unit: candela (cd)

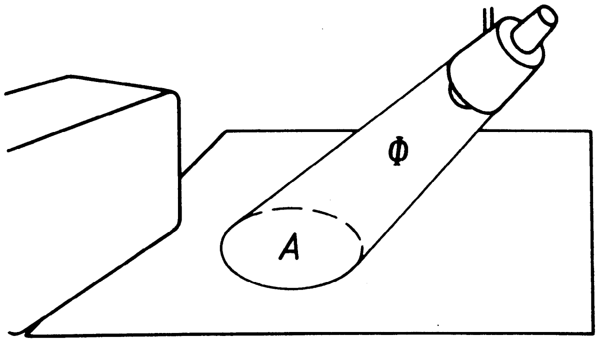


3.2.3 illuminance: The density of the luminous flux (Φ) incident at a point. In practice the average illuminance of a given surface is calculated by dividing the flux falling on it by the area (A) of the illuminated surface.

Symbol: E

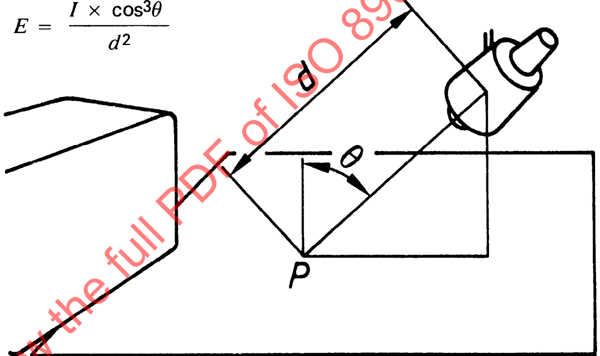
$$E = \frac{\Phi}{A}$$

Unit: lux (lx) (1 lx = 1 lm/m²)



NOTE — The illuminance at a specified point P at a given distance d from the source of intensity I in that direction and at an angle of incidence θ is calculated using the formula

$$E = \frac{I \times \cos^3\theta}{d^2}$$



3.2.4 luminance: The physical measurement of the stimulus which produces the sensation of brightness, in terms of the luminous intensity in a given direction ε (usually towards the observer) per unit area of an emitting, transmitting or reflecting surface. It is the luminous intensity of the light emitted or reflected in a given direction from an element of the surface, divided by the area of the element projected in the same direction.

Symbol: L

Unit: candela per square metre (cd/m²)

NOTE — The luminance L, in candela per square metre, of a perfectly matt surface is given by the formula

$$L = \frac{\varrho \times E}{\pi}$$

where

E is the illuminance, in lux;

ϱ is the reflectance of the surface considered.

3.2.5 reflectance: The ratio of the luminous flux reflected from a surface (Φ_r) to the luminous flux incident (Φ_o) on it.

The reflectance depends on the direction of the incident light, except for matt surfaces, and on its spectral distribution.

Symbol: ϱ

Formula: $\varrho = \dfrac{\Phi_r}{\Phi_o}$

3.2.6 luminous efficacy (of a light source): The quotient of the total luminous flux emitted by a source to the total power input to the source. (If the power loss of the control gear is included the term circuit efficacy should be used.)

Unit: lumen per watt (lm/W)

3.2.7 correlated colour temperature (of a light source): The temperature of the full radiator (black body) that emits radiation having a colour appearance or chromaticity nearest to that of the light source being considered.

Symbol: T_C

Unit: kelvin (K)

3.2.8 colour rendering: The colour rendering of a light source is the effect of that source on the colour appearance of objects compared with their colour appearance under a reference illuminant.

3.2.9 general colour rendering index: Value intended to specify the degree to which objects illuminated by a source have an expected colour relative to a reference illuminant.

It characterizes the degree to which the colours of eight test samples illuminated by the source conform to those of the same samples illuminated by a reference illuminant, suitable allowance being made for the state of chromatic adaptation (see CIE Publication No. 13.2).

Symbol: R_a

NOTE — R_a has a maximum of 100, which occurs when the spectral distributions of the test source and the reference source are substantially identical.

3.3 Interiors and systems

3.3.1 work system: The work system comprises a combination of people and work equipment, acting together in the work process, to perform the work task, at the work space, in the work environment, under the conditions imposed by the work task.

3.3.2 work space: A volume allocated to one or more persons in the work system to complete the work task.

3.3.3 work plane: The plane in which work is actually done.

3.3.4 reference work plane: A notional horizontal plane on which average illuminance is calculated for design purposes.

NOTE — Unless otherwise indicated, it is assumed to be 0,85 m above the floor (in the USA 0,76 m and in the United Kingdom 0,7 m for office tasks).

3.3.5 general lighting: Lighting designed to illuminate the whole of an area to approximately the same illuminance.

3.3.6 localized lighting: Lighting designed to illuminate an interior and at the same time provide a higher illuminance over a particular part or parts of the interior.

3.3.7 local lighting: Lighting for a specific visual task, additional to and controlled separately from the general lighting.

3.3.8 light loss or maintenance factor: Ratio of the illuminance provided by an installation at some stated time, to the initial illuminance when installed.

3.3.9 utilization factor (USA: coefficient of utilization): Ratio of the luminous flux reaching the work plane to the total luminous flux of the lamps in the installation.

4 Parameters influencing visual performance

The nature of the worker's visual system will ultimately determine the effectiveness of the design of the visual environment. In practice the effectiveness of the visual system is measured in terms of visual performance. The understanding of the capabilities of visual performance shall be in terms of the interaction between the visual system and the characteristics of the tasks seen within their environment and so cannot be viewed in isolation. Consequently, visual performance shall be considered in relation to those factors which are its major determinants.

The term "visual performance" is used to indicate quantitatively how a person "performs" in terms of speed, accuracy and probability of detection when detecting, identifying and responding to details in his visual field. Visual performance depends both on intrinsic task properties (size, shape, position, colour and reflectance of detail and background) and on the perception as influenced by the lighting.

Visual performance is, however, influenced by parameters such as glare, non-uniformity of illuminance, visual distraction, nature of the background, and the design of the work space in general.

"Fatigue" may occur after prolonged work under poor lighting conditions (low illuminance, non-uniformity, distraction, discomfort glare) and amongst others may consist of:

— fatigue of the central nervous system as the result of the effort required to interpret unclear or ambiguous signals;

— body muscle fatigue due to having to maintain an unsuitable posture in order to alter the task distance or avoid distractions or unwanted reflections which may occur, for instance, in a drafting task.

Localized muscular strain (for example of neck muscles) can also occur, for example in work involving the use of microscopes.

4.1 Visual task components

Visual perception may be considered to depend on the following components of the stimulus:

a) contrast;

b) size, form and texture;

c) movement and time available;

d) position of the image on the retina;

e) colour;

f) luminance.

4.1.1 Luminance

Under normal conditions, increases in illuminance produce an improvement in visual performance which is initially rapid but eventually flattens off at a level at which further increase in illuminance produces no effect.

The visual performance of tasks of small size and/or low contrast can be improved by providing high levels of luminance (i.e. by increasing illuminance), but the performance of tasks of large size and high contrast rapidly reaches a maximum at moderate values of luminance.

4.1.2 Contrast

The perception of an object in its surroundings is mainly dependent on the contrast, in terms of luminance and/or colour, between the object and its background. Whenever possible, tasks and lighting should be designed to optimize contrast.

Within certain limits, as luminance is increased so is the sensitivity of the eye to contrast. Sensitivity is also affected by the gradients of the boundaries between the two luminances or colours, but is reduced by too large a variation in luminance and colour within the visual field surrounding the task to be perceived. For example, if a bright source of light is within the field of view, disability glare will cause an apparent reduction of contrast. A reduction can also be caused by looking away from the task towards a more brightly lit area, causing a brief change in the adaptation of the eye (transient adaptation).

