Lighting Guide 4: Sports Lighting

The Society of
Light and Lighting

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The Society of Light and Lighting is part of the
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Foreword

This revised Lighting Guide replaces the LG4 Lighting Guide: *Sports Lighting* published in 1990. Recommendations within this guide have been aligned to the British Standard and European Norm BSEN 12193:1999. In updating the information note has been taken of new and emerging sports that were not included in the 1990 guide or BSEN 12193:1999 but which are played in the UK, and of proposed amendments to BSEN 12193.

The sport requirements and recommendations have been changed to give specific information relating to good lighting practice for each individual sport. Tabulated lighting parameters are provided for each sports application relative to the new system of lighting classes. There is additional information regarding colour television (CTV) group categories and colour rendering index recommendations.

The revised guide is now in four parts.
Part A: Principles of lighting with respect to sport
Part B: Specific lighting requirements for individual sports (indoor and outdoor)
Part C: Maintenance and operation of sports lighting
Part D: Specification of equipment for sports lighting

As before, the aim of the guide is to create design flexibility while achieving basic lighting requirements for each sport.

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Section 7 has been superseded; see addendum 7a, pages 51a to 51f

Part A: Principles

1 Scope

This guide is concerned with the lighting of sports areas and other playing and recreational areas.

Specific recommendations for individual sports are given in section 3 of the guide. The requirements of large multi-purpose venues and specific provision for television broadcasting are provided in sections 4–7.

The general information and lighting levels provided in the guide are aligned to the requirements of the British and European standard BSEN 12193:1999.

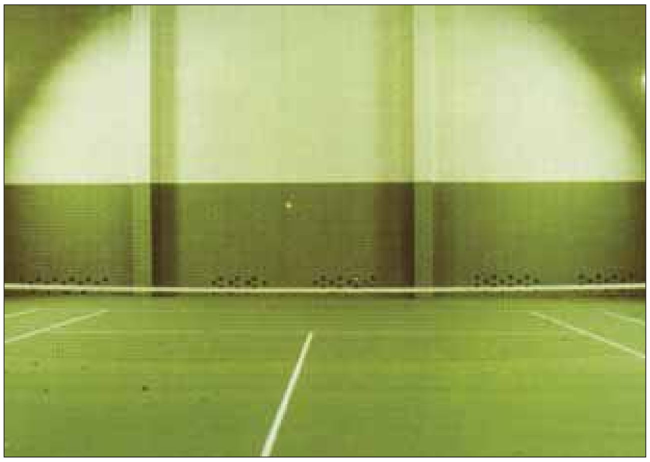
2 Requirements

Sports and sports areas should be lit so that those taking part and those watching, whether at the event or on television, can see clearly all that is going on. This calls for suitable brightness and contrast over the playing area, sufficient light at all points, correct distribution of light and adequate control of glare. Playing objects will be seen because they contrast with their background in brightness, colour or both. The more marked the contrast, the more clearly objects are perceived in general. There are additional special requirements for television transmission which are discussed in section 7.

2.1 Colour, brightness and reflectance

Colour contrast is important in some sports and the choice of surface colours for interiors can help to make the object more visible. The brightness of a surface depends on how much light it receives and how this light is reflected from it – ie on its illuminance and its reflection properties. In principle, therefore, brightness contrasts can be controlled by adjusting the reflectance and illuminance for both the object and the background. In practice, however, there are often restrictions on what can be done, especially outdoors. For example, as the reflection properties of a sports pitch cannot be altered, the illuminance is the main mechanism used to improve contrast. There is usually more freedom indoors. For instance, the reflectance and illuminance of tennis court surfaces can be specified, and so produce the background needed for the ball to be seen clearly in silhouette (see figures 1 and 2).

Figure 1 (Below left) The tennis ball can be clearly seen in contrast to the dark green background. The lower wall reflectance is 0.2.



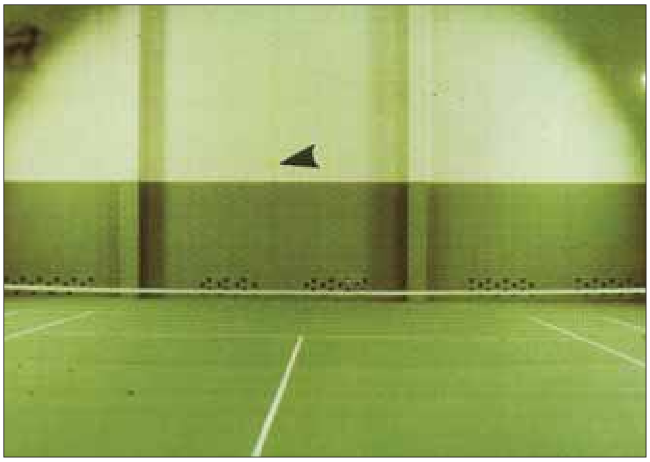


Figure 2 (Above right) Insufficient contrast between ball and background makes it difficult to see. The upper wall reflectance is 0.5.

Reflectance values and types of surface materials used must be taken into account in the design. The reflectance and colour of the surroundings and background of a light source will also influence the amount of discomfort experienced.

2.2 Illuminance requirements

The determination of how much light is required to play any given sport depends upon several factors, some of which can be assessed with a degree of scientific and/or clinical accuracy. Contributing factors include:

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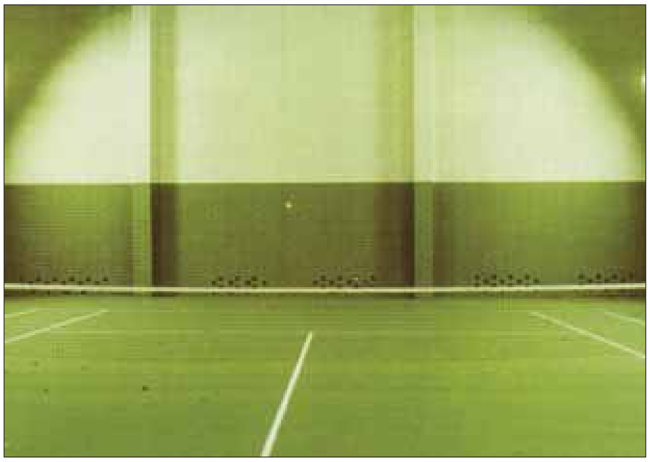

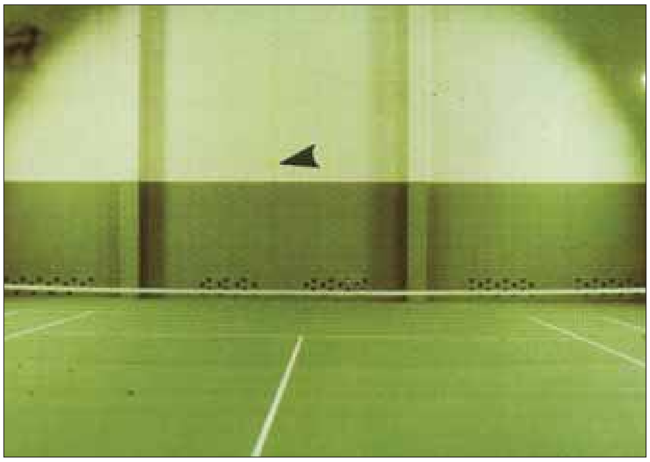

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2.2 Illuminance requirements

The determination of how much light is required to play any given sport depends upon several factors, some of which can be assessed with a degree of scientific and/or clinical accuracy. Contributing factors include:

– the size of the playing object;
– the viewing distance;
– the speed of the activity;
– the contrast sensitivity;
– adaptation;
– the directional qualities of the incident light;
– the reflectance of surfaces to be illuminated; and
– the atmospheric and environmental factors.

Visual acuity normally applies when the observer and visual task are both static. In sport it is more likely that either the observer and/or the visual task are moving, in which case we must consider dynamic visual acuity, ie the ability to discern detail when the observer, the visual task or both are in motion.

It is also important to consider the effects of adaptation. The effect of a stimulus on the human visual system is not constant since it will be influenced by the state of adaptation of the retina at the instant the stimulus is introduced into the field of view. In essence, two forms of adaptation exist: dark adaptation and light adaptation. It can be shown that, when an individual is light adapted and then suddenly introduced into a dark environment, the time taken for the eyes to adapt is considerably longer than it is when the situation is reversed, ie when suddenly traversing from a dark environment to a light one. This phenomenon can have a major influence, particularly when there are inconsistencies in the 'evenness' of lighting.

Levels of illuminance for outdoor sports provided by artificial light sources are usually lower than for the same sport when played indoors. Similarly, illuminances for outdoor sports under artificial lighting are usually lower than the level of prevailing daylight in which the same sport is played. This is due to the corresponding improvement in contrast and adaptation that occurs when viewing a lit surface against a dark background such as the night sky.

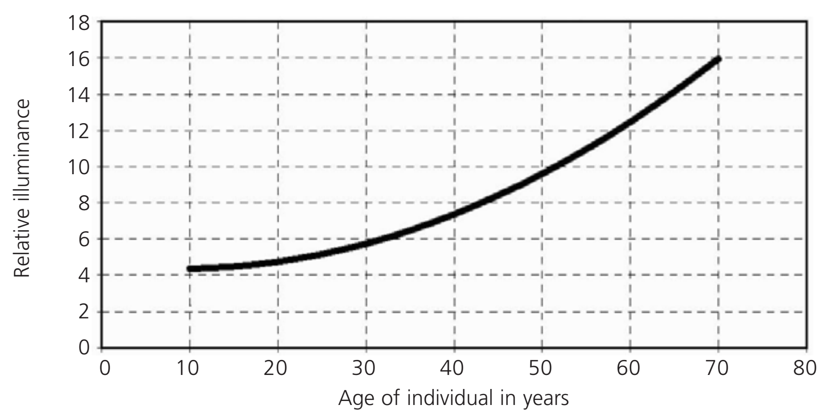
The illuminances stated are maintained values and apply to the principal playing area (PA). Where a sport has specified total area (TA) playing dimensions, the illuminance requirements over the total area should be a minimum of 75% of that provided for the principal area (PA) (see section 2.11).

The velocity of a moving object also influences the lighting requirements for sport. Any lit object passing before the eyes excites the light-sensitive cones on the retina. However, if the object is moving relatively rapidly the number of cones excited at any one instant is relatively small, and therefore the object must be well illuminated for efficient vision.

The illuminances specified are those values measured on a horizontal plane, based primarily upon the needs of participants. However, there is a need to provide an adequate vertical component. The illuminance on principal vertical planes should not be less than 30% of the horizontal level.

The illuminances referred to are those applicable to someone approximately 40 years old. No account has been taken of the changes in the ageing eye, which can be sub-divided into perceptual and physical changes. Figure 3 shows the typical change in illuminance requirements as a function of age.

Figure 3 Typical relationship between the relative illuminance requirement and the age of the individual



The level of sport competition/participation and class of play will be used to determine the recommended minimum illuminance required. The higher the standard of play and the longer the spectator viewing distance, the higher the lighting class. Due to the nature of some levels of competition and lighting classes, there may be overlap in specified minimum illuminances.

Lighting class I

– International and national competition
– Large spectator capacities with long viewing distances
– Top-level supervised training

Lighting class II

– Mid-level competition; principal local clubs and county regional competition
– Medium spectator capacities with medium viewing distances
– High-level supervised training

Lighting class III

– Low-level competition; local or small club competition
– Minimal or no spectator provision
– General training; school sports and recreational activities

Table 1: Selection of lighting class

Level of competition	Lighting class		
	I	II	III
International and national	*		
Regional and county	*	*	
Principal clubs	*	*	*
Small clubs		*	*
General training, recreational and school sports			*

2.3 Light distribution, uniformity and illuminance gradient

Ideally, playing surfaces should appear uniformly bright when viewed from relevant directions. How far this can be achieved in practice depends on the reflection properties of the surface and how it is illuminated.

The first step is usually to design for an acceptable uniformity of illuminance as expressed by the recommendation for the sport. These are minimum values. All uniformities specified are defined as the minimum-to-average illuminance over the area, where these illuminance values are calculated at the specific grid points.

In some sports an illuminance gradient may be specified to ensure that the rate of change of uniformity is acceptable. This is usually associated with the avoidance of banding or acute patchiness on the playing surface.

The resulting uniformity of brightness depends on the reflection properties of the surface as well as on the uniformity ratio. With grass, for example, it depends on the angles at which the light falls on the grass, the direction from which the surface is viewed, the ways in which the grass has been cut and rolled and whether the ground is wet or dry.

The effects of irregular surface reflection can seldom be estimated by calculation alone. It is important to remember that the appearance of the lit playing surface may not relate to the illumination pattern and is influenced by viewing direction.

The lit space above the playing area should be reasonably uniform. If not, playing objects will appear to accelerate as they pass from a light to a dark zone, causing difficulties in judging flight and speed.

2.4 Glare

Glare may either impair vision (disability glare) or cause discomfort (discomfort glare). As both forms can occur simultaneously or separately, the control of glare is therefore a major factor to be considered in defining lighting.

In sports applications, direct discomfort glare is generally caused by high-brightness light sources coming into a participant’s field of view. Minimising this may require special attention to the selection, positioning and screening of light sources and the use of diffusers, reflectors, refractors and similar devices on the luminaires. As the viewing direction of the participants constantly changes, it is difficult to provide definitive advice. However, some sports have frequently recurring viewing directions, so there is a need to limit discomfort glare as far as possible in principal viewing directions.

Some glare from light sources is unavoidable and may cause a certain amount of discomfort to players, officials and spectators. In exterior applications glare may also produce obtrusive light to the surrounding locality if not adequately controlled.

The degree of glare should always be restricted to a level where vision is not seriously affected. The levels of brightness of both the light source and adjacent background are important factors in the cause of glare. If the contrast between these is reduced, so will the effect of the glare.

This can be achieved in several ways.

- Lamps can be screened from view by an internal baffle and/or external louvre or cowl fitted to the luminaire.
- Luminaires may utilise a deep reflector to recess the lamp from view.
- Luminaires may incorporate a variable reflector to emit the beam forward from the nadir to the front glass, allowing shallower luminaire elevations in use.
- Luminaires may incorporate precise beam control to restrict stray light and focus the beam within the lit area.
- Luminaires can be positioned so that the observer's line of sight is avoided.
- Background brightness can be controlled by utilising suitable room surface reflectances to reduce contrast in indoor sports applications.

The need to limit glare may conflict with other requirements. For instance, players and spectators are likely to be troubled most by glare when light reaches them at angles near the horizontal. However, it is this light which contributes to vertical plane illumination, enabling shuttles to be clearly seen in flight during badminton. The problem usually occurs where mounting heights are too low.

Glare associated with exterior sports may be evaluated by calculating the glare rating for the lighting installation. Control of discomfort glare in indoor applications may be evaluated using the unified glare rating (UGR) method. Disability glare in interior lighting is controlled by limiting the shielding of bare lamps (see SLL *Code of Lighting*). The recommended procedure for evaluating both glare rating and unified glare rating are provided within the Calculations section of the *Code for Lighting* CD edition.

2.4.1 Glare rating

Glare rating is calculated at a regular array of observer positions and viewing directions, specified to allow determination of the highest degree of glare over the playing surface. The maximum GR value achieved over the sports surface is taken as the glare rating for the sports installation. In this glare assessment the lower the value of GR, the better the glare restriction.

Glare rating is expressed for practical purposes as a number between 10 and 90, with interpretation as shown in Table 2.