Contrast can also be reduced by veiling reflections. This occurs when high luminance is reflected by the task towards the eyes and thus veils, or interferes with, the perception of the task. In particular, reflections of light sources in specular or semi-specular visual tasks can result in substantial losses in contrast. Adequate diffusion of the lighting, for example, by light reflected from the ceiling and/or walls or light directed on to the task from the side or behind the person, normally avoids this.

4.1.3 Size, form and texture

Discrimination of size, form and texture, a complex psycho-physiological process of recognition of the environment, involves at least three functions: the perception of contrast, the resolution of visual details, and the perception of depths and distances.

Conventionally, the resolution of visual details is expressed quantitatively and is dealt with by the term visual acuity. Visual acuity is a function of the quality of a person's eyesight and of the environmental characteristics and, in particular, the magnitude of the perceived luminance.

Manipulation of size can be an important means of improving visibility. For example, performance can often be improved by enlarging the detail, bringing it nearer to the viewer or by using optical aids.

The perception of depth, relief, and distance depends not only on the occulomotor functions, such as quality of binocular vision, and on intellectual functions, such as memory of size and form of known objects, but also on the interpretation of contextual cues as illustrated in the creation of optical illusions. Perception of texture depends upon the pattern of shadow and light on a surface.

When designing the lighting for a particular task in order to provide the required luminance levels, care shall be taken that directionality and diffusion of the light do not reduce the contrast required for the perception of texture and form of objects by excessive diffusion of the light. Some shadow is often helpful in perception (see 5.8), but some types of shadow will make it more difficult. For example, too many shadows can be confusing and misinterpretation of the shadow pattern is possible.

4.1.4 Colour

Colour is an attribute of light which contributes considerably to the general impression of our environment as well as to visual performance. In particular, it is useful in the quick and easy identification of objects in the work space.

Colour perception improves as illuminance increases, within certain limits. Colour perception varies across the retina of the eye. Colour discrimination is at its best in the central area of the retina.

Colour constancy describes the way in which colours are perceived in relation to each other. The colours of the scene maintain a relatively constant relationship under light having a spectral composition sufficiently similar to that found in daylight. However, if the spectral composition deviates too much from this, colour constancy is not retained, and the colour appearance of the scene will change. Colour appearance is dependent not only upon the spectral composition of the light, but also upon the characteristics of the surface examined, the luminance, colour contrasts and the state of colour adaptation.

The eye can perceive quite small differences in colour between two adjacent surfaces even if the luminances are identical, but comparison with remembered colours is more difficult. Different light sources can improve or reduce discrimination of certain colours.

However, defects in colour vision occur in some individuals, and this can alter the appearance of colours and the power of discrimination between them, and may be important in some circumstances for certain occupations (see 4.3).

4.1.5 Movement and time available for viewing

The perception of motion requires movement of the image of the target on the retina. The *fovea* of the eye is more sensitive to the perception of movement than is the periphery. The peripheral area of the retina is relatively more sensitive to motion than to form so the eyeball turns toward the moving target to bring the image into the centre of the retina for more detailed inspection.

The accuracy of perception of movement depends on speed, size, form and contrast. Also, visual perception of an object depends on the time available for viewing. A brief glance may suffice if it is a large, high contrast object. A prolonged gaze may be needed if it is not. The visibility of a moving object can be improved by allowing the eye to follow it over an adequate length of its path. If the speed of movement across the visual field is too high or the path is too erratic, or both, visibility deteriorates very rapidly.

4.1.6 Position of image on the retina

Visual acuity, the ability of the eye to resolve fine details, decreases rapidly as the retinal image of the target becomes displaced from the central part of the retina (*fovea centralis*). For tasks which require the recognition of details the visual system performs with maximum efficiency when the target to be viewed falls on the primary line of sight and its image falls on the *fovea*. Flicker is more easily detected in the periphery of the retina.

4.2 Lighting characteristics

For the interaction of luminance and directionality with task attributes, see 4.1. This clause deals primarily with glare and flicker.

4.2.1 Glare

Glare is experienced if the luminance of luminaires or windows is excessive compared with the general brightness in the interior (direct glare) or when such light sources are reflected in glossy or semi-matt surfaces (reflected glare).

Glare can take one of two forms, which sometimes occur separately but are often experienced simultaneously. The first is known as disability glare and impairs the vision of details or objects without necessarily causing discomfort. The second is known as discomfort glare and causes discomfort without necessarily impairing the vision of details or objects.

In many interiors, for example offices, but not necessarily industrial premises, discomfort glare is likely to be more of a problem than disability glare. Measures taken to control discomfort glare caused by luminaires and windows will normally take care of disability glare also.

Glare may also occur by reflection from surfaces with high reflectance, especially where bright sources and specular surfaces such as polished metal are involved. When a bright image reaches the eyes it may cause discomfort and prove distracting to workers. Reflected glare may comprise both disability and discomfort glare.

4.2.1.1 Discomfort glare

Discomfort glare is normally experienced as a feeling of discomfort which tends to increase with the passage of time and may contribute to fatigue.

Discomfort is greater the higher the luminance of the sources, the greater the solid angles they subtend, and the greater their number within the normal field of view. It is lower the greater the angle formed by the direction of the source and the visual axis, and the higher the luminance of the background. Other parameters such as the characteristics of the eyes of the individual subject and the degree of visual concentration on the visual scene may also affect the degree of discomfort experienced.

Normally, the background luminance controls the general adaptation level of the eye. When the source becomes large, for example, in the case of a window, the effect of the source luminance on the adaptation level has to be taken into account.

International agreement exists on the extent to which the above parameters such as source luminance, source area and background luminance affect the degree of glare. Research in several countries has related values of these parameters to the subjective assessment of glare sensation.

4.2.1.2 Disability glare

Disability glare usually occurs when a large source of low luminance (or a small source of high luminance) is seen close to the line of sight to the visual task. An example is the difficulty in reading signs placed in front of, or close to, a window through which the sky is visible.

4.2.2 Flicker

Fluctuations in light, either from a source or from an illuminated area in the field of view, are perceived if the frequency of fluctuations is low. This phenomenon of "flicker" can be troublesome and may give rise to effects such as annoyance. It varies greatly from individual to individual, as does the degree of discomfort experienced.

The frequency of flicker that can be perceived depends on the luminance and area of the source or illuminated field, the position at which its image falls on the retina, the shape of the luminance-versus-time curve and on the amplitude of the fluctuations. Fluctuations of light can also cause a "stroboscopic" effect, which can cause objects to appear to move jerkily or can mask the true speed of rotation of rotating objects (see 5.9).

4.3 Eyesight

The visual process is a complex system both in terms of perceiving the object and in general reactions to the visual environment. In normal health the visual system is to a large extent self-regulating and will adjust itself to maximize the clarity of the transmitted information.

However, stress may be produced by excessive demands or conflicts connected with accommodation, adjustment of pupil diameter, or eyeball positioning. In the case of close vision, two types of mechanisms are combined which may cause strain. These are maintaining of convergence of the visual axes and accommodation. This should be taken into account in the design of the task and the work space.

The characteristics of the eye vary from individual to individual and change with age. They also depend upon certain diseases, for example diabetes. The most important change in the older eye is that the range of accommodation is reduced. Consequently, the use of correctly prescribed optical aids is helpful. Other physical changes in the ageing eye are

— reduction in light transmission through the eye which is important in very dimly lit conditions;

— increased scattering in the eye, creating greater sensitivity to glare (particularly disability glare).

Provision of adequate and glare-free illumination is thus even more important for older workers than for young people; greater attention should therefore be paid to these aspects.

4.4 Work space variables

Parameters such as visual field constraints, adequate postural requirements, etc., are not dealt with because they are beyond the scope of this International Standard. However, it is anticipated that such parameters will be taken into account in the application of good lighting practice as outlined in clause 5.