Table 2 Glare rating

Glare rating	Interpretation
10	Unnoticeable
30	Noticeable
50	Just admissible
70	Disturbing
90	Unbearable

2.4.2 Unified glare rating

In interior applications the likelihood of glare being experienced can be estimated by calculating the unified glare rating. The calculated index for a particular interior and lighting system can then be compared with a limiting value given in the recommendations of the SLL *Code for Lighting*. If the calculated value is greater than the recommended limit, modifications to the lighting system or the interior may be required.

2.5 Requirements for sport played by the visually impaired

The term ‘visual impairment’ refers to a permanent loss of visual function that will exist even after correction with either spectacles or contact lenses. Loss of vision may develop following disease or trauma, and the incidence of sight loss increases in older individuals.

Though improved lighting can remedy some of the problems likely to be experienced by older individuals, they can often be more seriously affected by the lighting conditions so produced. They often require more light to perform a given visual task but simultaneously may become more easily affected by dazzle from sources of glare due to the increased luminance subsequently produced.

However, where there is some clearly acknowledged pathology, an individual’s preference for lighting will depend very much on the precise nature of the pathology from which they suffer. In some situations increased lighting will produce far worse conditions both in terms of the way the retina responds and the way ocular structures such as the cornea, if damaged, will increase the adverse effect of glare.

2.6 Daylight

The extent to which daylight should be admitted into a building is a primary decision taken at the design stage. The use of daylight within a sports area can have a positive affect upon participants, although the sun or sky seen through windows or by reflection in glossy surfaces can cause an unacceptable level of disability or discomfort glare. It may contribute to energy savings provided that it is controlled effectively.

It is therefore recommended that any proposed use of daylight in playing areas is very carefully designed and controlled so as not to distract or impair the visual requirements of participants, officials or spectators (with the use of high-level, north-facing glazing for example).

2.7 Ancillary areas

Ancillary accommodation for sports facilities can usually be divided into:

- administrative areas (offices, meeting room, staff room, reception, corridors);
- social areas (bar, reception room, entrance lobby, viewing area);
- plant areas (chemical store, plant room, lift motor room); and
- other areas (changing rooms, toilets, first aid and general circulation areas).

Where a further area is to be used for sporting activity, many of the criteria and requirements for sports halls can be applied, depending on the particular activities. Recommendations for areas that are not specific or unique to sports facilities are provided in the SLL *Code for Lighting*.

2.8 Emergency lighting

Emergency lighting should be provided when the main lighting system fails. There are two types: escape lighting and standby lighting. However, in sports applications standby lighting may be subdivided into ‘safety lighting’ and ‘continuation of an event’ (see Figure 4).

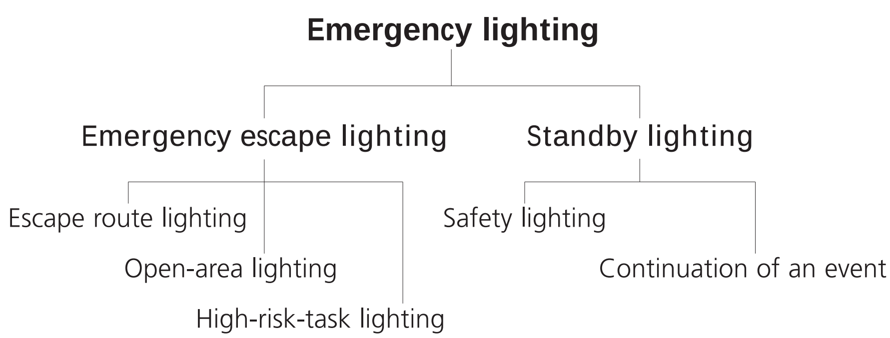


Figure 4 The hierarchy of emergency lighting systems

BS 5266 *Code of Practice for Emergency Lighting* lays down minimum standards for the design, implementation and certification of emergency lighting installations. These must be in accordance with the Building Regulations 2000 as implemented by the building control officers. Regular risk assessments should be carried out on the premises by the appointed "responsible person".

Note that outside England and Wales the regulatory framework for fire safety differs from country to country

2.8.1 Emergency escape lighting

Emergency escape lighting is provided to ensure the safe and effective evacuation of the building in accordance with the requirements of BS 5266-1:2005 *Emergency Lighting Part 1: Code of practice for the emergency lighting of premises*.

Emergency escape lighting must:
- clearly and unambiguously indicate the escape routes;
- illuminate the escape routes to allow safe movement towards and out of exits; and
- ensure that fire alarm call points and fire equipment provided along the escape route can be readily located.

Lighting levels should be as recommended in BS 5266-7:1999/BSEN 1838:1999.

Application requirements and guidance are provided in:
- BS 5266-8:2004/BSEN 60172:2004; and
- SLL LG12:2004 *Emergency Lighting Design Guide*.

2.8.2 Standby lighting

It may not be possible or desirable to evacuate some sports facilities immediately in the event of an emergency or power failure. This may be because life would be put at risk or a safe shutdown procedure is required. In these instances standby lighting is required to allow appropriate actions to take place (see section 2.8.2.1) or activities to continue (see section 2.8.2.2). The level of standby lighting will depend upon the nature of the activity, its duration and the associated risk.

2.8.2.1 Safety lighting

Safety lighting is required to ensure that, in case of a power failure, the safe stopping of an event can be achieved without injury to the participants. In some sports it could be dangerous to continue in the absence of safety lighting, which should not be confused with emergency lighting.

The recommended illumination level(s) for the safe stopping of events are given in the appropriate sports application sections.

2.8.2.2 Continuation of an event

Standby lighting may be provided to allow the continuation of an event in instances of power failure.

Careful thought needs to be given to the system of lighting that will take over while the main lighting is out. Possible options are:
- the installation of a secondary lighting system that activates with the supply at all times. This may be either incandescent or fluorescent;
- the provision of a change-over switch that automatically switches on a secondary lighting system, with a detector switching it off when the main system is operational and fully run up; and
- the installation of a 'hot re-strike' system. This requires a special control gear circuit to generate the high voltage necessary to re-strike the hot lamp instantly. Because of the high voltage, such a system may require a special design of lamp and luminaire. It is usual to install a percentage of these devices sufficient to enable the event to continue, rather than for the whole installation.

In interior sports applications it is advisable for ancillary lighting powered by battery back up to be utilised to provide instantaneous power while the auxiliary power is run up. It can take up to 20 s before the power source has reached normal output. The system is usually activated simultaneously with the standby power/generator installation.

For the continuation of a sports event, the lighting level required should be at least that associated with class III for that particular sport.

2.9 Surveillance lighting

Surveillance lighting is provided to allow the monitoring and recording of crowd movement, traffic monitoring and protection of the building fabric by CCTV cameras situated internally and externally to the building. While cameras for surveillance are available with a wide range of lenses and controls, for sporting applications the following factors determine the choice of equipment:

– picture quality; and
– camera positioning.

The type of camera required and the associated lighting installation should be decided at the design stage.

2.10 Planning requirements

During the feasibility study and creation of the design concept for any lighting installation it is recommended that local planning requirements are considered. Early discussion with planning authorities is advised. In exterior applications the likely issues arising from floodlighting may involve:

– mounting height restriction;
– obtrusive light (light pollution);
– installation aesthetics; and
– landscaping or screening.

There may also be a need to discuss floodlight usage.

2.10.1 Obtrusive light

In exterior applications the obtrusive light from floodlighting should be considered with respect to:

– sky glow (direct upward waste light);
– overspill (intrusive light and light into windows); and
– glare (source intensity).

These potential problems should be given consideration at the design stage as part of an overall environmental impact appraisal (see the SLL *Guide to Obtrusive light*, the ILE *Guidance Notes on the Reduction of Obtrusive Light* and CIE 150 *Guide on the limitation of the effects of obtrusive light from outdoor lighting installations*). Light pollution is a recognised statutory nuisance in the UK under the Clean Neighbourhoods and Environment Act 2005. Recommended limitations on obtrusive light are shown in Table 3.

Table 3: Recommended obtrusive light limitations.

Environmental zone	Sky glow ULR inst. (max %)	Light trespass (into windows) E_v (lux) max	Source intensity I (kcd) max
E1 Dark landscapes	0	2	2.5
E2 Rural, village, dark urban locations	2.5	5	7.5
E3 Urban locations and small town centres	5	10	10
E4 Town and city centres	15	25	25

Note 1: Lower values may apply in relation to light trespass and source intensity where curfews are implemented by a local planning authority.

Note 2: ULR inst. relates to the upward light ratio for the full lighting installation.

Note 3: Where sports lighting overspills onto public highways, a limiting value of threshold increment should apply (TI = 15% max). To calculate TI see EN 13201-3.

Figure 5 Example of multi-use pitch with good obtrusive-light control.

2.11 Definitions of playing areas

Principal area (PA) – The playing area needed for the performance of a certain sport. Usually this means the actual marked out ‘court’ or ‘pitch’ area for that sport (eg football), but in some cases this area comprises an additional playing area around the marked area (eg tennis, volleyball, table tennis). Note: The particular area dimensions should be checked with the relevant sport governing body when designing a lighting installation.

Total area (TA) – Generally this area comprises the principal area plus an additional safety area outside the principal area.

2.12 Safety and protection of luminaires

In order to ensure the safety of sports participants and to reduce the risk of damage from balls and other objects, it is important that all luminaires and equipment are, wherever possible, located outside the main activity zone and adequately protected. All parts of the installation should also be carefully detailed to avoid obvious traps for balls, shuttles and similar objects, even when outside the normal playing zone.

Part B: Applications

3 Specific sports

Recommendations for lighting individual sports are given in this section. The sports are listed in alphabetical order. The following notes interpret and supplement some aspects of the recommendations.

- Design illuminances are generally given from the point of view of players to enable them to participate. Where there are specific spectator requirements these are shown separately. For TV requirements see section 7.
- The recommended illuminance in this guide is the minimum maintained average illuminance. Separate values are recommended for different classes of play.
- The uniformity ratio is defined in the guide as the ratio of the minimum illuminance over an area to the average illuminance. The recommended values are minima.
- Unless a specific lighting solution is recommended or certain constraints given, the user is free to meet the required performance criteria from any installation layout deemed suitable.

3.1 Archery ranges

Archery ranges generally accommodate target distances of 30–90 m at 10 m increments. The lighting must enable the targets to be easily seen at each distance and allow archers to see the position of each arrow in the target.

Sufficient light is also needed in the shooting zone for nocking, making bow adjustments and for general safety and movement. It is also important to provide general illumination of the ground between the shooting line and the targets to assist in judging distances.

Floodlighting positions should be located behind the shooting line and aimed directly at the furthermost targets. It is usual for several shooting positions to converge onto a single target.

If adequate illumination of the furthermost targets is provided, then sufficient illumination of the nearer targets and ground to the shooting line is normally achieved. Whether or not the main lighting produces sufficient spill light to illuminate the shooting zone will depend upon the type of lighting system used.

Glare should not cause a problem for archers when they are shooting at targets. After retrieval of the arrows, however, glare may be experienced when the archers are returning to the shooting line.

Indoor archery generally takes place in large multipurpose sports halls or arenas (see sections 4 and 6).

Class	Horizontal illuminance shooting zone		Vertical illuminance on target					Colour rendering index
			Outdoor		Indoor			
					25m dist.	50m dist.		
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}	E_{vav} (lx)	E_{vav} (lx)	E_{vmin}/E_{vav}	
I	200	0.5	750	0.8	1000	2000	0.8	60
II	200	0.5	750	0.8	1000	2000	0.8	60
III	200	0.5	750	0.8	1000	2000	0.8	60

CTV group A

3.2 Athletics

Most athletics events take place in a stadium or indoor arena that is likely to be lit to a standard that simultaneously satisfies the illuminance requirements both for track events and for those areas bounded by the track that are used for field events (see sections 5 and 6).

Athletics encompasses such events as discuss and hammer throwing, shot put, high jump, hurdling, long jump, javelin, pole vault, running, triple jump etc, and takes place either outdoors or indoors. Indoor events that do not use the running track are still referred to as field events.

For events involving discuss, hammer and javelin throwing, it is important for the lighting to show the full flight of the projectile.

Class	Horizontal illuminance				Colour rendering index	Glare rating
	Indoor athletics		Outdoor athletics			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	500	0.7	60	50
II	300	0.6	200	0.7	60	50
III	200	0.5	100 (note 3)	0.5	20	55

CTV group A

Note 1: Glare should be controlled by careful positioning of luminaires, over the pole vault area for instance.

Note 2: The vertical illuminance at the finishing line should be at least 1000 lux for photo-finish equipment.

Note 3: For outdoor tracks (class III) the level of horizontal illuminance can be reduced to 50 lux for jogging (see section 5).

Figure 6 (Below left) An indoor athletics track with low ceiling height.

Figure 7 (Below right) An indoor athletics track training facility with a glazed side wall for maximum use of daylight.

3.3 Badminton (indoor)

As the shuttle may move at relatively high speeds over the net, it is essential for players to be able to follow the flight of the shuttle, seen in contrast against the dark background, without being troubled by glare or having their concentration adversely influenced by high-intensity light sources in the vicinity of sight lines.

For optimum visual conditions the shuttle is more easily seen when illuminated against a dark background. The path of the shuttle during play is often high above the net and therefore sufficient vertical illuminance must be provided.

Badminton is typically played either in a dedicated facility or in a multi-purpose sports hall (see section 4).

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group B

Note 1: No luminaires should be positioned in that part of the ceiling directly above the playing area.

Note 2: The reflectance values of court-side fabrics should not be greater than 0.5 for walls and 0.6–0.9 for ceilings. Background colours of blue and green are preferable.

Note 3: The Badminton Federation may require particular specifications for competition and international provision.

3.4 Baseball

A fast sport when the ball is pitched and hit, baseball requires high levels of illumination to enable the action and flight of the ball to be followed. Most of the fast action takes place in the regulation-sized infield, which will require a significantly greater illuminance and overall uniformity than the larger outfield (the area of which may vary). Floodlighting must minimise shadowing and achieve good modelling of players while providing control of glare to players, officials and spectators.

Due to the regulation infield layout of pitcher, hitter and three base-plate fielders, baseball is probably unique in having nine fixed lines of sight within which mast locations should be avoided if glare from floodlighting is to be adequately controlled. Masts are not permitted within a 90° zone directly behind the home plate to ensure good viewing conditions for outfielders.

These mast placement regulations generally dictate the use of either six- or eight-mast floodlighting systems, with floodlights aimed to illuminate three distinct zones (infield diamond, far infield/near outfield and deep outfield). The provision of at least bi-directional lighting into each zone is necessary if adequate modelling of players is to be achieved.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Infield		Outfield			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	750	0.7	500	0.5	50	60
II	500	0.7	300	0.5	50	60
III	300	0.5	200	0.3	55	20

CTV group B

3.5 Basketball

Basketball is played indoors at all levels of competition and outdoors at a primarily recreational level. The lighting should enable players to follow the movement of the ball while being able accurately to discern the court markings at floor level. Good vertical illuminance on a fast-moving ball is important so as to prevent apparent changes in ball speed.

Basketball is typically played in a dedicated facility, a multipurpose sports hall (see section 4) or a multipurpose outdoor court. Luminaires should be positioned so as to cause a minimum of visual distraction to players, although the total elimination of glare is almost impossible.

In order to reduce glare in interior installations it is particularly important to control the fabric reflectance of the ceiling so that, taken as a whole, the luminance contrast of the ceiling (against which the luminaires will be viewed) will not be excessive. Their relatively rapid start, colour rendering and correlated colour temperature characteristics make tubular fluorescent lamps particularly suitable for illuminating indoor basketball courts.

For indoor courts on which different classes of competition may be played, it may be useful to consider dimming when lower competition levels are being staged.

Class	Horizontal illuminance				Colour rendering index	Glare rating
	Outdoor courts		Indoor courts(note 1)			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	-	-	750	0.7	60	-
II	-	-	500	0.7	60	-
III	75	0.5	200	0.5	20	55(note 2)

CTV group B

Note 1: The reflectance values of court-side fabrics should not be greater than 0.5 for walls and 0.6–0.9 for ceilings. Background colours of blue and green are preferable.

Note 2: Outdoor courts only.

3.6 Bowls (indoor)

Indoor greens are normally divided into several parallel 5 m lanes. Visual requirements are for the player to be able to see the jack and the lie of the woods around it and to follow the run of the live wood. Although the speed of the wood is slow, as the viewing distance is high, sufficient illumination must be provided for the position of the woods to be visible at the end of the lane.

Because of the large open area, the uniformity of the brightness of the green is very important. This will be influenced not only by the lighting system but also by the material of the green itself. This generally has a nap that will give a different brightness impression when viewed from different directions. Experience has shown that the effect of the material on the brightness pattern is

Figure 8 An indoor bowling green showing luminaires parallel to the lines of play.

difficult to predict by calculation. An illuminance gradient of not more than 5% per metre is recommended.

The green is preferably illuminated by fluorescent luminaires mounted at a height of at least 3 m in lines parallel with the direction of play. While these lines should ideally be either side of the designated lanes, at heights less than 3 m it may not be possible to achieve this as well as meeting the illuminance gradient requirements. The system must ensure that the green is illuminated uniformly with no discomfort glare for the players. Glare can also be controlled by reducing the contrast between the luminaires and the room surfaces. This is achieved by ensuring that the reflectance is at least 60% for the ceiling and at least 40% for the walls.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	500	0.8	60
II	500	0.8	60
III	300	0.5	20

CTV group A

3.7 Bowls (outdoor)

A player must be able to see the jack and the lie of the woods around it and to follow the run of the live wood. The judgement of the players must not be impaired by harsh shadows, even when both jack and woods are closely clustered.

The bowling green should appear to be uniformly bright from all playing ends while maintaining low glare to participants and spectators. The green should be illuminated from floodlights located either at the four corners or at a minimum of two opposite sides. A high degree of uniformity is necessary with the light reaching all points of the green from at least two directions. This will soften the shadows produced by the woods.

The line of sight is a little below the horizontal, enabling glare to be controlled by careful selection of mounting height and aiming floodlights within near parts of the green.

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	200	0.7	50	60
II	200	0.7	50	60
III	100	0.7	55	20

CTV group A

3.8 Bowling (nine or ten pin)

A player must be able clearly to see the positions of the pins on the pin deck and follow the ball's movement down the lane.

Each lane should appear uniform while maintaining low glare to both the players and spectators without casting major shadows in any direction. Illumination of the lane area is usually provided by a series of ceiling-mounted luminaires, usually behind a saw-toothed ceiling grid providing general illumination or recessed overhead lighting, both of which ensure that shadows are not cast on the lanes.

For competition bowling especially, when players 'exchange' lanes, lane lighting should not offer any advantage to players on one lane over any immediate adjoining lane. Lighting immediately over each set of pins should be of a higher level than that over the lanes and should not cast shadows.

The viewing area is usually situated immediately behind and above the lane area. No shadows or stray light should encroach from the viewing area into the lane area.

Class	Horizontal illuminance (approach lanes)		Vertical illuminance (pins)		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}	
I	200	0.5	500	0.8	60
II	200	0.5	500	0.8	60
III	200	0.5	500	0.8	60

CTV group A

3.9 Boxing

Action is rapid and takes place at close quarters. Referees, judges, spectators and participants need good visibility from all directions.

For supervised training it may be possible to use the general lighting installation. For competition standards the lighting installations should be provided from a ceiling-mounted array of luminaires positioned to provide uniform illumination.

Although horizontal illuminances over the boxing ring are high, the corresponding values on vertical planes can be relatively low (see note 1). The requirements of distant viewing spectators should be considered.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	2000	0.8	80
II	1000	0.8	80
III	500	0.5	60

CTV group C

Note 1: Vertical illuminance should be at least 50% of horizontal illuminance.

3.10 Canoe slalom

Canoe slalom courses are formed from very fast-flowing turbulent water with access and removal points at each end of the course. This turbulence forms a non-level reference surface. Although the course direction is predominantly downhill it is necessary for participants to paddle against the direction of flow so as to negotiate scoring gates hanging above the water.

Lighting should be bi-directional with masts located along both banks of the water and directed predominantly down the course axis. Direct glare to participants should be restricted, but it will not be possible to prevent high-luminance images of the floodlights in the water.

In the case of power failure it should be assumed that canoeists will be in the water. Safety lighting should be provided to enable the event to be stopped without risk to participants.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Water course		Access and removal points			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	200	0.5	50	0.5	50	60
II	100	0.5	50	0.5	50	60
III	50	0.5	50	0.5	55	20

Note 1: Safety lighting (see section 2.8.2.1). Lighting level for the safe stopping of an event is 10% of that for the appropriate class for a minimum of 120 s.

Note 2: The calculation reference plane is at water's edge – finished level per course section.

Note 3: These lighting specifications may also be utilised for white water rafting.

3.11 Cricket (outdoor)

The development of day/night cricket almost invariably involves starting a game in natural daylight but carrying it on through dusk until (depending upon several factors including the time of the year) total darkness prevails. There is therefore a requirement for some form of floodlighting to be installed.

Floodlighting installations, whether temporary or permanent, are subject to some constraints which include:

- satisfying local authority regulations for the use of portable generating equipment (with its attendant noise problems) into the evening, which may be unacceptable for adjacent residents; and

– restricting the mounting heights of floodlighting towers to accommodate local planning requirements.

The total playing area is separated into the infield (the wicket square) and the outfield extending to the boundary. Each will have a different lighting requirement.

Glare can be a problem and, whilst its adverse effects can be minimised, total elimination is very unlikely. Good contrast helps to provide optimum visual conditions for participants and spectators, and to this end a white or light-coloured ball is used to provide acceptable contrast against the night sky.

Generally, installation 'switch on' occurs at the end of the innings of the first batting side so that the lamps can reach their luminous stability in preparation for the second batting side to start its innings. However, the umpire has overriding control of the floodlighting at any time during play.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Infield (wicket square)		Outfield			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	750	0.7	500	0.5	50	60
II	500	0.7	300	0.5	50	60
III	300	0.5	200	0.3	55	20

CTV group C

3.12 Cricket (indoor)

Action is rapid and can take place at close quarters. Umpires, spectators and players need good visibility from all directions to enable the movement of the ball to be followed.

The lighting installations should be provided from ceiling-mounted luminaires positioned to provide uniform illumination without glare. Where protective netting is required, this should ideally be installed 1 m below the luminaires.

Glare cannot be eliminated completely as players must look upwards, but can be controlled by diffusing the light output and reducing the contrast between the luminaire and the ceiling.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group C

3.13 Cricket (indoor training nets)

Participants must be able to concentrate in safety without distraction from the lighting installation. The bowler and batsman must be able to follow the movement of the ball during its flight. The bowler must have a clear view of the wicket and the batsman must be able to study the bowler's action and run up.

Figure 9 An indoor cricket training facility showing luminaires parallel to the axis of play with the nets being used to reduce glare

Lighting is normally provided by luminaires mounted transversely to the practice area, with care taken to minimise glare.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	1500	0.8	60
II	1000	0.8	60
III	750	0.8	20

CTV group C

3.14 Curling

Curling can be played either outdoors or indoors. Artificial lighting may therefore be from floodlights on poles (outdoors) or overhead luminaires (indoors). Lighting should preferably be placed to the side of the lanes. In the case of outdoor facilities, several lanes may be illuminated from poles placed on either side.

As the participants' viewing distance is long, sufficient illumination must be provided for the position of the stones to be visible at the end of the rink. A higher illuminance is recommended for the 'house'. The ice acts as a good diffuse reflector, thus helping to ensure that there are no strongly marked patterns of light that could distract from the game.

Glare control is relatively easy to achieve as the main direction of view is below the horizontal plane. Care needs to be taken in the selection and location of luminaires so that direct glare is minimised. Suitable louvres and screening can prove effective in limiting the glare. The ceiling reflectance needs to be high (at least 60%) to reduce the luminance contrast when compared with the ice rink surface.

Class	Horizontal illuminance 'House'		Horizontal illuminance Rink		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}	
I	300	0.7	200	0.7	60
II	300	0.7	200	0.7	60
III	300	0.7	200	0.7	60

CTV group A

3.15 Cycle racing (track)

The ergonomics of the normal riding position are such that the cyclists look straight ahead and slightly downwards. It is essential therefore that the reflectance of the track is not excessive; values of 0.2–0.4 are generally considered acceptable.

As spectators are required to view action on distant sections of the track, it is important for illuminances to be adequate without creating unwanted glare. It is necessary to maintain good lighting uniformity and avoid the creation of black spots that may lead to accidents when competitors are fast-moving.

If the central area of the velodrome is used for hospitality, then it is important to prevent the ambient lighting of the central area from impinging onto the track, as this may be disturbing for the competitors.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Indoor tracks		Outdoor tracks			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	750	0.7	500	0.7	50	60
II	500	0.7	300	0.7	50	60
III	200	0.5	100	0.5	55	20

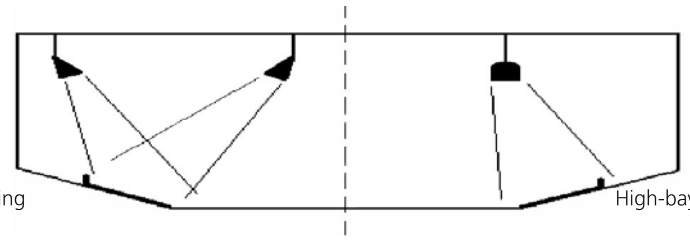
CTV group B

Note 1: Illuminance is taken on the track surface, whether it be horizontal or inclined.

Note 2: Vertical illuminance at the finish line should be 1000 lux to aid the use of photo-finish equipment.

Note 3: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 10% of that for the appropriate class for a minimum of 60 s.

Figure 10 Examples of luminaire locations for indoor track lighting (cross-sectional track detail)



3.16 Dancing/aerobics/keep fit

Participants must be able to concentrate on their movement and rhythm without the distraction of the lighting installation. This activity involves various positions and speed of movement around the dance floor or activity area.

The lighting installation should be provided from a ceiling-mounted array of luminaires positioned to provide uniform illumination. During the design process, the type of light source and the positioning of the luminaires should be selected to reduce the possibility of glare.

Dance/keep-fit is typically performed in a multipurpose sports hall (see section 4).

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	500	0.7	60
II	300	0.6	60
III	200	0.5	20

CTV group B

3.17 Darts

Participants must be able to concentrate on their throwing in safety without distraction from the lighting installation.

Illumination of the dart board is usually provided by an overhead point-source luminaire of sufficient beam width to achieve uniform illumination over the target. It is essential that the target lighting should enable players to identify clearly all scoring segments of the dartboard.

Separate illumination should be provided over the adjacent scoreboard and oche (throwing line at 3–4 m from the dartboard).

Class	Horizontal illuminance (over oche) E_{av} (lx)	Vertical illuminance (over target) E_{vav} (lx)	Colour rendering index
I	200	750	60
II	100	500	60
III	50	300	20

CTV group A

3.18 Equestrian sports (outdoor and indoor)

This section deals with the lighting of areas used for showjumping, dressage, schooling and the practice and training of horses. Major showjumping and dressage events are normally held in sports stadia or indoor arenas often equipped with facilities for television broadcasting (see sections 5, 6 and 7).

Lighting is provided to enable the safe movement of both horse and rider appropriate to the standard of participation. The action of both must be clearly seen by spectators, officials and trainers.

The lighting installation should provide illumination over the total floor area. Shadows should be minimised as these may distract the horses. In many cases, the most cost-effective lighting solution is a side-lighting system.

Most purpose-built arenas are rectangular in design, although the overall dimensions may vary considerably. The smallest arena size suitable for dressage tests is 20 x 40 m while a full showjumping round will require a minimum of 80 x 210 m. A suitable area for schooling would be approximately 25 x 65 m.

The lighting must be adequate to enable the safe progress of both horse and rider over the jumps and to discern the finer points of dressage. It is important that a high degree of lighting uniformity is achieved with minimal shadowing around showjumping fences.

The eye level of a rider is typically 2–2.5 m above ground level and may significantly increase when jumps are taken. This should be considered when determining a suitable mounting height for luminaires.

Glare to both horse and rider should be controlled as much as possible. The main course direction for showjumping and dressage will be along or diagonally across the principal arena axis.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Indoor		Outdoor			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	500	0.7	50	60
II	300	0.6	200	0.5	55	60
III	200	0.5	100	0.5	55	20

CTV group A

Note 1: Safety lighting (see section 2.8.2.1). Lighting level for the safe stopping of an event is 5% of that for the appropriate class for a minimum of 120 s.

3.19 Fencing

The speed of action in fencing is generally extremely fast. The activity involves varying positions and speed of movement on the floor. Participants must be able quickly to discern the opponent's movements, gauge or make attacks and perform movements without the effects of glare from the lighting installation. The contrast between the ceiling and the luminaires should be low to eliminate distraction. The lighting should be provided from a ceiling-mounted array of luminaires positioned to provide uniform illumination over the piste.

Fencing is typically played in a multipurpose sports hall (see section 4).

Class	Horizontal illuminance (on piste)		Vertical illuminance (along piste axis)		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}	
I	750	0.8	500	0.7	60
II	500	0.8	300	0.7	60
III	200	0.8	200	0.7	20

CTV group C

3.20 Five-a-side football (indoor)

Five-a-side football is usually played in multi-use sports halls. Some competitive events plus a similar six-a-side version are played in large halls or small arenas, but in all cases the requirements are similar.

Players must be able to follow movement of both the ball and other players. Many five-a-side courts are defined on a multi-use playing surface which may also be marked out for other sports such as basketball or badminton. The lighting must enable players easily to identify the court markings.

Suitable illumination can usually be provided by luminaires fixed above the playing area and spaced to meet the uniformity requirements. Although the play generally takes place at low level there is a risk of deflection of the ball to high levels. Luminaires may therefore require protection against ball impact.

Glare should be minimised by controlling luminance to lower the brightness contrast between the luminaires and the ceiling.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

3.21 Fitness training

Participants must be able to concentrate in safety on their training without distraction from the lighting installation. This activity is different from most sports in that there are no principal area layouts due to the varying nature of fitness training rooms. The lighting system should control glare within the area so that the participants can take part in fitness training. Where potentially difficult or hazardous tasks take place, it may be useful to improve the illumination at the location by the use of additional lighting.

Horizontal illuminance		Colour rendering index
E_{av} (lx)	E_{min}/E_{av}	
500	0.8	60

Figure 11 (Below left) A large training gym illuminated to provide good lighting uniformly over all apparatus areas.

Figure 12 (Below right) A separate training area lit using a low-brightness ceiling system.

3.22 Football (American)

The lighting should provide uniform illumination over the long, narrow pitch, ensuring that the full flight of the ball is visible while providing good viewing conditions for players, officials and spectators at all times. For competitions, the lighting requirements will probably be dictated by the viewing requirements of spectators, which in turn are related to the viewing conditions and spectator capacity of the sports ground (see section 5.2.2).

Various lighting systems may be suitable for American football grounds and stadia (see sections 5.1 and 5.2). Owing to the possibility of large spectator attendance, it is important to consider the requirements for emergency lighting (see section 2.8).

In the provision of any lighting system, thought should be given to reducing the visual obstruction of the event for spectators wherever possible. Care should be taken to ensure that shadows are not cast onto the pitch from floodlights located behind grandstand rooflines.