5 Lighting criteria

The lighting characteristics of the visual environment affect both the physiological visual functions (visual performance) and the psychological visual functions (comfort) and may thus contribute to the performance, safety, visual comfort and satisfaction of man in his visual environment. The criteria that shall be satisfied by lighting for this purpose are dealt with in this clause.

5.1 Lighting requirements

The lighting of an interior by daylight and electric lighting should provide the optimum conditions for performing the tasks required and the appropriate visual environment when looking away from the task for relaxation or change of task. Special requirements may be needed in certain commercial, industrial, and other applications (e.g. hospitals).

The visual impression of an interior is influenced by the appearance of the following surfaces:

a) main visual objects: for example, the tasks, the faces of people, and equipment;

b) large surfaces in the interior: walls, ceilings, floors, windows (at night) and surfaces of equipment;

c) light sources: luminaires and windows (during the day).

5.1.1 Lighting and design of task

In a work system the visual field of an occupant is different depending on whether the occupant is concentrating on a task or looking away for relaxation. The criteria that shall be satisfied are different for both situations. For this reason a distinction is made between lighting of the task and lighting of the environment. The effectiveness of lighting the task is judged mainly by the criteria of visual performance, which are influenced by the parameters discussed in clause 4. As the lighting of the environment can avoid causing distraction, unfavourable adaptation, and discomfort occurring in the field of view while performing the task, it can also play a part in assisting visual performance, which in turn improves the comfort and satisfaction experienced in carrying out the task.

In addition to contrasts of luminance, the visual task usually includes some colour contrasts; these can be used to improve conspicuity, especially when luminance contrasts are low.

5.1.2 Lighting of the environment

The relationships of the luminances and colours of the surfaces of the environment should be appropriate to the function of the interior, visually pleasing and free from glare.

Among the objectives sought, by providing appropriate lighting of the environment, are the following (not in order of priority):

a) to give the space adequate brightness in order to clearly define it;

b) to facilitate safe and easy movement in the interior;

c) to aid concentration on the task areas;

d) to provide areas of slightly lower luminance than the task areas;

e) to achieve natural modelling of faces and soften harsh shadows by the correct balance of directional and diffuse light;

f) to reveal the occupants and contents of the interior in acceptably "natural" colours by the use of light sources of good colour rendering quality;

g) to produce, in a working interior, a pleasant variety of luminance and colour that contributes to the well-being of the occupants and to the reduction of work stress[1]. One possible solution is to have small bright areas in the visual environment but not within the direct line of sight to the visual task;

h) to encourage cleanliness by choosing light colours, particularly for floors and (in a workshop) machinery.

Certain elements may be found to be in conflict and appropriate compromises have to be found without sacrificing safety requirements and well-being.

1) For the definition of "work stress", see ISO 6385.

5.2 Illuminance

Table 1 gives illuminance ranges for different areas, tasks or activities. The values are related to the visual requirements of the task, practical experience and the need for cost-effective use of energy. They help provide satisfactory visual performance and contribute to the well-being of the user.

For each type of area, task or activity a range of three illuminances is given.

The higher values in the range may be used under the following circumstances:

— when unusually low reflectance or contrast is present in the task;

— when it is costly to rectify errors;

— when visual performance is critical;

— when accuracy or higher productivity is of great importance;

— when the visual capacity of the worker makes it necessary.

The lower values in the range may be used:

— when reflectance or contrast is unusually high;

— when speed or accuracy is not important, and

— when the task is only executed occasionally.

Table 1 — Typical illuminance ranges for different areas, tasks or activities

Illuminance range lx	Type of area, task or activity
20 — 30 — 50	Outdoor circulation and work areas
50 — 100 — 150	Circulation areas, simple orientation or short temporary visits
100 — 150 — 200	Rooms not used continuously for working purposes
200 — 300 — 500	Tasks with simple visual requirements
300 — 500 — 750	Tasks with medium visual requirements
500 — 750 — 1 000	Tasks with demanding visual requirements
750 — 1 000 — 1 500	Tasks with difficult visual requirements
1 000 — 1 500 — 2 000	Tasks with special visual requirements
above 2 000	Performance of very exacting visual tasks

The appearance of many working interiors is dim at illuminances less than about 200 lx, and for this reason the minimum illuminance recommended for long periods of work at a fixed work space is 200 lx, irrespective of the visual ease of the task.

Lighting systems may need to combine general and local lighting to achieve high illuminances on to certain tasks. For example, this could apply to tasks involving fine detail, or those which need special requirements, such as directional lighting. Both of these may require additional local lighting.

Different countries have included recommended illuminances for a large number of interiors and tasks in their codes for interior lighting. Annex B gives an example of a possible national recommendation developed by using table 1.

These recommendations are not intended to supersede any national recommendations in use.

5.3 Luminance of surfaces in interiors

The luminance of a surface illuminated by a source is dependent both on the illumination and the reflection characteristics of that surface.

The planned distribution of luminance in an interior shall be considered in addition to the design based on illuminance. Attention should be paid to the following luminance relationships:

a) the task and its immediate surroundings, such as bench and desk tops (luminance ratios);

b) ceilings, walls and floors (reflectances);

c) luminaires and windows (luminance limits).

The luminance of the immediate surroundings of the task should, if possible, be lower than the task luminance but not less than one-third of this value. When the reflectances of the task are not known in advance, the reflectance of the working surfaces should be taken as between 0,3 and 0,5.

In working interiors the diffuse reflectance of ceilings (or undersides of roofs) should be as high as possible, especially if recessed luminaires are used, to reduce the risk of direct glare, reflected glare and veiling reflections. The reflectance of the walls should preferably lie between 0,3 and 0,7.

5.4 Glare limitation

Discomfort or disability glare produced by a lighting installation or by windows may be limited by restriction of the parameters described in 4.2.1.1.

5.4.1 Glare limitation methods

Several countries have developed practical design methods for ensuring that a lighting installation does not produce an unsatisfactory degree of glare sensation. These are described in the CIE Publication No. 55.

In the Glare Index System that is used in the United Kingdom and certain other countries, and in the Visual Comfort Probability (VCP) System used in North America, the extent to which glare may be expected in a given situation is predetermined (evaluation systems).

The Luminance Curve System used in central European countries simply ensures that a chosen upper limit for the degree of glare will not be exceeded, without indicating how far below the upper limit the design will be (limitation systems).

In CIE Publication No. 29/2 one method is given as an example. This method is described in annex A. This glare safeguard system can be used to select suitable luminaires for general lighting in interiors and to check the glare limitation of existing lighting installations. Care shall be taken in the application of such glare assessment systems for industrial situations, especially where the nature of the operating tasks are not restricted to one location.

This example of the method is not intended to supersede any of the national systems currently in use.

5.4.2 Glare from windows

Some general recommendations may be made to reduce the glare from windows:

a) Sunlight penetration can be a major source of glare, whether it is seen directly or by reflection. Whenever this does occur, some sort of screening should be provided.

b) The degree of discomfort due to glare from a window depends mainly on the luminance of the sky seen through it, and only to a small extent on its size unless it is very small or distant from the observer.

c) Except on very dull days, the occupant of a room looking directly at the sky through an unshielded window is likely to experience some discomfort. Unless the occupants in their normal positions can avoid having the windows in their normal field of view, all windows should be provided with some type of shading (for example light curtains, blinds or louvres) to reduce the apparent luminance of the sky on bright days, regardless of whether or not sunshine can penetrate.

d) Other means of reducing the discomfort from windows, without reducing the quantity of daylight admitted, include the choice of shape and reflectance of the surfaces immediately surrounding them and of the window members in order to increase the luminance of the immediate surrounds of the glazing.

e) Disability glare can be avoided by ensuring that the luminance of the sky through a window is not seen close to the line of sight of a visual task.

5.5 Reflected glare and veiling reflections

There are various ways of dealing with reflected glare and veiling reflections referred to earlier in 4.2.1. The most effective method is to locate the worker and/or the primary source in such a way that reflections of the latter are directed away from instead of into the worker's eyes. A complementary method is to reduce the glossiness of the materials used.