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	200	0.6	50	60
III	75	0.5	55	20

CTV group B

Note 1: American football leagues will require particular lighting specifications for competition and stadia provision.

3.23 Football (association)

Lighting should provide uniform illumination over the pitch, appropriate for the proposed grade of supervision or league status. For non-league play and supervised training, a relatively low illuminance and uniformity may be acceptable. For competition matches the lighting requirements will probably be dictated by the viewing requirements of spectators, which are in turn related to the viewing conditions and spectator capacity (see section 5.2.2).

Particular attention should be paid to providing low glare and uniform lighting within goalmouth areas. This is to ensure good visual conditions for goalkeepers during set plays (corner kicks, free kicks, penalties). To ensure good viewing conditions for goalkeepers defending corners, lighting masts should not be located in line with the goal-line axes (±10°).

Various lighting systems may be suitable for football grounds and stadia (see sections 5.1, 5.2). Owing to the possibility of large spectator attendance, it is important to consider the requirements for emergency lighting (see section 2.8).

In the provision of any lighting system, thought should be given to reduce the visual obstruction of the event for spectators wherever possible. Care should be taken to ensure that shadows are not cast onto the pitch from floodlights located behind grandstand rooflines.

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance(note 2)		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	200	0.6	50	60
III	75	0.5	55	20

CTV group B

Note 1: The Football Association, Football League and Premier League will require particular lighting specifications in accordance with UEFA and FIFA criteria for competition and stadia provision.

Note 2: Determination of maintained illuminance (see appendix 1 footnote)

3.24 Football (Gaelic)

Lighting should provide uniform illumination over the pitch, appropriate for the proposed grade of competition. The lighting should ensure that the full flight of the ball is visible while providing good viewing conditions for players, officials and spectators.

For competitions, the lighting requirements will probably be dictated by the viewing requirements of spectators, which are in turn related to the viewing conditions and spectator capacity (see section 5.2.2).

Particular attention should be paid to providing low glare and uniform lighting within goalmouth areas. This is to ensure good visual conditions for goalkeepers relative to set plays. To ensure good viewing conditions for goalkeepers, lighting masts should not be located in line with the goal-line axes (±10°).

Various lighting systems may be suitable for Gaelic football grounds and stadia (see sections 5.1 and 5.2). In the provision of any lighting system, thought should be given to reducing the visual obstruction of the event for spectators wherever possible. Care should be taken to ensure that shadows are not cast onto the pitch from floodlights located behind grandstand roof lines.

Owing to the possibility of large spectator attendance, it is important to consider the requirements for emergency lighting (see section 2.8).

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	200	0.6	50	60
III	75	0.5	55	20

CTV group B

Note 1: The Gaelic Athletic Association may require particular specifications for competition and international provision.

3.25 Golf courses

While most golf course lighting is restricted to practice areas and putting greens, there is growing interest in lighting par-three and shortened courses for night play. The principal requirement in all cases is to ensure that environmental impact is minimised while creating a pleasant night-time appearance with good viewing conditions for golfers.

Figure 13 A golf course floodlit to achieve uniform illumination of the fairways, greens and tees with minimal glare.

Holes should be separately illuminated with floodlights located and directed so as to prevent or minimise distraction and glare to adjacent playing areas. Each hole consists of a tee, fairway and green areas and each may have somewhat different lighting requirements. However, the principal lighting considerations will be:

- to enable the course features to be easily discerned;
- to minimise glare in the principal direction(s) of play;
- to provide continuous illumination of each hole and enable golfers to assess distance;
- to enable the full flight of the ball to be followed and its final resting place to be easily observed; and
- to provide uniform illumination over putting greens and tees.

The tees: These areas will require reasonable illuminance uniformity, with bi-directional lighting to ensure that golfers cannot shadow the ball. Floodlight mounting heights may be lower than usually required for the fairways since the lighting provision is generally dedicated to the tee and initial fairway area. As the speed of the ball in the initial flight zone is too high to enable the ball to be followed visually, only horizontal illuminance need be considered. Floodlights should be located so as to minimise glare to players as they tee off.

The fairways: Over these areas it is important that the flight of the ball can be followed easily; therefore adequate vertical illuminance over the ball in flight to a height of 20 m is necessary. This is usually achieved via a staggered lighting system along the edges of the rough on either side of the fairway. The floodlighting direction should be longitudinally down and across the fairway to minimise glare to golfers playing the hole. A reduced level of horizontal illuminance and overall uniformity is acceptable over the main fairway and semi-rough areas on either side, sufficient to allow balls to be played. It is generally accepted that balls played into the rough will only be illuminated by spill light and that their location and play may prove difficult.

The greens: These should be illuminated to a higher horizontal illuminance than tees or fairways to enable them to be discerned easily at a distance. Lighting of the green should be multi-directional, ensuring minimal shadowing to all areas and a high level of horizontal uniformity. Floodlight mounting height should be adequate to ensure that the ball is seen over its full, pitched height onto the green while minimising glare. To achieve this it is also acceptable for green floodlights to be aimed in the general direction of adjacent bunkers and semi-rough areas surrounding the green.

In general: Holes are located over adjacent areas and are often in close proximity, separated by rough ground or landscaped features. Where possible the floodlighting masts of one hole should be utilised to illuminate adjacent holes separately so as to minimise obstruction over the whole course.

Water features (lakes) deliberately placed as obstructions within the line of play need not be separately illuminated. However, the air space above the water must be lit so as to achieve adequate vertical illuminance to allow golfers to follow the flight of the ball.

Bunkers adjacent the greens should be illuminated from the green floodlighting system and shadowing within them reduced as much as possible. However, bunkers within fairways need only receive general illumination from the main fairway floodlighting. Strong shadowing may occasionally result and should be accepted as a feature of the obstacle, unless specified otherwise by the course designers.

Class	Horizontal illuminance on tees		Horizontal illuminance on fairways(notes 2/3)		Vertical illuminance on fairways(notes 1/2)		Horizontal illuminance on greens		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}	E_{av} (lx)	E_{min}/E_{av}		
I	200	0.7	100	0.5	200	-	250	0.7	50	60
II	100	0.7	75	0.5	150	-	150	0.7	50	60

CTV group C

Note 1: Vertical illuminance at 5 m above the fairway.

Note 2: Semi-rough ground to be included.

Note 3: Not applicable over water obstacles and features.

Note 4: The lighting levels stated do not relate to requirements for general course maintenance.

3.26 Golf driving ranges

The distance markers must be clearly visible and the player must be able to follow the flight of the ball. While the tee areas will require separate illumination, there should be general illumination of the full length of the golf range surface.

End-range lighting systems have primarily been utilised to illuminate golf ranges. This type of system employs high-powered floodlights behind tee locations with high angles of elevation to achieve adequate vertical illuminance at each target area. Mounting heights will have little significant influence upon the resultant illumination of the distance markers, and, as the glare to golfers will not be an influencing factor, low mounting heights may be used. Glare to the surrounding neighbourhood is probable from viewing directions towards the tees in

Figure 14 A golf range illuminated using a Berm lighting system to reduce light pollution whilst enhancing the visual experience.

the direction of play. Natural screening or careful siting of the golf range will provide the best practical solution to alleviate any direct glare.

In instances where low obtrusive light to the surroundings is required, alternative floodlighting systems may prove to be more suitable. These primarily consist of Berm, pit and side lighting installations. Berm lighting utilises floodlights located within the golf range surface and should achieve uniform vertical illumination of the golf balls in flight and a patterned illumination of the range surface. Direct glare at the boundary can be prevented by low screening or fencing, provided that the installation is not overlooked. Pit lighting is a variation of Berm lighting but the floodlights are mounted within shallow pits in the range surface. A mound is built in front of the floodlight and is used to provide a forward shadow zone to prevent direct glare to properties overlooking the end of range. Since recessed floodlights will not illuminate the range surface, additional general lighting is necessary from side-mounted floodlighting. Side lighting from floodlights located on columns along each side of the range should provide uniform horizontal and vertical illumination with reduced obtrusive light compared to an end-range system.

The main floodlighting for the driving range is unlikely to provide sufficient illumination of open tee areas. These should be separately lit from additional floodlights mounted on columns located behind the tees.

Golf ranges with covered tee booths will require separate lighting within the booths, usually from fluorescent luminaires suitable for outdoor use. It may also be necessary to utilise additional low-powered floodlights mounted above the tee booths should the employed lighting system not adequately illuminate the range surface foreground area.

Class	Horizontal illuminance (on tee)		Vertical illuminance on distance marker (+1m AGL)	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	
III	100	0.8	50	20

3.27 Greyhound racing

This section deals only with track lighting in greyhound stadia. The general lighting of stadia is described in sections 5 and 7.

Spectators must be able to identify the individual dogs clearly throughout a race. This may prove difficult when greyhounds are racing on the opposite side of the track due to long viewing distances and inner-rail obstructions that may impair spectator vision. It is therefore important to provide adequate vertical illuminance on inwardly directed surfaces of the track facing the spectators. The lighting should be confined to the track in order to enhance the viewing spectacle.

Additional general lighting may be necessary to illuminate the central stadium area if used by officials for presentations and to parade the greyhounds. For economic reasons it is advisable to install track lighting that may be switched to a lower illuminance during the intervals between races.

There are two main types of lighting systems generally used for illuminating greyhound tracks.

3.27.1 Low-mounting system

Lighting of the track is provided from special-purpose luminaires suspended over the track from a large number of poles sited around the inner or outer periphery. As racing is mainly confined to the inner third of the track, luminaires are positioned at about one-third of the track width from the inside rail.

The luminaire spacing-to-height ratio should not exceed 1.5:1 as dark bands across the track must be avoided. Dark bands caused by either poor design or failed lamps can produce confusion among the dogs during a race as they lose sight of the hare due to poor visual adaptation. Light should be restricted to the track area in order to minimise glare and provide race atmosphere.

Although most of the light is provided directly above the main race width of the track, illuminance on vertical surfaces is comparatively low. As a result the greyhounds may not be seen as clearly as might be expected. The view of spectators may be obstructed by the large number of poles. Consideration should also be given to lowering or removing poles when the stadium is used for other purposes.

Luminaires should be protected from any sand kicked up off the track and may be required to incorporate dual-lamp provision to permit switching between racing and general lighting levels.

3.27.2 High-mounting system

The use of a greater mounting height reduces the number of poles required. This will result in less overall visual obstruction.

Lighting over the track is provided by groups of floodlights mounted on columns positioned around the inner track periphery. This system gives more light on inward-facing vertical planes, thus allowing improved race viewing along the opposite side of the track. There will, however, be less illumination of outward-facing vertical planes, and care must be taken to ensure that there is sufficient light to allow greyhound recognition along the front straight.

In stadia with grandstand provision it is necessary to relocate columns to the outer perimeter of the front straight or from the grandstand roof to ensure adequate viewing conditions. Lighting from large mounting heights is not easily confined to the track area, and care should be taken to control discomfort glare.

Illumination of the greyhound track to a general lighting level between races may be achieved by the use of dual-lamp luminaires or by switching off some floodlights on each column. It may also be possible to install additional floodlighting to permit lighting of the central field area for general usage or as illumination for other sporting activities. Careful consideration should be given to the maintenance of high-mounting systems as many sand-filled greyhound tracks will not support the use of heavy vehicles.

Class	Horizontal illuminance				Colour rendering index
	Race track		Central field		
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}	
I	300	0.7	50	0.5	60
II	100	0.5	50	0.5	60

CTV group B

Note 1: The vertical illuminance at the finishing line should be 1000 lux for photo-finish equipment and officials.

Note 2: Recommended minimum mounting heights are 5 m for low-mounting and 10 m for high-mounting systems.

3.28 Gymnastics

Gymnastics consists of a range of exercises carried out on various types of apparatus: vaulting horse, pommel horse, parallel bars, asymmetric bars, beam, rings and floor. However, for training purposes these pieces of equipment are often used in conjunction with aids such as safety pits, floor mats, trampolines etc.

Gymnastics competitions generally take place in large multi-use sports halls or arenas (see sections 4 and 6).

Lighting is required to allow the participants to perform precise, accurate movements on all the apparatus, and to allow spectators and judges to follow the action during competition. Suitable illumination is usually provided by luminaires located at high level over the whole activity area, with due allowance for particular apparatus that involve activity at considerable distances above the floor (rings, bars etc).

Glare should be minimised by the careful selection and location of luminaires, and light-coloured ceilings are usually preferred to prevent the light source from producing too much contrast with the background.

Figure 15 (Near right) A dedicated gymnastics facility with separate variable illuminances for each apparatus area obtained using switched luminaire clusters.

Figure 16 (Far right) An indoor gymnastics training area lit with recessed, low-brightness luminaires.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	500	0.7	60
II	300	0.6	60
III	200	0.5	20

CTV group B

Note 1: Safety lighting (see section 2.8.2.1). Lighting level for the safe stopping of an event is 5% of that for a particular class for a minimum of 30 s.

3.29 Handball (indoor)

Most handball courts are defined on a multi-use playing surface (see section 4) which may also be marked out for basketball, volleyball or badminton. The lighting installation must allow players quickly to discern the court markings and follow the fast movement of the small ball and other players.

An acceptable lighting installation can usually be provided by luminaires mounted above the court and spaced to meet uniformity requirements. Glare should be minimised by careful control of the brightness contrast between the luminaires and ceiling.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

3.30 Hockey (indoor)

Many indoor hockey courts are defined on a multi-use playing surface (see section 4). The lighting installation must allow players quickly to discern the court markings. The ball is small, speed of play is fast and players must be able to follow the movement of the ball and other players.

A suitable lighting installation can usually be provided by luminaires mounted above the playing area and spaced to meet uniformity requirements. Glare should be minimised by careful control of the brightness contrast between the luminaires and the ceiling.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group B

3.31 Hockey (outdoor)

Hockey is a visually demanding sport due to the combination of fast action and small ball. As a consequence, the illuminances necessary to participate and follow play are greater than with most other exterior ball sports. A high level of illuminance uniformity is necessary in both horizontal and vertical planes to prevent adaptation problems for players, officials and spectators at all levels of play.

The game is played primarily at ground level. The lighting must minimise shadowing, enabling the ball to remain in view at all times. Particular attention should be paid to providing low-glare, uniform lighting within goal areas, along goal lines and at corner locations. This is to ensure good visual conditions for goalkeepers relative to set plays (corners, half corners, free hits and penalties).

Lighting masts should not be located in line with the goal-line axes (±10°). End-mast positions should preferably be located outside the intersection of side and goal lines to minimise corner shadows. There must be an obstacle-free zone extending 5 m beyond the goal lines and 4 m beyond the sidelines, within which masts must not be located.

Various lighting systems may be suitable for hockey grounds and stadia (see sections 5.1 and 5.2). Owing to the possibility of large spectator attendance, it is important to consider the requirements for emergency lighting (see section 2.8).

Figure 17 An outdoor hockey pitch illuminated using flat glass floodlights to minimise direct upward light, overspill and glare.

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	300	0.7	50	60
III	200	0.7	55	20

CTV group B

Note 1: The FIH and national hockey governing bodies may require particular specifications for competition and international provision.

3.32 Horse racing (gallop and trotting)

Horse racing is a sport with large spectator provision, usually via one or more grandstands situated along the home straight and opposite the finish line. Floodlighting provision for racing will probably have a requirement for CTV coverage that can be switched to a competitive racing level for non-televised occasions. The lighting is principally confined to the width of track, with spill light adequate to provide supplementary lighting of adjacent areas. Lighting for the paddock and observation areas may utilise lower illuminances than those necessary for racing.

Horses are sensitive to variations in lighting levels and are known to act erratically and irrationally when confronted with large variations in luminance uniformity. In extreme cases poor lighting uniformity may cause confusion and could be dangerous during racing. It has been known for horses to attempt to jump prominent bands of luminance over the track during racing, with potentially disastrous results.

Visual conditions during racing are therefore of prime importance for both horses and spectators. For horses the lighting must provide a uniformly lit track (longitudinally and crosswise) with gradual transition zones of horizontal illuminance between the back straight and the bends, home straight and finish lines. For spectators the lighting should illuminate the vertical-facing sides of the horses and jockeys at all times whilst ensuring minimal visual intrusion from floodlighting-support structures. The finishing line will require specialist lighting for photo-finish cameras, often incorporating mirror systems to allow the finish to be viewed from both sides of the track simultaneously.

Twin-track courses (all-weather and grass tracks) may require separate switching facilities to allow the full racing programme to be accommodated.

Very large sporting venues will require a large lighting load. It is therefore essential to consider the environmental impact of floodlighting proposals throughout the lighting design process.

Horse racing gallop tracks provide some of the largest floodlit sporting venues. As a consequence it is generally necessary to utilise high-mast structures to carry the large number of floodlights and achieve large spacing between lighting points. The use of high masts will also allow greater offset distances to the track, necessary to ensure an unimpeded view of the home straight during racing and minimal visual intrusion of the back straight and bends.

Figure 18 A large horse racing track illuminated using a floodlighting system designed for CTV but with control of obtrusive light.

Mast-offset distances should preferably not exceed the mounting height; otherwise there will be minimal penetration of lighting between the racing horses and severe shadowing may occur across the track. At greater mast-offset distances it may become difficult to achieve lighting requirements in full as the apparent target track width decreases.

In order to provide adequate vertical illuminance of the horses and jockeys, it is generally necessary to switch mast positions from the outside of the home straight to the inside of the back straight and bends. Off-chute tracks will need similar consideration, while sections of track requiring CTV coverage may need double-sided lighting if inner and outer roadways are used for running-camera transmissions.

CTV provision will require specialist consideration due to the numerous camera directions required (see section 7).

Owing to the additional height of the horse and jockey compared with normal sporting participants, it is necessary to use an increased observer height at 2.5 m for glare rating calculations. Since the observer direction (horse and jockey) is primarily viewing straight ahead, only axial glare rating calculations along the principal axes of the racecourse and in the direction of racing are necessary.

Trotting tracks are generally smaller venues than gallop tracks. As a consequence trotting tracks may use lower mounting heights where applicable, although general horse racing track lighting principles apply. For trotting track lighting, however, it is essential to balance the lighting loads over a three-phase electrical supply for each lighting point in order to prevent the stroboscopic effect of the trotting cartwheels that causes them to appear stationary or slow moving. With the jockey seated within the racing cart, the observer height for glare rating calculation returns to a nominal 1.5 m above ground level.

Class	Horizontal illuminance		Vertical illuminance						Glare rating	Colour rendering index
			Home stretch			Back stretch and turn				
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}		E_{vav} (lx)	E_{vmin}/E_{vav}			
				Length	Cross		Length	Cross		
I	200	0.6	750	0.6	0.4	500	0.6	0.4	50	60
II	100	0.4	300	0.6	0.4	200	0.6	0.4	50	60
III	50	0.2	100	0.3	-	-	-	-	55	20

CTV group B

Note 1: The vertical illuminance at the finishing line should be 1000 lux for photo-finish equipment and officials.

Note 2: For equine safety the lighting level for the safe stopping of an event is 10% of that for a particular class for a minimum of 120 s.

Note 2: When horses are under observation (by vets for instance), the E_{av} (horizontal illuminance) should be at least 100 lux.

3.33 Hurling

Hurling is a visually demanding sport due to the combination of fast action and small ball. As a consequence the illuminances necessary to participate and follow play are greater than with most other exterior ball sports. A high level of illuminance uniformity is necessary in both horizontal and vertical planes to prevent adaptation problems for players, officials and spectators at all levels of play. As the ball may be carried or struck on the ground or in the air, the lighting should ensure that the full flight of the ball is visible while minimising shadowing.

Particular attention should be paid to providing low-glare, uniform lighting within goal areas, along goal lines and at corner locations. This is to ensure good visual conditions for goalkeepers during set plays. Lighting masts should not be located in line with the goal line axes (±10°). End-mast positions should preferably be located outside the intersection of side and goal lines to minimise corner shadows.

Various lighting systems may be suitable for hurling grounds and stadia (see sections 5.1 and 5.2). Owing to the possibility of large spectator attendance it is important to consider the requirements for emergency lighting (see section 2.8).

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	300	0.7	50	60
III	200	0.5	55	20

CTV group B

Note 1: The Gaelic Athletic Association may require particular specifications for competition and international provision.

3.34 Ice hockey

A high standard of lighting is required as the small, black and fast-moving puck has to be made to contrast against the ice rink so that the spectators and players can see it. This is especially true where there is a large distance between the ice and the spectators, such as in arenas or halls. As ice acts as a good diffuse reflector there should be no strong patterns of light that could distract from the game. Good lighting uniformity is important for seeing the puck. Also, the illumination of the spectator area should be an average of at least 30% of that of the rink in order to limit visual fatigue for spectators and players.

An acceptable lighting installation can be provided by luminaires mounted in a regular array over the arena. Side lighting can improve the vertical illuminance on skaters and give improved spectator viewing.

Glare control is relatively easy to achieve as the main direction of view is below the horizontal plane. Care needs to be taken in the selection and location of luminaires so that direct glare is minimised. Suitable louvres and screening can prove to be effective in limiting the glare.

The ceiling reflectance needs to be high to reduce the luminance contrast compared with the ice rink surface. This is achieved by ensuring that the reflectance of the ceiling is at least 60%.

Class	Horizontal illuminance				Colour rendering index
	Indoor ice hockey (note 1)		Outdoor ice hockey		
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	750	0.7	60
II	500	0.7	500	0.7	60
III	300	0.5	200	0.5	20

CTV group C

Note 1: Heights below 8 m, $E_{min}/E_{max} \geq 0.5$. For class III the uniformity can be relaxed to 0.5.

Note 2: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 5% of that for a particular class for a minimum of 30 s.

3.35 Ice sports (artistic)

A high standard of lighting is required for artistic ice sports to ensure that the judges can see the fine detail and movement clearly. This is especially true where there is a large distance between the ice and the spectators, such as in arenas or halls. The ice acts as a good diffuse reflector. There should not be a strong patterns of light that could be distracting.

An acceptable lighting installation can be provided by luminaires being mounted in a regular array over the rink.

Glare control is relatively easy to achieve as the main direction of view is below the horizontal plane. Care needs to be taken in the selection and location of luminaires so that direct glare is minimised. Suitable louvres and screening can prove to be effective in limiting the glare.

The ceiling reflectance needs to be high to reduce the luminance contrast compared with the ice rink surface. This is achieved by ensuring that the reflectance of the ceiling is at least 60%.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group B

Note 3: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 5% of that for a particular class for a minimum of 30 s.

Figure 19 A large multi-functional indoor arena in use for ice sports.

3.36 Lawn tennis (indoor)

As the tennis ball may move at relatively high speeds over the net, it is essential for players to be able to follow the flight of the ball, seen in contrast against a dark background, without being troubled by glare or having their concentration adversely influenced by high-intensity light sources in the vicinity of sight lines.

A large area of the ceiling directly above the court will be in view of the players, and for this reason it is important for the ceiling to be kept free from obstruction. It follows therefore that light sources with high luminances should be avoided and that the background, against which the ball will be viewed, should be as uniform as possible across the whole area.

The arrangement of luminaires must be such that it continues along the sidelines and beyond the baseline in order to achieve an adequate illuminance at the ends of the court and to provide suitable illuminance on the vertical face of a ball travelling towards a player positioned on or behind the baseline.

Recommended systems of lighting use luminaires that are mounted parallel to the sidelines and outside the court area. No luminaires should be positioned in that part of the ceiling that is directly above the area limited by the rectangle of the marked area extended to 3 m behind the baselines. Luminaires may require shielding to minimise glare.

Figure 20 Dedicated indoor tennis facility showing no luminaires over the principal area.

Class	Horizontal illuminance over principal area		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.5	20

CTV group B

Note 1: No luminaires should be positioned in that part of the ceiling directly above the principal area.

Note 2: The reflectance values of court-side fabrics should not be greater than 0.5 for walls and 0.6–0.9 for ceilings. Background colours of blue and green are preferable (see Figures 1 and 2).

Note 3: The LTA has specific requirements for illuminances over the total playing area and the principal area (see section 2.6).

3.37 Lawn tennis (outdoor)

The primary visual requirements in tennis are for the players, match officials and any spectators to see both the ball and the court together with its associated markings. It is important that a player does not suffer from disability glare when serving or following a ball. The type of light source and positioning of luminaires should be considered during the design process.

For the playing of tennis under floodlights the reflectance of the court surface is significant. The characteristics of the surface material of the court are of importance when considering floodlighting systems.

Sharp cut-off luminaires are preferable for tennis court floodlighting, the benefits of which include accurate light output control, a restriction in light overspill and a reduction in direct glare for the players. Columns should be positioned so that participants are unlikely to collide with them.

Class	Horizontal illuminance over principal area		Colour rendering index	Glare rating
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	60	50
II	300	0.7	60	50
III	200	0.6	20	55

CTV group B

Note 1: No luminaires should be positioned over the principal area.

Note 2. The LTA has specific requirements for illuminances over the total playing area and the principal area (see section 2.11).

3.38 Martial arts (including aikido, judo, karate, kendo etc)

The speed of action in martial arts is often extremely high. This activity involves varying positions and speed of movement around the floor or activity area. Participants must be able quickly to discern the opponent's movements, gauge or make attacks and perform throws without glare from the lighting installation. The contrast between the ceiling and luminaires should also be low to eliminate distraction.

The type of light source and positioning of luminaires should be considered during the design process.

Martial arts are typically performed either on a dedicated facility or in a multi-purpose sports hall (see section 4).

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

3.39 Netball

Netball courts are usually defined on a multi-use playing surface. Although the ball is large, the action is often fast and players must be able to discern the court markings while following the movement of both the ball and other players.

Glare cannot be completely eliminated as the nature of the sport requires players to look upwards from time to time. In indoor facilities this can be controlled by reducing the contrast between the luminaires and the ceiling and by careful control of luminance.

The principal axis of play for netball may conflict with the main axis of play for alternative sports that may be played on the court, such as tennis. In outdoor installations the lighting system should recognise the needs of netball and ensure that no floodlights are located behind the end-of-court D areas, since this may cause undue glare and distraction.

Class	Horizontal illuminance				Glare rating (note 2)	Colour rendering index
	Outdoor		Indoor (note 1)			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	750	0.7	50	60
II	200	0.6	500	0.7	50	60
III	75	0.5	200	0.5	55	20

CTV group B

Note 1: No luminaires should be located in that area of the ceiling above a 4 m diameter circle around the baskets.

Note 2: For outdoor courts.

3.40 Rugby (league and union)

The lighting should provide uniform illumination over the full pitch, appropriate to the proposed class of competition. It should also ensure that the full flight of the ball is visible while providing good viewing conditions for players, officials and spectators.

For competitions, the lighting requirements will probably be dictated by the viewing requirements of spectators, which in turn are related to the viewing conditions and spectator capacity of the sports ground (see section 5.2.2).

Various lighting systems may be suitable for rugby grounds and stadia (see sections 5.1 and 5.2). In the provision of any lighting system, thought should be given to reduce visual obstruction of the event for spectators wherever possible. Care should be taken to ensure that shadows are not cast onto the pitch from floodlights located behind grandstand rooflines. It is permissible to place masts in line with or close to the scoring (try) line as masts located close to this line can reduce shadowing from the high goal posts.

Owing to the possibility of large spectator attendance, it is important to consider the requirements for emergency lighting (see section 2.8).

Obtrusive light limitations will need to be considered if planning consent is required (see section 2.10.1).

Class	Horizontal illuminance		Glare rating	Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	50	60
II	200	0.6	50	60
III	75	0.5	55	20

CTV group B

Note 1: The RFU and IRFB may require particular specifications for competition and international provision.

3.41 Shooting (indoor)

Participants must be able to observe the targets from various distances and identify target markings.

For fixed target shooting, a high and uniform illuminance should be provided at the target with low-level illumination over the firing position. To focus attention on the target it may be preferable to provide a high contrast between target and background.

Luminaires should be positioned in such a manner as to avoid impact from bullets and pellets.

Class	Horizontal illuminance at firing line		Vertical illuminance on target				Colour rendering index
			Outdoor ranges		Indoor ranges		
					25 m dist.	50 m dist.	
	E_{av} (lx)	E_{min}/E_{av}	E_{vav} (lx)	E_{vmin}/E_{vav}	E_{vav} (lx)	E_{vmin}/E_{vav}	
I	200	0.5	750	0.8	1000	2000	60
II	200	0.5	750	0.8	1000	2000	60
III	200	0.5	750	0.8	1000	2000	60

CTV group A

3.42 Skiing (artificial slopes)

The lighting must enable skiers safely to negotiate the full length of the artificial ski slope. The general contours of the slope, depressions and surface irregularities must remain recognisable.

On long ski runs, the skier may be travelling at high speed. Therefore the lighting must allow quick recognition of changes in slope or incline. The position of floodlights must not provide the skier with a false impression of the route of the ski run.

Illumination is generally provided from floodlights positioned along both sides of the slope and aimed both across and down it. This should result in low glare and minimal distraction to descending skiers. Bright light sources that might distract attention should not be visible to skiers while descending the slope. The lighting should also provide for safe ascent of the slope by drag lifts or alternative facilities.

Outdoor ski slopes are usually illuminated from columns of low-mounting height above the immediate slope. They provide a larger effective mounting height once the slope itself is taken into account.

Indoor ski slopes are generally illuminated from luminaires located so as to provide an atmospheric ambience while still allowing details of the slope to be revealed.

Class	Horizontal illuminance				Colour rendering index
	Outdoor slopes		Indoor slopes		
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}	
III	100	0.5	300	0.5	60

Note 1: Illuminance is taken on the track for both horizontal and inclined surfaces.

Note 2: Safety lighting (see section 2.8). The lighting level for the safe stopping of an event is 10% of that for the particular class for a minimum of 30 s.

Note 3: For artificial snow-covered indoor slopes, illuminances may be reduced due to increased reflection off the slope surface.

3.43 Snooker and billiards

The table must be uniformly illuminated so that the players can follow the balls. The lighting should be shadow-free and enable the players to distinguish the colours of the balls. Referees, spectators and participants need good visibility from all directions.

Illumination is normally provided by a purpose-built lighting canopy with general lighting provided to the surrounding area. If the event is to be televised (see section 7), it is usual to install a modified overhead system or additional high-intensity lighting.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.8	80
II	500	0.8	80
III	500	0.8	80

CTV group A

3.44 Speed skating

Speed skating may be held on either 400 m tracks or on what are known as short tracks. Short-track skating will usually take place in a multipurpose arena used for other sports. In this case the specific requirements for speed skating should be met in conjunction with recommendations for other sports. The 400 m track will usually have a dedicated facility where only the track area will need to be lit for the participants.

An acceptable lighting installation can be provided by luminaires mounted in a regular array over the arena. Side lighting can improve the vertical illuminance on skaters to give improved spectator viewing.

Glare control is relatively easy to achieve as the main direction of view is below the horizontal plane. Care needs to be taken in the selection and location of luminaires so that direct glare is minimised. Suitable louvres and screening can prove effective in limiting glare.