Annoying and distracting reflections in the surroundings of the task can be prevented by avoiding the use of high-gloss finishes on desk tops and similar surfaces.

Veiling reflections actually reduce task contrast. Pencil marks, for example, become harder to see when they catch the light, because the added sheen turns them from black to pale-grey. Printed matter can be similarly affected. Once again, correct relative positioning to direct such reflections away from the eyes is the best method of prevention. If this is impossible, the effect may be minimized by raising the task illuminance with local lighting angled so that it does not itself contribute veiling reflections.

Other measures are the use of luminaires having a large surface area and low luminance, or luminaires with reduced luminance in the critical direction. Increasing the luminance of the whole ceiling by using high-reflectance matt finishes on ceiling, walls and floor, preferably in combination with luminaires with some upward light, also contributes to a reduction of reflected glare and veiling reflections. As a quantitative expression of these effects the Contrast Rendering Factor (CRF) has beeen introduced (see CIE Publication No. 19/2).

5.6 Daylight

The developments in electric lighting have not eliminated a widespread preference for daylight in buildings wherever practicable. The reliance on daylight is greater in homes, offices, schools, and patient areas in hospitals than in factories and shops. Under certain climatological conditions the use of daylight from roof-lights can save a great deal of the energy used for lighting shallow rooms and factories. This must be balanced against the heat gains and losses through the glazing (see CIE Publication No. 16).

5.6.1 Criteria

Windows can provide

— visual contact with the outside;

— useful illumination on working areas within the interior.

Daylighting by roof-lights can provide information about sky conditions and the weather, but cannot provide the visual contact similar to windows. From the subjective point of view, roof-lighting is more similar to electric lighting than daylighting through windows.

Direct sunlight is desirable for various types of buildings such as homes in temperate climates, but should be avoided in working areas. The solar energy associated with daylight entering the interior produces heat gains, which may require cooling of the interior during the warm season; on the other hand, heat gains may reduce heating costs during the cold season. However, heat losses through the window during the cold season may offset the savings and may increase heating costs.

The optimum size and shape of windows and/or roof-lights should be determined for each building according to local conditions taking into account architectural, lighting, visual, thermal and acoustic considerations. The savings in energy and reduction in costs are very important but should be achieved without sacrificing human well-being.

Glare from windows is referred to in 5.4.2.

5.6.2 Requirements for visual contact with the outside

When calculating the minimum window area for interiors occupied permanently, consideration should be given to the need for visual contact with the outside.

Research indicates that the width of the windows in dwellings and some working interiors should be at least 55 % of the window wall width. The view of the surroundings at ground level thus obtained is preferred by office workers.

However, in working interiors such as large offices, satisfaction with the external view can be obtained if the glazed area occupies between 20 and 30 % of the window wall area as seen from inside; satisfaction falls steeply if the area is below 20 %. The ratio of window width to intervening solid wall width should be between 1,5 : 1 and 3 : 1. The fewer vertical divisions between glazed areas, the better, although windows should be spaced evenly along the perimeter. Windows giving an extensive view of the sky tend to cause discomfort and lower satisfaction. In order to obtain a reasonable view outside in offices and similar environments, the window sill height should not exceed 0,9 m above the floor.

5.6.3 Requirements for brightness

The size of windows which meet the requirements of 5.6.2 will ensure that there is an adequate impression of interior brightness in daytime. This will apply to rooms which have a depth of approximately 2 to 3 times the distance of the top of the window to the sill. This is only applicable to clear glazing and where the windows are not substantially obstructed.

Supplementary electric lighting properly integrated with daylighting will improve the brightness distribution in deep interiors and avoid the sensation of gloominess in the parts of the interior distant from the windows.

5.6.4 Illumination by daylight

Daylight levels in interiors change with the time of day and depend largely on sky conditions, obstructions, and the orientation of the windows or roof glazing, as well as on geographical location. Because of the constantly changing daylight level, the major role of daylight calculations is to predict the average length of time during the day/month/year when the specified illuminance on the work plane is equalled or exceeded by the available daylight illuminance. For the remainder of the time some electric lighting shall be used. The length of time spent using daylight in relation to the daily working hours is the basis for predicting the possible energy and cost savings by using daylighting.

These calculations, taking orientation into account, should be based on known luminance distributions of the local (long-term) average sky conditions.

5.6.5 Daylight and electric light

Electric light complements or replaces daylight when it alone cannot ensure satisfactory illuminance on the work plane. The illuminance given by the electric lighting should be designed for the worst possible daylighting conditions, i.e. a complete lack of daylight. Automatic or manual switching and/or dimming should be arranged so that electric light can be used in any area at any time when the daylight illuminance falls below the required value.

In certain types of interiors, it may be necessary to have rooms that are illuminated entirely by electric light. Particularly in this situation attention should be given to the luminance of the surfaces of walls, floors and ceilings. This is because a room that has dark walls and low vertical illuminance tends to look gloomy even if the work plane is adequately lit.

5.7 Colour of sources

The colour qualities of a near-white lamp are characterized by two attributes:

a) its colour appearance;

b) its colour rendering capabilities, which affect the colour appearance of objects illuminated by the lamp.

Both the colour appearance and the colour rendering properties of a light source are determined by the spectral composition of the light emitted. Completely different spectral compositions, however, can result in a similar colour appearance and yet can produce great differences in colour rendering. It is impossible, therefore, to draw any conclusions regarding the colour rendering properties of a lamp from its colour appearance.

5.7.1 Colour appearance

The "colour appearance" of a lamp refers to the apparent colour (chromaticity) of the light it emits. It may be described by its correlated colour temperature.

Lamps normally used for interior lighting may be divided into three groups according to their correlated colour temperature (see table 2).

Table 2 — Lamp colour appearance groups

Colour appearance group [1)]	Colour appearance	Correlated colour temperature K
1	Warm	below 3 300
2	Intermediate	3 300 to 5 300
3	Cold	above 5 300

1) group 1: is appropriate for residential type areas
group 2: is most widely used in working interiors
group 3: should be used only for high lighting levels, for special tasks (like colour matching) or in warm climates

The colour appearance of objects depends on the spectral distribution of the light which illuminates them, the chromatic adaptation of the observer, and the spectral reflection characteristics of their surfaces.

5.7.2 Colour rendering

To provide an objective indication of the colour rendering properties of a light source the general colour rendering index R_a has been introduced. It has a value of 100 if the test source gives exactly the same effect as the reference illuminant. This figure becomes progressively less as the colour rendering properties of the test lamp deviate farther from those of the reference source.

In order to simplify specifications for the colour rendering indices of the lamps to be used for lighting interiors, colour rendering groups have been introduced, as indicated in table 3.

5.8 Directional effects

Some directional effects of light make it easier to recognize the details of a task. Light directed at a low angle across a surface will reveal certain surface defects, as well as displaying surface texture. This may be especially important for inspection tasks.

Also, the general appearance of an interior is enhanced when its structural features and the people and objects within are lit so that form and texture are revealed clearly and attractively. This occurs when the light is directed from a specified source. However, the lighting should not be too directional or it will produce harsh shadows, nor too diffuse or the modelling effect will be lost entirely.

5.9 Flicker and stroboscopic effects

The light output of all lamps on an a.c. supply has a cyclic variation which is small for most filament and fluorescent lamps and more marked for pure discharge lamps. The variation may cause flicker or stroboscopic effects, or both.

A fundamental cyclic variation of 100 (120) Hz is present in the light emitted by lamps operating on the 50 (60) Hz a.c. supply. This variation is very rapid and can rarely be detected visually. In some fluorescent lamps, however, a 50 (60) Hz variation is also present, occurring mainly near the electrodes at the end of the lamp and seen by certain individuals as flicker. This can usually be avoided by appropriate shielding of the ends of fluorescent lamps. Flicker usually increases as fluorescent lamps age and can be avoided by regular replacement.