The ceiling reflectance needs to be high to reduce the luminance contrast when compared with the ice rink surface. This would be achieved by ensuring that the reflectance of the ceiling is at least 60%.

Class	Horizontal illuminance				Glare rating	Colour rendering index
	Indoor track		Outdoor track			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{min}/E_{av}		
I	500	0.7	500	0.7	50	60
II	300	0.6	200	0.5	55	60
III	200	0.5	100	0.5	55	20

CTV group B

Note 1: Outdoor tracks. For class II the colour rendering index limit can be reduced to 20.

Note 2: The vertical illuminance at the finishing line should be increased to 1000 lux for photo-finish purposes.

Note 3: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 5% of that for the appropriate class for a minimum of 30 s.

3.45 Speedway

Speedway is a relatively fast-moving sport and consequently the illuminances provided must be sufficient to allow the participants to be able to detect the track ahead, other competitors and any signals (including emergency signals) from race officials

The lighting should be sufficient to allow spectators to discern action when the riders are on distant sections of the track whilst not causing a visual distraction to participants. Visual tasks associated with the preparation and maintenance of machines are undertaken in the pits area and this must therefore be lit to a sufficient illuminance. The performance of visual tasks involved in maintenance work in the pits is likely to benefit from the installation of localised lighting that should be suitably shielded from the view of any riders simultaneously racing on the track.

Lighting for speedway use is confined to the areas encompassing the track and pits. However, many tracks form part of a multi-sport arena where other sports are played at different times. It is therefore rare to consider the design of lighting for speedway in total isolation.

The creation of suitable and sufficient vertical illuminance is particularly important when the riders are on distant sections of the track, and for this reason the location of columns or towers on the inside of a track is not recommended.

It is normal practice to restrict the number of columns and towers used for the lighting of speedway tracks since they can increase the likelihood of rider collision and can also obstruct the view for spectators. Furthermore, the use of a smaller number of greater mounting-height columns and towers results in:

– luminaires less likely to be affected by dust, dirt and generally foreign bodies being thrown up by the action of the machines on the track (if luminaires are mounted at low levels, flying particles could be deleterious to their condition and hence their performance); and
– reduced likelihood of direct glare being experienced by the riders.

Schemes involving luminaires suspended from catenaries spanning the track width, and mounted on columns or towers located on both sides of the track, may be used, but it is emphasised that any columns or towers located on the inside of the track are likely to cause visual obstruction to spectators, particularly when the riders are on distant sections of the track.

Class	Horizontal illuminance					Glare rating	Colour rendering index
	Track		Pits	Central field			
	E_{av} (lx)	E_{min}/E_{av}	E_{av} (lx)	E_{av} (lx)	E_{min}/E_{av}		
I	400	0.6	200	100	0.25	50	60
II	300	0.6	100	50	0.25	50	60
III	150	0.5	100	50	0.25	55	20

CTV group B

Note 1: Additional localised lighting may be required for illumination of the finishing line.

Note 2: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 10% of that for a particular class for a minimum of 60 s.

3.46 Squash (rackets and raquetball)

The visual demands for these sports are exacting, primarily because the action is fast and the ball is small in size. The ball must be seen in silhouette against the court surface, which should be fairly bright. The court lines must be clearly visible to players, spectators and markers. In instances where court walls are glazed it is important to ensure that luminaires are positioned so as to reduce reflection on the glass surfaces. It is very important that glare be restricted.

Squash courts are often illuminated by ceiling-mounted luminaires positioned in a standard layout. The illumination of fully glazed courts is the subject of specialist design.

Ceiling-mounted luminaires should be constructed so as to eliminate the possibility of balls becoming lodged in them. It is essential for impact-resistant covers or guards to be installed on all luminaires in order to prevent damage.

The court ceiling should receive some illumination, which may be provided directly by the luminaires aided in all instances by reflection from the side walls.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group C

Note 1: Luminaires running within 1 m of side walls should be avoided.

Note 2: The recommended reflectance of walls is 0.6–0.8, of ceilings is 0.6–0.8 and of floors is 0.3–0.4.

3.47 Swimming (all activities)

The main requirement is to ensure the safety of users by providing adequate illumination and control of reflection on the water surface. The control of surface reflection is particularly important to allow staff to deal with any swimmers in difficulty in the pool. With the complex nature of pool design and restrictions on positioning luminaires, it is important that lighting is considered at the earliest stages of design.

3.47.1 Indoor pools

The wide variety of techniques used is dictated by the building design, the balance of artificial lighting and day lighting as well as safety, energy efficiency and practical economic considerations. Direct and/or indirect lighting may be utilised in the illumination of the pool hall.

Indirect luminaires should be positioned high enough to avoid a direct view of the lamp by participants walking around the pool or by spectators seated well

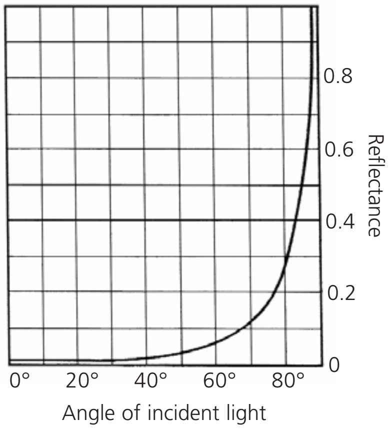


Figure 21 Reflectance of water as a function of the angle of incident light.

above pool level. With the exception of diving and synchronised swimming, pools are not areas where participants have to perform difficult visual tasks. The major requirement, therefore, is to provide a safe and pleasant ambience in the pool hall. This is particularly important to allow staff to be able to detect swimmers in difficulty. This may be hampered by the reflection of a luminaire obscuring the view of a swimmer in the water.

The reflected image of a luminaire in water increases with the angle of incidence (see Figure 21). Once this angle exceeds 70° such reflections could mask the swimmer from view by divers and pool attendants (see Figure 22a). However, turbulence in the water makes the situation worse by effectively changing the angle of incidence to the point where the critical angle reduces to 30° (see Figure 22b). This means it will be harder for someone on poolside to see into the water than for someone higher up. Care must therefore be taken in the positioning of luminaires relative to the main viewing direction of safety attendants.

In synchronised swimming, swimmers have to perform gyrations in unison. Viewed from above, these formation patterns can be a pleasing effect. As it is a relatively new sport, specific international recommendations are in the process of being formulated. However, good vertical illuminance across the pool surface is required to ensure that leg movements can be correctly observed.

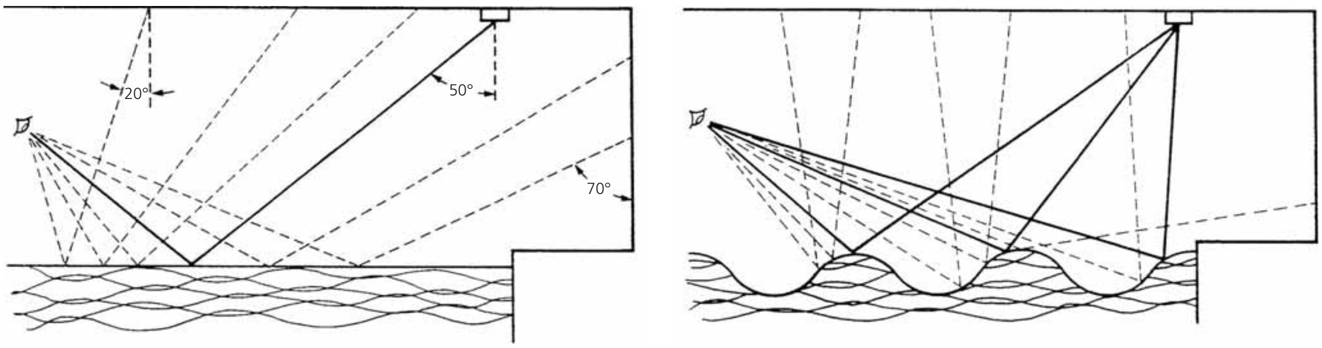


Figure 22 Reflections of a luminaire, walls and ceiling at the water surface: 22a (left) calm water; 22b (right) turbulent water.

Illumination of the pool hall is normally provided by direct or indirect techniques, with luminaires constructed to withstand high ambient temperatures, humidity and corrosion. It is therefore recommended that the luminaires should be constructed to a minimum standard of IP54.

Luminaire selection should also take account of access requirements for maintenance, cleaning and re-lamping. For this reason luminaires should not be positioned over the pool unless catwalks, gantries or rear access from the ceiling void are available. These requirements tend to lead to luminaires being positioned at the poolside, up-lighting the ceiling. Where the mounting height is restricted this can cause problems of glare. For pool users they should be mounted at least 1.85 m above the floor, allowing at least 0.5 m clearance to the ceiling to avoid high ceiling brightness. Spectators seated above the floor level should not have a direct view into the luminaires.

Figure 23 Indoor 50 m swimming pool illuminated by indirect lighting to reduce surface reflections.

3.47.2 Outdoor pools

For outdoor pools it is an accepted method to fix luminaires on masts located near the pool surround. The mounting height depends on their distance from the poolside. In order to achieve adequate light penetration into the water, an angle of incidence at the far side of the pool should be more than 50°, preferably 60°. This method ensures that only low luminance images of the floodlights occur in the water. The small dimensions of the light source produce only small areas of reflection on the water separated by large areas of dark sky.

3.47.3 Underwater lighting

Underwater lighting reduces the effect of veiling reflections on the pool surface by increasing the luminance of the pool surface. It also illuminates underwater swimmers, thus increasing pool safety and allowing coaches to study technique. Usually luminaires are installed on the longitudinal sides of the pool basin. This means the bright beams pass the shortest distance through the water and cause minimum annoyance to swimmers. Where narrow-beam floodlights are used, the peak intensity should be aimed approximately 10° above the horizontal. As almost total internal reflection takes place at the surface of the water there is no risk of glare to the swimmer, officials or spectators, and reflected light is redirected to light the sides and bottom of the pool evenly.

There are two basic types of underwater lighting: 'dry' and 'wet' niche mounting. For wet niches, luminaires are recessed into the walls of the pool with a cable long enough for them to be serviced at the pool side. Dry niches contain luminaires behind watertight portholes.

Class – swimming/ diving/racing/ polo/synchronised	Indoor and outdoor pools			Colour rendering index
	Horizontal illuminance		Diving (additional requirement)	
	E_{av} (lx)	E_{min}/E_{av}	E_h/E_v	
I	500	0.7	0.8	60
II	300	0.7	0.5	60
III	200	0.5	0.5	20

CTV group A

Note 1: Swimming. The above are general requirements only. Special requirements may be needed for individual pools.

Note 2: Racing and polo. No underwater lighting should be used.

Note 3: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 5% of that for a particular class for a minimum of 30 s.

3.48 Table tennis

The small, fast-moving white ball must be clearly visible during flight, which may extend considerably beyond the area of the table. The table area will require a uniform level of illumination. A lower uniform level is generally acceptable over the remaining playing area.

Good contrast is necessary to perceive the small ball. To achieve this, the background should be kept relatively dark. Lighting of the surrounding play area should be uniform and to at least 50% of the level on the table.

For a small number of fixed table positions it is often preferable to consider individual table illumination from luminaires mounted above and outside the main playing area. In sports halls with a greater number of tables in use, the general illumination must be adequate for the standard of play required. Luminaires should be positioned at high mounting heights and outside the main viewing zone of the players to avoid glare. At mounting heights above 5 m, suitable luminaires containing discharge lamps may be considered.

Class	Horizontal illuminance (note 1)		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	300	0.7	20

CTV group C

Note 1: Taken on the table and over the surrounding floor-level playing area (see section 2.11).

Note 2: Reflectance: back walls 0.2; side walls 0.4–0.6; ceilings 0.6–0.8

Note 3: The standard height of a table tennis table is 0.76 m

3.49 Volleyball (indoor)

Most volleyball courts are defined on a multi-use playing surface (see section 4). The lighting installation must allow players quickly to discern the court markings. The action is fast and, although the ball is relatively large, players must be able to follow movement of both the ball and other players.

An acceptable installation may be provided for training and recreational purposes by luminaires mounted above the court and spaced to meet uniformity requirements. Glare can be controlled by careful luminance control and by reducing the contrast between luminaires and ceiling.

Class	Horizontal illuminance over principal area		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

Note 1: No luminaires should be positioned in the area of the ceiling directly above the net.

Note 2: See section 2.11 for a definition of the playing area.

3.50 Wall climbing

This activity involves differing speeds of action and movement on the climbing wall. This action can vary from general climbing or practice to speed climbing. Participants must be able to recognise the various hand holes and undulations on the wall.

Illumination should be provided by an overhead array of luminaires providing vertical illuminance on the climbing wall without causing disability glare to the participants. In cases where the climbing wall is adjustable, the lighting installation should be designed to accommodate these changes.

For higher standards of competition, luminaires that concentrate most of the light on the vertical surface are suspended over the wall. If the event is to be televised it is usual to install a modified overhead system or additional high-intensity lighting.

Class	Vertical illuminance		Colour rendering index
	E_{vav} (lx)	E_{vmin}/E_{vav}	
I	500	0.8	60
II	300	0.8	60
III	200	0.8	20

CTV group A

Note 1: Safety lighting (see section 2.8.2.1). The lighting level for the safe stopping of an event is 10% of that for a particular class for a minimum of 60 s.

3.51 Weight training

Participants must be able to concentrate in safety on their training without distraction from the lighting installation. This activity is different from most sports in that there are no principal area layouts owing to the varying nature of weight training rooms and the positioning of equipment.

The lighting system must control the possibility of glare within the area so that the participants can take part in the training. Where potentially difficult or hazardous tasks take place, it may be necessary to improve the illumination at that location with the use of additional lighting.

Horizontal illuminance		Colour rendering index
E_{av} (lx)	E_{min}/E_{av}	
500	0.7	60

3.52 Wrestling

As the action takes place at close quarters, the referees, judges, spectators and participants need good visibility from all directions.

The lighting installations should be provided from ceiling-mounted luminaires positioned to provide uniform illumination.

Wrestling can occasionally take place in multi-use facilities (see section 4).

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

4 Sports halls

A lighting scheme must be able to provide adequate illuminance, suitable brightness and contrast, uniform light distribution and satisfactory control of glare. It must also contribute towards overall ambience.

The size and shape of the area, together with the colour, material and finish of all surfaces within the space, will all have an effect on the quality and type of lighting produced. It is essential, therefore, that the lighting design is considered as an integral part of the overall design of the hall. It is also important that the intended activities are defined in order for the lighting requirements to be assessed and the playing areas co-ordinated with the layout of the artificial lighting and the overall design of the space.

Any proposed use of natural light in a sports hall requires very careful consideration because of difficulties in controlling glare and ensuring reasonably stable and uniform levels of lighting. The specific visual requirements will depend on the activity. Most sports halls have to cater for a range of activities, and it may be necessary occasionally to accommodate different activities simultaneously in order to maximise use.

Non-sporting use of a hall may also be considered in order to maximise income, and special lighting may be required for some arts or social activities as well as competitive sporting events such as table tennis. It is normally necessary to design a general lighting scheme to cater for a wide range of activities and, if necessary, incorporate switching arrangements for different activities, levels of play or simultaneous multi-use.

It is generally recommended that the lighting design be based on the requirements of the activity with the highest priority while ensuring that, as far as practicable, all other potential activities are catered for.

It is vitally important for the layout of the playing areas and the type and arrangement of the lighting system to be planned together. Lighting schemes and arrangements should be co-ordinated with the layout of all playing areas so that the highest-priority use is covered and all other activities catered for.

Where there is limited information on expected usage, or badminton is one of the potential uses, it is generally recommended that a scheme be designed to suit the layout of badminton courts. Badminton has the most exacting visual requirements in the majority of multi-use sports halls, and a lighting scheme that satisfies badminton requirements and is located to suit the court layouts will often cater adequately for a wide range of other activities.

Figure 24 (Below left) Sports hall with variable illuminances achieved by switching between multiple luminaire clusters, thus maintaining a high uniformity.

Figure 25 (Below right) Typical sports hall with limited switching between illuminances.

Class	Horizontal illuminance		Colour rendering index
	E_{av} (lx)	E_{min}/E_{av}	
I	750	0.7	60
II	500	0.7	60
III	200	0.5	20

CTV group B

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Figure 24 (Below left) Sports hall with variable illuminances achieved by switching between multiple luminaire clusters, thus maintaining a high uniformity.

Figure 25 (Below right) Typical sports hall with limited switching between illuminances.

For visual comfort, illumination on walls should be at least 50% and illumination on ceilings at least 30% of that on the playing area.

The lighting requirements for the various sports are detailed in the individual sports sections.

5 Stadia – small and large

5.1 Small sports stadia

A small sports stadium may be considered to be an outdoor sports ground with spectator facilities. It may have the added provision of an athletics track on the perimeter of the central field area. In certain circumstances there may also be a cycle track either in addition to, or as an alternative to, the athletics track.

Almost invariably where full athletics provision is provided, track and field events will be held and the central area will have a grass surface. In addition the central area may be suitable for staging sports such as football, rugby and field hockey, thereby leading to greater utilisation of the facility. While some areas within the athletics track may be deliberately constructed from synthetic material, the staging of field events will not be possible when the whole of the inner area is constructed from such resources.

The generally accepted criteria for small stadia are:

– a spectator capacity of less than 5000; and
– spectator provision principally in the form of a small main grandstand usually located on one side of the playing area with additional terracing or open seating to surrounding sides of the ground

For small sports stadia the lighting requirements relevant to class II and III events are, in general, suitable for athletics and other sporting uses (football, rugby, hockey etc). The lighting requirements usually demanded for colour television broadcasting are generally unnecessary, although lighting for the coverage of events by video camera may be justified. The lighting requirements for large sports stadia are detailed separately in section 5.2. National and international meetings are generally staged in major sports stadia with CTV provision (see section 7).

Viewing distance is significant in determining the optimum lighting conditions for sport with the longest viewing distance demanded by spectators. The visual requirements placed on the participants and match officials in respect of viewing distance will be satisfied if the simultaneous requirements of the spectators are similarly fulfilled.

For small stadia it is not necessary to evaluate vertical-plane illuminances over the playing area provided that the horizontal-plane illuminance requirements are achieved. However, discomfort glare should always be considered during the determination of the glare rating.

Figure 26 Small sports stadium illuminated using a four-corner mast system.

For visual comfort, illumination on walls should be at least 50% and illumination on ceilings at least 30% of that on the playing area.

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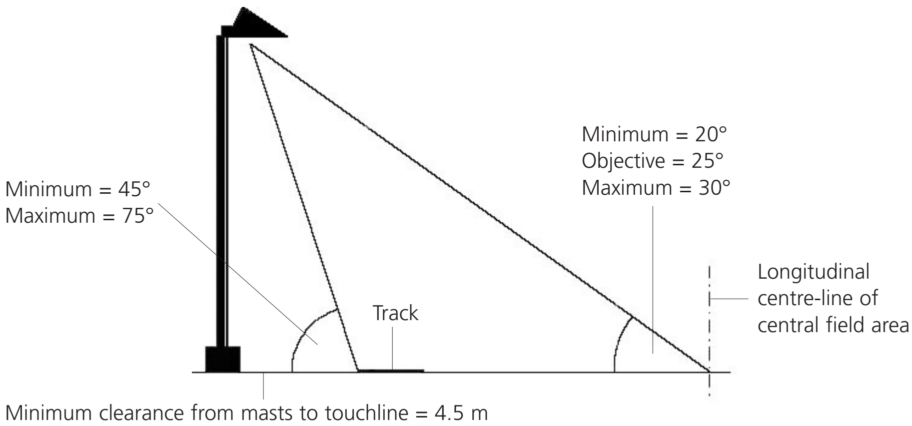
Figure 26 Small sports stadium illuminated using a four-corner mast system.

Figure 27 Half-section showing the criteria for the mounting height for side lighting.



Conformity with the recommendation of Figure 27 will ensure the adequate modelling of participants and provide generally accepted mast and floodlight locations to enable reasonable viewing conditions for players and officials.

The type of floodlighting system will be influenced by the events likely to be staged. Individual sporting activities may have their own specific lighting requirements fulfilled by the appropriate choice of an all-embracing, full installation; alternatively, each separate activity may be lit individually using different switching sequences.

The individual lighting requirements may encompass track-only (athletics), track-and-field (athletics) or central-field areas (football, field hockey etc) and are detailed in sections 5.1.2, 5.1.1 and 5.1.3, respectively.

5.1.1 Track and field

Lighting systems incorporating masts located around the perimeter are usually considered the most cost-effective solution when illuminating both track and field. The recommended mounting height and offset of masts are generally determined from Figure 27.

The lighting for the central field area is usually provided by luminaires mounted on masts located along the sides. Care should be taken to ensure that floodlights provide sufficient vertical illuminance to enable the flight of a javelin, shot, hammer and discus to be followed in safety. Supplementary masts spaced evenly around the bends of the track are often utilised when lighting the semicircular end segments of a stadium.

When considering track events such as long jump and pole vault, it is important not to produce unwanted glare towards participants. Masts and floodlights should be located so as not to impair the vision of athletes as they undertake their jump or vault. These events may be staged inside or outside the main track, depending upon the stadium design. With inside arrangements the overall width of the central field area is increased, often making it necessary to utilise increased mounting-height masts on one or both sides of the stadium. Where events are held outside the track, luminaires mounted back-to-back on the stadium's main luminaires can be used to good effect.

Options for the illumination of both track and field areas for small stadia include:

- a four-corner tower system, although mast heights may need to be large to ensure that the lighting parameters are achievable; and
- a combined system incorporating masts along the side of the track together with lower mounting-height masts positioned around the track bends. The heights of the masts can be determined from Figure 27. Where grandstands are of a suitable height they may also be used to carry a proportion of the track or central-area floodlighting.

Attention must be given to the prevention of shadows on the playing area caused by the roof obstructing the output from floodlights mounted on masts. The installation of supplementary floodlights mounted on or under a grandstand roof may alleviate shadow problems.

5.1.2 Track only

Smaller masts are usually evenly spaced around the perimeter of the track. The recommended mounting heights may be determined from Figure 27. Any stray lighting from such a system that may spill onto the central inner area is unlikely to be sufficient for the training associated with field events.

5.1.3 Central field

In general the recommendations of section 5.1.1 should be followed when considering floodlighting for the central area only, with the proviso that any lighting not contributing to the illuminance over the central field area should be switched off.

The principal benefits of this are energy saving and reduced glare to participants. Some spill lighting on the track can be useful as it highlights the edges of the track area.

The recommendations for individual sporting activities other than the normal field events that are likely to take place in the central area, such as football and field hockey, are detailed in section 3.

Note: For field events such as discus, javelin, shot and hammer the equipment used may travel above the line of sight during flight and will therefore be out of view for some part of the trajectory. It is important therefore to light the areas where such events are taking place so as to ensure the continued protection of all personnel likely to be in the vicinity.

5.2 Large sports stadia

A large sports stadium is one in which major sporting events are staged. In general such a stadium consists of a central grassed area for field events or ball sports surrounded by an athletics track. In many instances the stadium will be dedicated to one particular sport such as football. Spectator capacities will invariably be greater than 5000 and will typically exceed 10 000.

Large sports stadia are typically used for staging national, international and professional events. The lighting should permit a range of illumination levels switchable to suit the proposed levels of play and training purposes. Lighting provision should be applicable to the lighting level class (see Table 1 on page 9) and the CTV group stated for each lighting application in Part B of the guide. Full details in relation to CTV provision are provided in section 7.

Glare rating should always be determined to ensure that values are within acceptable limits (see section 2.4.1). It will be necessary to incorporate some form of switching in order to energise the appropriate number of luminaires for each class of competition.

Figure 28 Side lighting to national and international standards, designed to meet requirements for CTV in large sports stadia.

5.2.1 Training

Since training is likely to be of a high standard, the lighting requirements are normally those associated with classes I and II (see Table 1 on page 9).

5.2.2 Normal events

The illuminances for normal events are greatly influenced by the requirements of spectators. In general a greater spectator capacity coupled with an increase in the distance of the spectators from the action will demand a greater illuminance. The equation below gives an approximation for determining illuminances.

$$E = 324\,\{\ln(2.1[D+S])\} - 1530$$

(where D is the maximum viewing distance in metres to the centre of the stadium; S is the spectator capacity in thousands; E is the illuminance in lux; and ln is a natural logarithm).

5.2.3 Systems

Large stadia will require either high-mast corner installations, side lighting from grandstand roofs or a hybrid solution combining elements of both systems. In new stadia the overall design concept may dictate a specific lighting approach.

Most high-mast installations will be four-corner tower solutions, but very large venues (such as cricket grounds and athletics stadia) may require additional structures or exceptionally high masts. The type of lighting system will be dictated by several factors including the construction and layout of the facilities. Particular attention should be paid to the avoidance of shadows, which may be cast by large overhanging grandstand canopies if the location of the masts is not ideal.

Corner-mast systems usually provide an easier means of achieving high vertical illuminances at furthermost distances (opposite sides of the pitch). The production of adequate vertical illuminance along near touchlines may be difficult where minimal mast-offset distances are allowed. In these cases assistance from a complementary side-lighting system may be beneficial.

High-mast corner systems normally utilise floodlights with a variety of symmetrical beam configurations designed to focus light into the stadium arena. Internal baffles will help to improve efficiency and alleviate obtrusive-light issues.

Where side-lighting installations are selected, the luminaires may be mounted in continuous runs either along or beneath the edge of the stand canopy, depending upon the offset required. Typical roof heights should be in excess of 20 m above ground level in order to be an effective platform for a side-lighting system.

Side-lighting systems usually provide an easier way of achieving higher vertical illuminances along near touchlines. However, floodlights aimed towards the far side of the stadium may easily cause glare to spectators. A hybrid system of side lighting and high masts can alleviate this situation if insufficient roof height is available.

Care must be taken in order to prevent the creation of potentially dangerous shadows caused by grandstand roofs, and special design considerations may be required to illuminate such areas.

As it is nearly always the case that no two sports stadia are identical, each large stadium is likely to require a unique lighting design.

6 Indoor arenas

An indoor arena will usually be built to cater for a variety of events. However, the principal design consideration will be for its use as a multipurpose sports venue. This means there will usually be upward of 2000 permanent seats evenly spaced around the perimeter of the event floor.

However, most arenas will also double for use as a general-event venue. There is therefore the temptation to include lighting for all possible uses. Experience shows that in most cases it is best to provide temporary lighting for these events so that the permanent lighting only needs to cater for the sports area itself. For setting up and for house lighting see section 2.7 and the SLL *Code for Lighting*.

Figure 29 A small indoor arena with a multi-functional lighting system.

5.2.3 Systems

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Most high-mast installations will be four-corner tower solutions, but very large venues (such as cricket grounds and athletics stadia) may require additional structures or exceptionally high masts. The type of lighting system will be dictated by several factors including the construction and layout of the facilities. Particular attention should be paid to the avoidance of shadows, which may be cast by large overhanging grandstand canopies if the location of the masts is not ideal.

Corner-mast systems usually provide an easier means of achieving high vertical illuminances at furthermost distances (opposite sides of the pitch). The production of adequate vertical illuminance along near touchlines may be difficult where minimal mast-offset distances are allowed. In these cases assistance from a complementary side-lighting system may be beneficial.

High-mast corner systems normally utilise floodlights with a variety of symmetrical beam configurations designed to focus light into the stadium arena. Internal baffles will help to improve efficiency and alleviate obtrusive-light issues.

Where side-lighting installations are selected, the luminaires may be mounted in continuous runs either along or beneath the edge of the stand canopy, depending upon the offset required. Typical roof heights should be in excess of 20 m above ground level in order to be an effective platform for a side-lighting system.

Side-lighting systems usually provide an easier way of achieving higher vertical illuminances along near touchlines. However, floodlights aimed towards the far side of the stadium may easily cause glare to spectators. A hybrid system of side lighting and high masts can alleviate this situation if insufficient roof height is available.

Care must be taken in order to prevent the creation of potentially dangerous shadows caused by grandstand roofs, and special design considerations may be required to illuminate such areas.

As it is nearly always the case that no two sports stadia are identical, each large stadium is likely to require a unique lighting design.

6 Indoor arenas

An indoor arena will usually be built to cater for a variety of events. However, the principal design consideration will be for its use as a multipurpose sports venue. This means there will usually be upward of 2000 permanent seats evenly spaced around the perimeter of the event floor.

However, most arenas will also double for use as a general-event venue. There is therefore the temptation to include lighting for all possible uses. Experience shows that in most cases it is best to provide temporary lighting for these events so that the permanent lighting only needs to cater for the sports area itself. For setting up and for house lighting see section 2.7 and the SLL *Code for Lighting*.

Figure 29 A small indoor arena with a multi-functional lighting system.

6.1 Sports lighting

The first stage of the design will be to identify the likely sports that will take place. This will include any temporary changes that might be made to the seating. The largest area requiring lighting will usually be for the playing of ice hockey, if applicable. Lighting positions will need to be over the playing area itself as well as outside the playing area. This is to ensure a minimum vertical illuminance on players right up to the edge of the playing area.

It is important for likely lighting positions to be discussed with the building designers at an early stage to ensure that suitable locations are considered and obstructions are avoided. The positioning of luminaires must allow a clear view of the area to be illuminated, with access preferably via catwalks. Often there is a compromise between the lighting requirements and ease of access. Equipment location should also take into account future maintenance and lamp replacement.

6.2 Broadcast lighting

The specific requirements for television are discussed in section 7. However, many stadia now broadcast the action on internal video walls for the benefit of the spectators. While these systems may not demand the same lighting level as commercial broadcasters, the positioning of lighting equipment to achieve sufficient vertical levels is just as critical.

6.3 Developing the design

In most cases the lighting will be provided by floodlight projectors similar to those used for outside stadia. The design will be built up from a series of overlapping beams until the whole area is covered. Higher lighting levels are produced by adding further layers.

All sports require a maximum of three different levels achieved by switching to different layers. The design should allow for the most frequent configurations. For example, basketball requires an area 28 x 15 m to be lit while gymnastics requires the full arena. This suggests the need for two areas each with three levels, in other words six switched states. In theory it is possible to refine the design further by adding additional areas for other sports. In practice, however, this level of sophistication is unlikely to be used once the venue is operational.

The switching of the arena lighting is sometimes required to add impact to the team's arrival, for example. Discharge lamps used for this application require a period to cool down after being switched off before they will re-strike. If this is a requirement, then a hot re-strike facility will need to be specified. This is also needed if lighting has to be restored in the event of a power failure. Re-strike times vary and advice should be sought from the manufacturer (see section 2.8.2.2).

The recommended lighting levels for sports that are likely to be played in an indoor arena are given in the individual sport sections. Some compromise will be needed to accommodate all these requirements in one facility. From these tables it is likely that the design levels selected will be 200/500/750 lux. This means that those sports in which the action is fast will use just the 500/750 lux levels, as 200 lux is considered too low for safety and performance.