Flicker from high pressure mercury, metal halide and sodium discharge lamps is more noticeable in lamps with transparent envelopes than in those with a fluorescent coating on the outer bulb.

Flicker due to aperiodic fluctuation in supply voltage may also be evident but may not cause problems.

The stroboscopic effect produced on rotating machinery and other moving objects is annoying if the stroboscopic pattern appears on a task requiring special attention. It can be dangerous if it occurs on rotating parts of machinery because this might cause an impression of reduced speed, immobility or reversal of direction of rotation which might be potential risk factors. This can be avoided by lighting the revolving parts of the machines with individual incandescent lamps. Nevertheless the stroboscopic effect can be deliberately used for inspection purposes.

Stroboscopic effects may be reduced by dividing the lamps between three phases or, in the case of fluorescent lamps, by using lead-lag circuits. Flicker and stroboscopic effects may most effectively be reduced by operating the lamps from high frequency supplies.

5.10 Efficiency of electric lighting

The overall costs of a lighting installation depend on the investment costs and the operating costs. The latter are determined by

a) the illuminance desired;

b) the efficacy of lamps and light output ratio (efficiency) of luminaires;

Table 3 — Lamp colour rendering groups

Colour rendering group	Colour rendering index range	Colour appearance	Example of use: Preferred	Example of use: Acceptable
1 A	$R_a > 90$	Warm intermediate cold	Colour matching, clinical examinations	
1 B	$80 < R_a < 90$	Warm intermediate	Offices, hospitals	
		Intermediate cold	Printing, paint and textile industries, demanding industrial work	
2	$60 < R_a < 80$	Warm intermediate cold	Industrial work	Offices
3	$40 < R_a < 60$		Rough industries	Industrial work
4	$20 < R_a < 40$			Rough industries

c) the utilization factor (coefficient of utilization) of the lighting system;

d) the maintenance cost;

e) the hours of use;

f) continuous or discontinuous use.

When selecting the most economic installation not only initial costs should be considered but the running costs over a certain period of time should also be considered. This could mean accepting higher investment in order to achieve lower total costs.

The illuminances given in table 1 are based on the relation between visual performance and task luminance, on practical experience and on economic considerations.

Energy consumption and the major part of the running costs decrease proportionally with increase in efficacy of lamps and the utilization factor of the luminaires in a given situation.

The utilization factor takes into account the light output ratio of the luminaires, their luminous intensity distribution and their lay-out as well as properties of the interior such as dimensions and reflectance of the room surfaces. The greater the utilization factor the lower will be the energy consumption and the running costs of lighting.

Proper maintenance is also an important parameter to be considered in the economics of lighting. The better a lighting installation is maintained by regular replacement of lamps and regular cleaning of the installation and the room surfaces, the smaller will be the difference between initial illuminance for the installation and the recommended illuminance.

To allow flexible use of the lighting, localized lighting can be employed, or local lighting can be used in addition to general lighting. Local lighting should also be used if higher illuminances are only required at certain places. Control by switching or dimming, which allows any unnecessary lighting to be turned off or adapted to available daylight levels, reduces energy consumption and lowers running costs.

6 Operation of the lighting installation

6.1 Maintenance

The illuminance levels resulting from a lighting installation within a building decrease progressively during use due to

— the accumulation of dirt on the luminaires and other surfaces;

— the fall in lamp light output due to ageing.

Good maintenance of lighting systems, therefore, reduces deterioration of the equipment and interior, promotes safety, keeps the lighting performance within design limits, and helps to minimize the electrical load and capital costs. Maintenance includes renewal of failed or faulty lamps and control equipment, and cleaning of luminaires and room surfaces at appropriate intervals. Therefore, easy access to luminaires shall be provided to assist maintenance.

The optimum cleaning frequency for a given lighting installation will depend on the type of luminaire, the rate at which dirt accumulates, and the cost of cleaning. It may be more economical to combine the cleaning of luminaires with lamp replacement.

In a large installation it may be preferable to replace all the lamps at an agreed time rather than individually each time they fail. This is called group replacement. Individual replacement is usually expensive, can be difficult in busy areas of a building, and may result in noticeable differences in lamp colour and luminance.

The design of a lighting installation should make allowance for depreciation in light output by initially providing an illuminance which is higher than that required. This is done by including a suitable light loss factor or maintenance factor in the lighting calculation, the magnitude of this parameter depending on the dirtiness of the conditions, the maintenance schedule agreed on between the designer and the user, and on the type of luminaire selected.

6.2 Measurement

Field measurements made on a lighting installation can be used to check for compliance with specifications or with recommended practice. They can be compared with the results of previous measurement surveys to see whether or not there is a need for maintenance, modification or replacement.

Comparison surveys can also be useful when designing an installation that will be expedient from the standpoint of both lighting quality and economy.

6.2.1 Measuring equipment

For measuring accurately, the illuminance meter should have a cosine-corrected photocell to take account of the effects of light falling on it at oblique angles, and should be colour-corrected according to the CIE standard photometric observer [V (λt)].

Luminance meters should be colour-corrected. An aperture angle of 1° is suitable for most applications. Smaller aperture angles are required for special measurements, for example visual tasks with very fine details.

6.2.2 Determination of average illuminance

The illuminance shall be measured on the appropriate work plane. Where the rooms are as yet unfurnished, the positions and heights of work planes are not yet known, measurements should be taken at a height of 0,85 m above the floor (in the USA 0,76 m and in the United Kingdom 0,7 m for office tasks). In circulation areas the height of the measuring plane shall not be more than 0,2 m.

During measurement the incidence of light shall not be influenced by the person carrying out the measurement or by displaced objects (shading, reflections).

In general, the measurement of average horizontal illuminance is carried out in empty rooms or in rooms or zones free from furniture whose overall height is above the measuring plane.

This does not apply to storage areas or areas where obstructions by furniture or machines are an inherent part of the interior, for example libraries.

If the measurement is used to check the value of a new installation precautions shall be taken that the measurement is carried out under the appropriate conditions (nominal supply voltage, ambient temperature, choice of lamps, etc.) or that the readings of the illuminance meter are corrected taking into account these conditions.

The floor area of the room or zone shall be divided into a number of rectangles of equal size and shape, the dimensions of which are chosen according to the size and height of the room and the spacing of the luminaires. The ratio of the length and width of the rectangle shall not be greater than 2 : 1. The illuminances shall be measured at the mid-points of the rectangles and the average illuminance calculated from all readings. The usual distance between measuring points in rooms with normal height is approximately 1 m to 2 m; in industrial high-bays with a larger spacing of luminaires the distance may be 5 m and more. The location of measuring points should be related to the location of luminaires in such a way that not only maxima or minima are registered.

6.2.3 Measurement of illuminances at work space

The measurements should be taken at the precise location(s) where the task elements are being carried out. This should be done with the worker in his normal position and with his normal shadow. The cell of the light meter should be placed in the appropriate plane of the work (horizontal, vertical or inclined). Care should be taken not to interfere with the way the work is being carried out or the light falling on to the task. When measuring the illuminance levels no modification of the installation is allowed.

Where the area of the task is small, at least one measurement should be taken in the centre of this area. For more detailed measurements the area of the work space is divided into a suitable grid.

Uniformity of illuminance can be considered over two areas : on and around the task itself, and over the whole interior. For the task area and its immediate surroundings, uniformity of illuminance is important. In order to check uniformity it is desirable to measure at a number of points throughout the work area.

6.2.4 Measurement of luminances

Luminance surveys should be made under actual working conditions from representative work-point locations. The luminance meter is placed at the level of the worker's eyes and directed toward the source, the reflected light or the surface concerned.

Work spaces used during both day time and night time should be measured under both conditions.

In most cases the luminance pattern of the room is mainly determined by the luminances of the following surfaces :

a) visual task;

b) immediate surroundings of the task;

c) general background of the task;

d) vertical planes opposite the observer;

e) ceiling;

f) luminaires and windows.

At work points where veiling reflections should be avoided, those luminances that may give rise to reflections of light should also be measured.

Annex A
(informative)

A method to select luminaires to limit glare

The following is based upon the CIE glare safeguard system (CIE Publication No. 29/2).

A.0 General

Where the luminaires are placed in a regular pattern, the CIE glare safeguard system can be used to select suitable luminaires for general lighting in working interiors. It consists of the luminance curve system in combination with a shielding angle system for luminaires whose lamps or parts are visible over the critical range of viewing angles.

A.1 Luminance curve system

Discomfort glare in interiors illuminated by luminaires mounted overhead in a substantially regular pattern may be limited by using the luminance curve system which gives luminance limits for luminaires, for different quality classes, in the range of critical angles γ from 45° to 85° from the downward vertical.

The range of critical angles for which the luminance limitation of the luminaire should be observed covers the angles between 45° and the angle γ which is the angle between the downward vertical and the line from the observer's eyes to the most distant luminaire (see figure A.1). For practical reasons the maximum value of γ to be taken into account is 85°.

The limitation of direct glare is sufficient if the average luminance (luminous intensity divided by the projected luminous area in the direction of view) of the luminaires does not exceed the values of limiting curves in figures A.2 and A.3 for the appropriate range of critical angles γ. These figures give luminance limitation curves for a stepped scale of glare ratings representing quality classes from A to E and for various values of illuminance. The scale for the glare rating G mentioned in figures A.2 and A.3 comprises the principle points 0 = no glare, 2 = slight glare, 4 = severe glare, and 6 = intolerable glare.

The choice of figures A.2 or A.3 depends on the type of luminaire, its orientation and the viewing direction, and is indicated in the captions to the figures.

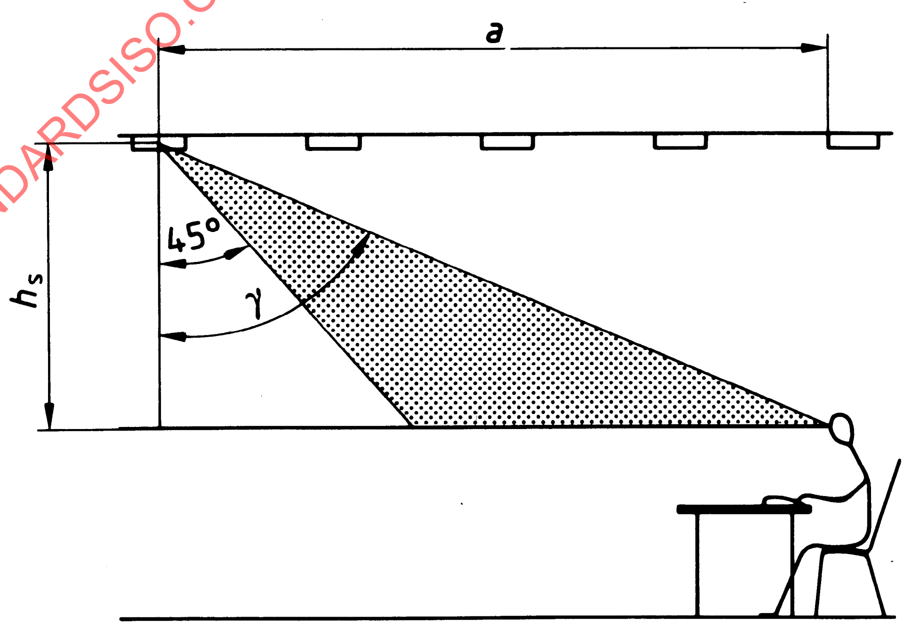


Figure A.1 — Angles of elevation in which luminance limits of luminaire have to be observed

For glare limitation, the type of luminaire shall be determined according to the following criteria:

1 a) luminaires with luminous sides

1 b) luminaires without luminous sides

NOTE 1 — A luminaire with a luminous side panel with a height not greater than 30 mm is considered as a luminaire without luminous sides.

2 a) linear luminaires

2 b) non-linear luminaires

NOTE 2 — A luminaire is considered as linear when the ratio of length to width of its luminous area is not less than 2 : 1.

Glare rating	Quality class	Service values of illuminance (lx)							
1,15	A	2 000	1 000	500	<300				
1,5	B		2 000	1 000	500	<300			
1,85	C			2 000	1 000	500	<300		
2,2	D				2 000	1 000	500	<300	
2,55	E					2 000	1 000	500	<300
		a	b	c	d	e	f	g	h

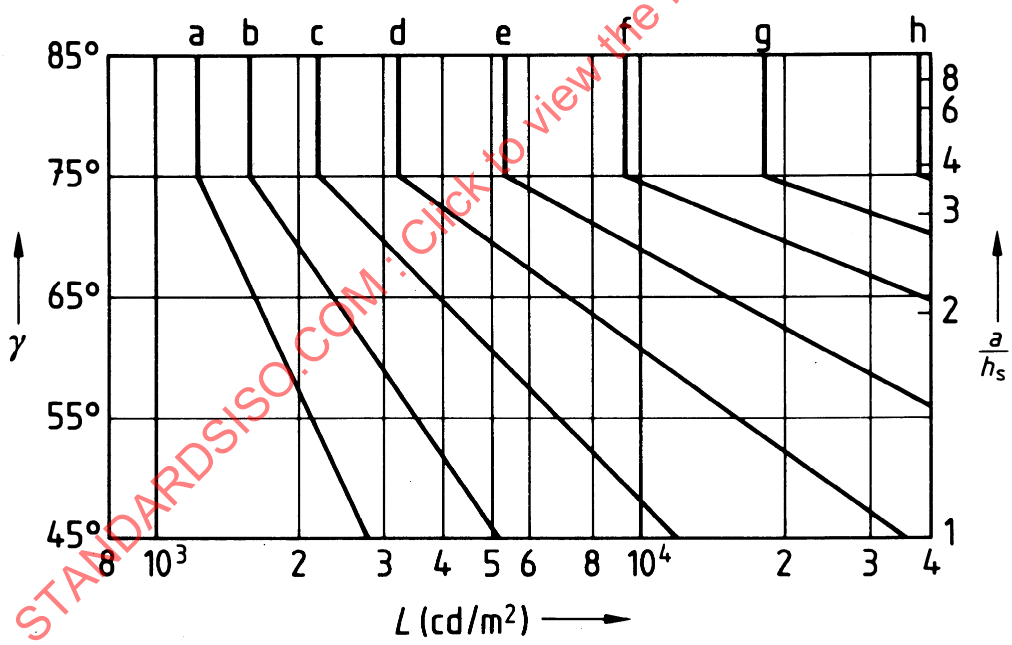


Figure A.2 — Luminance limitation curve for all luminaires without luminous sides and for linear luminaires with luminous sides when viewed endwise

Glare rating	Quality class	Service values of illuminance (lx)							
1,15	A	2 000	1 000	500	< 300				
1,5	B		2 000	1 000	500	< 300			
1,85	C			2 000	1 000	500	< 300		
2,2	D				2 000	1 000	500	< 300	
2,55	E					2 000	1 000	500	< 300
		a	b	c	d	e	f	g	h

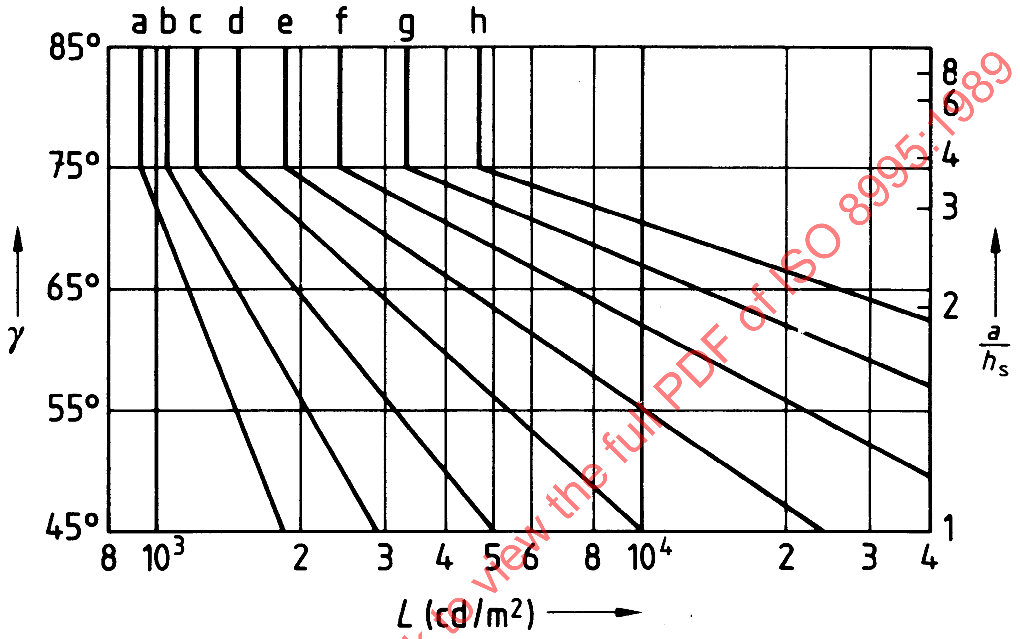


Figure A.3 — Luminance limitation curve for all luminaires with luminous sides except for linear luminaires with luminous sides when viewed endwise

A.1.1 Orientation of luminaires

When using figures A.2 and A.3 the luminance distribution of the luminaire in the two main perpendicular vertical planes, i.e. the $C_0 - C_{180}$ plane and $C_{90} - C_{270}$ plane (see figure A.4), should be considered.

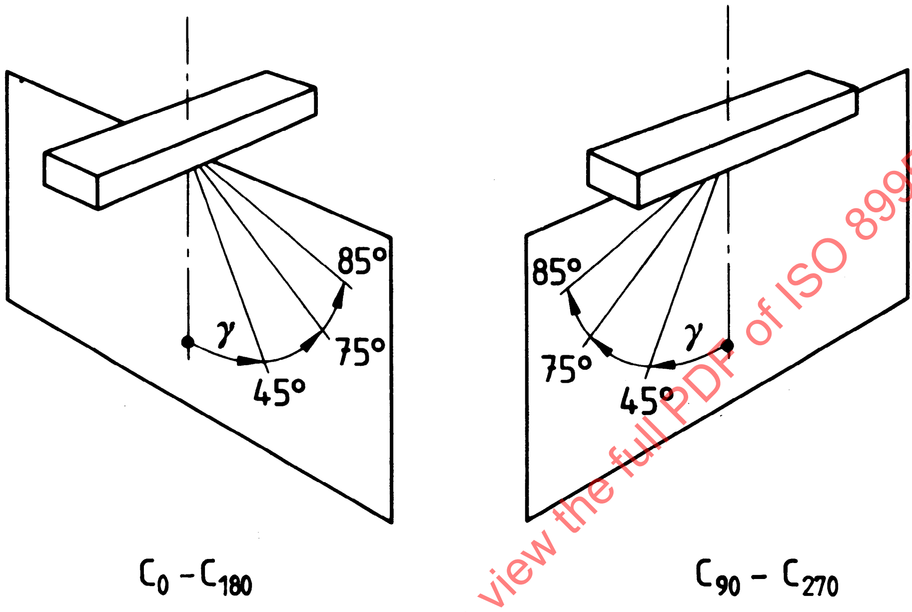


Figure A.4 — C-planes and γ-range for the checking of luminance distribution of the luminaire

When the luminaires are mounted with the $C_0 - C_{180}$ plane parallel to the length of the interior, the luminance distribution of the luminaire in this plane should be used for checking the glare limitation in the lengthwise direction and the luminance distribution in the $C_{90} - C_{270}$ plane for checking the glare limitation in the direction of the short axis (width).

When the luminaires are mounted with the $C_{90} - C_{270}$ plane parallel to the length of the interior, this plane should be used for checking the glare limitation in the lengthwise direction and the luminance distribution in the $C_0 - C_{180}$ plane for checking the glare limitation in the direction of the short axis.

For linear luminaires the $C_{90} - C_{270}$ plane is that through (or parallel to) the longitudinal axis of the lamp(s). When this plane is parallel to the viewing direction, viewing is said to be lengthwise; when the $C_{90} - C_{270}$ plane is perpendicular to the viewing direction, viewing is said to be crosswise.

A.1.2 Ratio a/h_s

Instead of the appropriate range of critical angles γ, a range of critical ratios of a/h_s can be used, the values of which are plotted at the right-hand side of figures A.2 and A.3: a is the horizontal and h_s the vertical distance between the observer's eye and the farthest luminaire (see figure A.1).

A.1.3 Luminance values

The luminance distribution of the luminaires in the $C_0 - C_{180}$ plane and in the $C_{90} - C_{270}$ plane to be taken into account are initial values, i.e. the initial luminous lamp flux is used for the calculation. The average luminance of the luminaire in a given direction can be calculated as the quotient of the luminous intensity in that direction and the apparent luminous area.

A.1.4 Quality class

For different activities and/or interiors the importance and extent of glare limitation is different. For this reason five quality classes have been introduced:

Class A: very high quality, very exacting visual tasks;

Class B: high quality, tasks with high visual demands;

Class C: medium quality, tasks with moderate visual demands;

Class D: low quality, tasks with low visual demands and concentration levels;

Class E: very low quality, interiors where workers are not confined to a work station and have tasks of low visual demand.

An example of guidance as to which quality class is appropriate is given in table B.1 together with the example of recommended illuminance values. The values of recommended illuminance from 300 lx upward constitute a parameter, in combination with the quality class, for selecting the appropriate luminance limit curve.

A.1.5 Validity of the luminance curve system

The limiting curves are valid if all three of the following conditions are met:

a) general lighting;

b) predominantly horizontal and downward lines of sight;

c) reflectance of at least 0,5 for ceilings and 0,25 for walls and furniture.

A.1.6 Shielding angle

For luminaires with diffusion type reflectors whose lamps or parts are visible, when viewed at angles from the vertical of 45° and greater, not only should the average luminance of the luminaire be limited according to the limiting curves of figures A.2 and A.3, but in addition the lamps should be sufficiently shielded; the degree of shielding depending on the luminance of the lamp and the selected quality class. The required shielding angles (see figure A.5) are given in table A.1. If the shielding angle is less than the tabulated value, the lamp luminance as shown in figure A.3 should be used for checking the glare limitation. In the case of luminaires for fluorescent lamps only the shielding angle in the $C_0 - C_{180}$ plane should be considered.

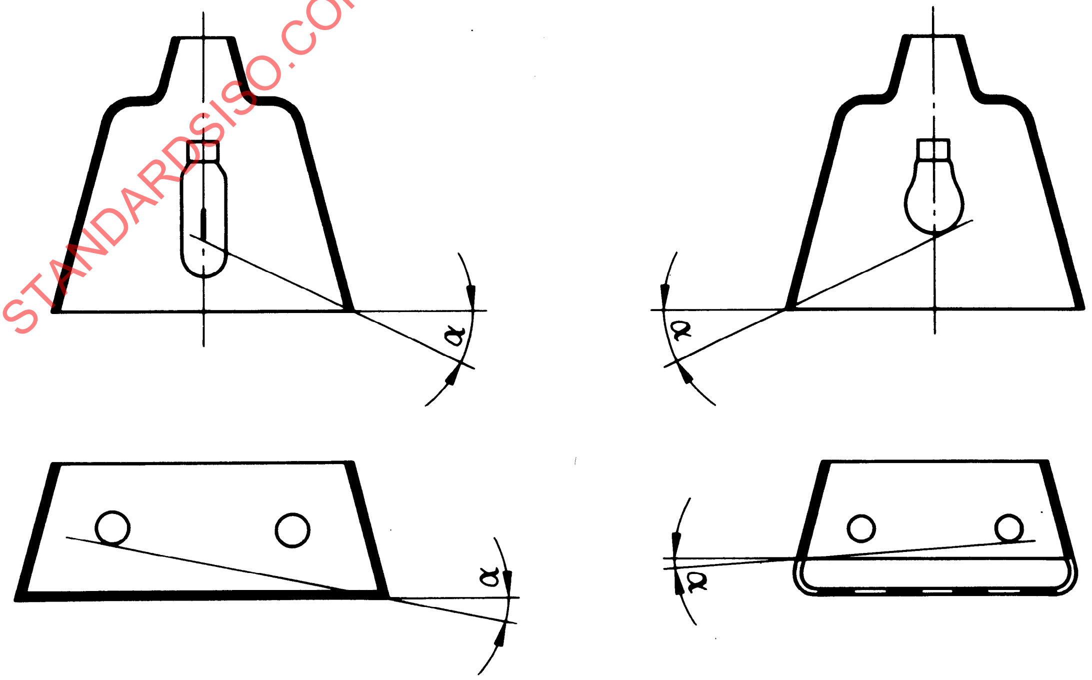


Figure A.5 — Shielding angles for various types of luminaires in which the lamps or parts (or reflected image) are visible when viewed at critical angles

Table A.1 — Additional minimum shielding angles for luminaires in which the lamps or parts are visible when viewed at critical angles

Range of average lamp luminance	Quality class of glare limitation		Lamp type
cd/m²	A, B, C	D, E	
$L < 20 \times 10^3$	20°	10°	Tubular fluorescent lamps
$20 \times 10^3 < L < 500 \times 10^3$	30°	20°	High-pressure discharge lamps with fluorescent or light-diffusing bulbs
$500 \times 10^3 < L$	30°	30°	High-pressure discharge lamps with clear bulb; clear-glass incandescent lamps

A.2 Luminance limitation for luminous ceilings

For luminous ceilings the limitation of glare is adequate if the ceiling luminance at angles greater than 45° from the downward vertical (see figure A.1) does not exceed 500 cd/m².

A.3 Relation of the luminance curve system to other national systems

The luminance curve system gives results, within the limits specified in A.1.6, corresponding to the alternative systems, as indicated in table A.2. It should be noted that a given luminance limit curve (indicated by the letter) corresponds to a given Glare Index (GI) or Visual Comfort Probability (VCP) criterion for all illuminances, but it corresponds to a different glare rating and quality class in the luminance curve system according to the illuminance on the work plane.

Table A.2 — Approximate equivalents of glare quality classes in national systems

Luminance curve system	Curve letter	a	b	c	d	e	f	g	h
Glare Index System	GI	15,5	17,0	18,5	20,0	21,5	23,0	24,5	26,0
Visual Comfort Probability System	VCP			75 %	65 %	55 %	45 %		

A.4 Instructions for use of the luminance curve system and examples

To use figures A.2 and A.3

a) choose the appropriate figure, taking into account the direction and the kind of luminaire. If there is no fixed direction for the observation, then make use of

— figure A.2 for luminaires with no luminous side panels, in particular for recessed luminaires;

— figure A.3 for luminaires with luminous side panels according to the instructions given in clause A.1;

b) choose the limiting curve that corresponds to the desired quality class of the task and to the illuminance level;

c) compare the luminance of the luminaire, determined for the initial flux of the lamps (obtained from the lamp manufacturer's catalogue), with the limiting curve chosen.

There should be no glare if the value of the luminaire luminance is lower than that of the limiting curve for the direction considered. This is always the case if the average luminance curve considered is located entirely to the left of the limiting curve. If it is located entirely to the right, the luminaire is not suitable.

If the average luminance curve cuts the limiting curve, ensure that the luminances are smaller than the limiting luminance at all critical viewing directions within the room considered.

A.4.1 Verification of direct glare requirements of a rectangular luminaire placed in a given room

Example 1: Recessed luminaire

a) Design conditions:

1) Recessed luminaire with prismatic diffuser, located parallel to the viewing direction of persons in an office;

2) E = 600 lx;

3) h_s = 1,80 m (see figure A.1);

4) luminance curves given by the manufacturer (see figure A.6).

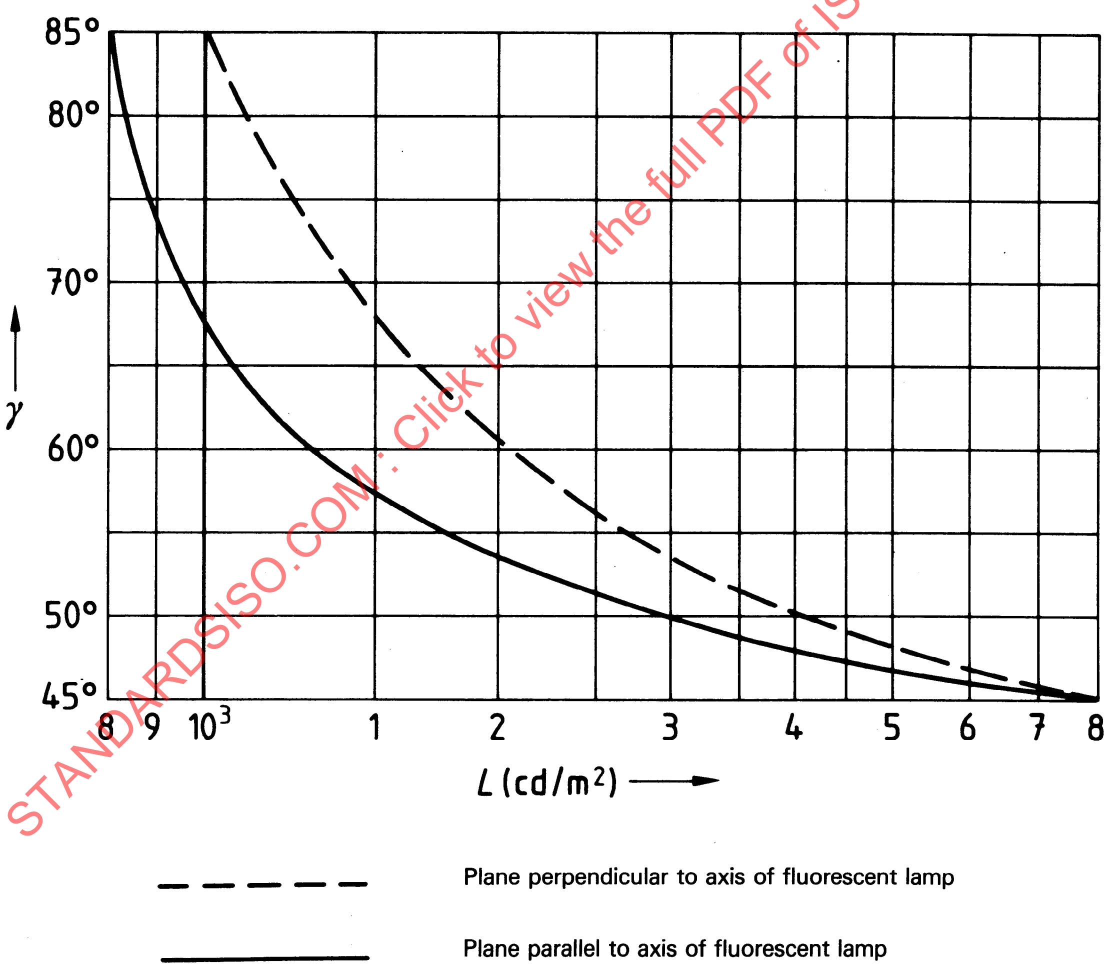


Figure A.6 — Luminance curves for examples 1 and 2