A matrix of defined areas and levels can be constructed on which the lighting design can be based. For example:

	Class III E_{av} (lux)	Class II E_{av} (lux)	Class I E_{av} (lux)
Basketball area 1	200	500	750
Ice hockey area 2	*	500	750

This gives us five separate designs that must be integrated. The specific recommendations listed under each individual sport (indoor) should be achieved in the arena.

6.4 Set-up lighting

This will be required for general use when events are not taking place, and may be operational for up to 24 hours a day. It is therefore usual to provide a separate installation for this purpose. The recommended maintained illuminance is 100 lux. In some cases this installation will also double as house lighting, in which case the use of lamps with a colour rendering index of over 80 should be considered.

6.5 Lighting of spectator areas

Unless the set-up lighting has to double as house lighting, a separate installation will be required over the seated area. This may need to be dimmed, in which case the choice of light source is restricted to tungsten, tungsten-halogen or fluorescent, although the latter is preferred on the grounds of energy efficiency.

To enhance the dramatic effect, the spectator areas should be kept relatively dark. This means that the lighting should cut off at the edge of the playing area. As this will also have the effect of making the athletes feel disconnected from the spectators, a compromise is to have a low level of lighting over the spectator areas.

7 Lighting for television

Section 7 has been superseded; see addendum 7a, pages 51a to 51f

While the human eye is able to adapt rapidly to variations in illuminance and hence luminances, cameras used for broadcasting do not have the same capacity. The lighting installation must therefore take into account the restrictions imposed by the cameras.

The principal viewing direction of main and secondary cameras will be such that participants are viewed in a vertical or near-vertical position. The accepted relationship between horizontal and vertical illuminance is given by:

$$0.5 \geq \frac{\text{Mean value of horizontal illuminance}}{\text{Mean value of vertical illuminance}} \leq 2.0$$

Where a number of camera positions are used, the lighting design should be based upon the four vertical planes facing the sidelines. Achievement of the required illuminance will depend upon the type of system used. Side-lighting systems with luminaires typically affixed to grandstand roofs are more efficient than corner-tower systems at achieving acceptable vertical illuminance.

Radio-controlled cameras are portable, are usually used pitch-side and are typically carried by an operator. As a consequence their aiming direction is often upwards, with the result that the likelihood of unwanted 'flares' being produced cannot be neglected.

For team games the main cameras are located on one side of the playing area. Nevertheless, it has become accepted practice to view some sections of play using pictures from cameras positioned on planes on more than one side of the playing area. Where this is done it is normal to have superimposed captions displaying 'reverse angle' or something similar, so that the constant changing of scenes between cameras located on different sidelines does not create an apparent change in the direction of play for the television viewer. For sports such as athletics this confusion does not normally occur and cameras may be positioned all around the arena.

Lighting that does not meet broadcast requirements will adversely influence the ability to provide close-up shots, and the depth of the field will be reduced to such an extent that players in different planes will not simultaneously appear in focus. In addition to meeting the previously specified recommendations, the evaluation of a given lighting installation still requires appraisal by broadcast authorities to ensure that current requirements are satisfied.

The CTV recommendations within this guide are based upon the following guides and standards:

– CIE 83 *Guide for the Lighting of Sports Events for CTV and Film Systems*;
– CIE 67 *Guide for the Photometric Specification and Measurement of Sports Lighting Installations*;
– CIE 112 *Glare Evaluation System for Use with Outdoor Sports and Area Lighting*;
– CIE 169 *Practical Design Guidelines for the Lighting of Sport Events for CTV and Filming*; and
– BSEN 12193 *Light and Lighting – Sports Lighting*.

7.1 Illuminance

The required illuminance will depend upon the type and sensitivity of the camera, lens angle and speed of play. Wider-angle views will require a lower illuminance than narrow-angle, close-up views. In practice, narrow-angle lenses are almost always required.

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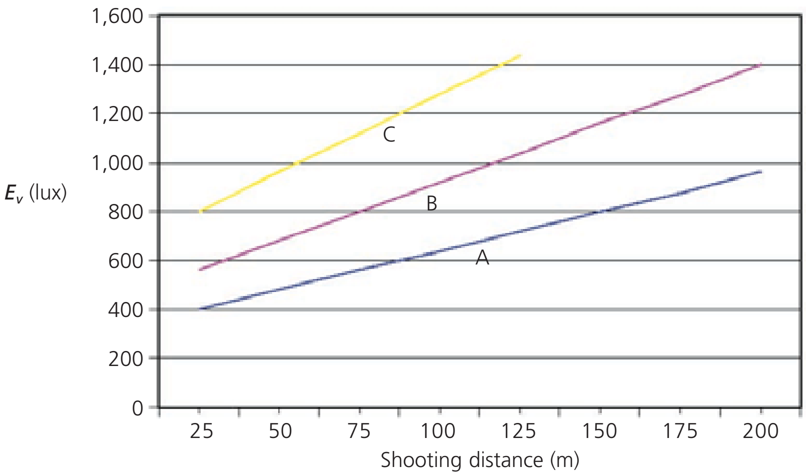
Figure 30 Maintained vertical illuminance plotted against maximum shooting distance for CTV groups A, B and C.

Section 7 has been superseded; see addendum 7a, pages 51a to 51f



Pictures of sporting action viewed on television often give the appearance that the scene is brighter than it is in reality. This is achieved by using gain control to increase the scene luminance. There is, however, a limit in respect of acceptable gain above which the television picture will appear grainy.

For colour television classification purposes, sports can be divided into three groups, referred to as CTV groups A, B and C. These are characterised primarily by the speed of the action during camera shooting and the dimensions of the object of interest. When the CTV group and the value of maximum shooting distance are known, the corresponding maintained vertical illuminance can be determined in accordance with Figure 30.

Where pitch-side cameras have an intrinsic slow-motion replay facility, the playing-area illuminance requirements are increased considerably over the requirements of normal speed cameras. This additional demand, however, is not applicable where slow motion replays are provided exclusively by studio-based facilities.

7.2 Uniformity

When a camera is panned across a scene it is important that variations in scene illuminance are limited. Failure to comply causes rapid adjustment in the exposure requirements of the camera and may ultimately cause confusion to the viewer. Additionally, though engineers may have the ability to control the cameras from within a portable control unit, it is almost impossible totally to conceal irregular illumination.

The imposition of limits on the allowable uniformity ensures that the desired transition is achieved and, in accordance with BSEN 12193, that uniformity ratio limits exist for both vertical and horizontal illuminance values.

On planes facing a sideline bordering a main-camera area or facing a fixed main-camera position, the vertical-illuminance uniformity ratio shall* be:

$$\frac{E_{vmin}}{E_{vmax}} \geq 0.4$$

where E_{vmin} is the minimum vertical illuminance in lux; and E_{vmax} is the maximum vertical illuminance in lux.

The vertical-illuminance uniformity ratio at a single point over the four planes facing the sides of the playing area shall be:

$$\frac{E_{vmin}}{E_{vmax}} \geq 0.3$$

The horizontal-illuminance uniformity ratio on the playing field area shall be:

* The word "shall" is used in this guide only when the recommendations repeat normative requirements of BSEN 121930.

Section 7 has been superseded; see addendum 7a, pages 51a to 51f

$$\frac{E_{hmin}}{E_{hmax}} \geq 0.5$$

where E_{hmin} is the minimum horizontal illuminance in lux; and E_{hmax} is the maximum horizontal illuminance in lux.

On large playing fields such as football pitches the maximum gradient in horizontal illuminance shall be not greater than 25% change every 5 m.

7.3 Colour parameters

7.3.1 Colour temperature and correlated colour temperature

For external installations, or internal installations with a considerable daylight contribution and where lighting is used from the hours of daylight continuing into dusk and possibly beyond, the colour temperature of the artificial lighting should fall within the range 4000–6500 K. Compliance with this recommendation should ensure that apparent colour changes within a scene are minimised as the daylight contribution reduces.

For installations where there is little contribution from natural daylight, the colour temperature of the artificial lighting should fall within the range 3000–6500 K. Care should be taken when replacing lamps to avoid mixing lamps with unequal colour temperature values.

Where discharge light sources are used, the term ‘colour temperature’ should be replaced by ‘correlated colour temperature’.

While cameras may exaggerate a variation in colour temperature quite severely, the human visual system is normally capable of compensating for colour changes. Throughout the reference area of a lighting installation, the colour temperature shall not deviate from the mean value beyond predetermined limits as specified in BSEN 12193.

7.3.2 Colour rendering index

The value of the colour rendering index (Ra) of the light sources used shall be greater than 65 with a preferred minimum value of 80.

7.4 Additional requirements for film

For filmed events the light source should match film manufactured for colour temperatures of 3200 K and 6000 K. Suitable correction filters will be required if the light source does not match these values. A flicker effect can be created due to the cyclic variation in electrical supply to the lamps, an adverse effect that can be exacerbated when filming in slow motion. The normal corrective measures for overcoming such pulsing light output, such as the use of balanced supplies of a three-phase network, should be initiated.

7.5 Display screens

Where video walls are installed it is important to ensure that there are no stray reflections of light likely to impinge onto the display screen and render some or all of the information on the screen illegible.

7.6 Requirements for non-broadcast-quality video

Video recorders for use with non-broadcast-quality systems are capable of discerning visual detail with minimum illuminances of 50 lux. This value is ideally for vertical illuminance; for optimum results a minimum illuminance of 100 lux on the horizontal plane should be achieved.

7.7 Requirements for HDTV

High-definition television may require an increase in definition per unit area of picture or an increase in the percentage of the visual field contained by the image. Lighting requirements to achieve this using HDTV cameras may not require increased scene illuminance over standard-definition television (SDTV) cameras due to the similar sensitivity of both camera systems.

7a Lighting for television

This addendum is based on the need to update the standard in line with current broadcast technology and production techniques. Account is taken of high definition (HD) television, super-slow-motion, 3-D television and the need to minimise the use of gain as a substitute for sufficient light. Other documents dealing with this subject are given in the references.

When considering the lighting for broadcasting the ideal situation is for the lighting to achieve the best possible standard relative to the events that will be regularly televised. These may fall into 3 categories: major events, national events and '2nd league' events. When the facility is being built from new it is possible for the needs of the lighting to influence the design in terms of location, aiming angles etc. However, if the facility already exists then available mounting heights, locations etc. may prevent the required standard being achieved. It is important therefore to realise that the lighting specification and building design work together.

7a.1 Definitions

Cameras are defined as follows:

- *Main cameras*: cameras at locations that are designated as being principal cameras that require full calculations.
- *Secondary cameras*: cameras at other fixed locations and may not require full calculations for each one.
- *Hand-held or roving cameras*: cameras whose position can be anywhere on the field of play (FOP) and require at least for the four vertical planes parallel to the field of play edges to be calculated.

7a.2 Specific requirements for colour television and film recording

The lighting requirements for broadcasting are usually the main consideration in most venues and will be the main driver for the lighting design. The levels of vertical illuminance depend mainly upon the speed of action, the shooting distance, the lens angle and the shutter speed of the camera. However, the needs of the athlete should not be forgotten. It is important to consider the lighting requirements at the earliest possible stage in the design of the venue, as incorrect allowance for the positioning of the lighting could severely affect the broadcast image.

Modern cameras are making use of CCDs (charge coupled devices) and CMOS (complementary metal-oxide semiconductor) technologies with reduced picture noise (degraded quality), increasing the dynamic range of the image device and allowing a broader range of contrast to be accommodated. In addition, video circuit improvements enable a film-like appearance and a greater range of scene contrast. Ultimately it is a balance between picture quality and cost.

7a.2.1 Vertical illuminance

The illuminance on a vertical plane perpendicular to the camera direction (E_{cam}) forms the basis of the lighting requirements for TV and film systems. To achieve this luminaires need to be placed sufficiently far away from the closest action, otherwise the angle will be too steep to achieve the required value. As a guide, angle y in Figure 7a.1 should be $>40°$. For luminaires aimed towards the opposite side of the playing area the angle x in Figure 7a.1 should be $<65°$.

Where vertical illuminance is determined, calculation points shall be as specified in the tables of lighting requirements in Appendix A1, on grid points at 1.0 m height (default value) or 1.5 m (Olympic Broadcast Service requirement) above the playing surface. It is essential that principle camera locations are known at the time of planning the lighting. When these are undefined and in positions somewhere in an area bordering one of the side-lines of, say, a football pitch, the illuminances on vertical planes facing that side-line shall fulfil the requirements for level and uniformity.

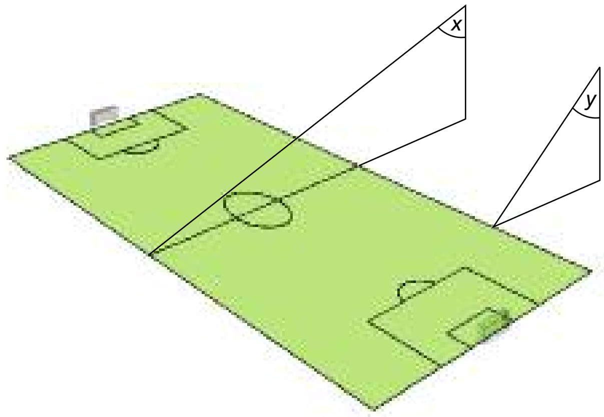


Figure 7a.1 Position of luminaires

On the rare occasions when only one fixed main camera position is defined, it is possible to take the vertical planes on which the requirements shall be fulfilled as those facing the main camera position.

In the case of an unrestricted choice of camera position or the use of hand-held cameras, the illuminances on vertical planes in four directions perpendicular to the sides of the reference area shall be taken into account.

Note: Where the reference area is not a simple shape like a rectangular football pitch, (e.g. running tracks, diving plummet) the orientation of the vertical plane(s) facing the camera position(s) should be decided according to the general principles described in CIE 67: *Guide for the Photometric Specification and Measurement of Sports Lighting Installations*, CIE 81: *Guide for the Lighting of Sports Events for Colour Television and Film Systems* and CIE 169: *Practical Design Guidelines for the Lighting of Sport Events for Colour Television and Filming*.

Event level	Camera illuminance					Vertical illuminance 4 planes perpendicular†
	Main cameras		Secondary cameras		Specific cameras	
	$E_{cam\ min}$ (lux)*	$E_{cam\ min}/E_{cam\ ave}$	$E_{cam\ min}$ (lux)*	$E_{cam\ min}/E_{cam\ ave}$	Gradient over 4 m (%)	$E_{V\ min}/E_{V\ ave}$
Major events	1400	0.7	1000	0.6	20	0.6
National events	1000	0.7	700	0.6	20	0.5
2nd league events	700	0.6	500	0.5	25	0.4

* To guarantee recommended minimum illuminance values during the whole period of operation of an installation, all the above values of $E_{cam\ min}$ are therefore maintained values.

† The ratio of vertical illuminances at any point on the FOP, between the four vertical orthogonal planes at 90° (or 45°) facing the four sides of the FOP should be ≥0.6 and ≤0.9

Note: Calculations are based on planes perpendicular to the viewing direction of the camera at the default height.

7a.2.2 Horizontal illuminance

As the illuminated field forms a major part of the field of view of the camera, an adequate luminance is important. This means the colour of the playing area will play an important part in achieving the correct balance. This is controlled by the ratio $E_{hor\ ave}/E_{cam\ ave}$.

Furthermore, the ratio between the average horizontal illuminance and the average vertical illuminance (relative to the main cameras) will influence the quality of the picture contrast. Because cameras react to luminance, the reflectance of the field of play will play an important part in achieving the correct balance, the specified ratio between horizontal illuminance and vertical illuminance being dependant on the playing area reflectance factor.

Event level	Horizontal illuminance			Glare ratio	
	$E_{H\ ave}$ / $E_{cam\ ave}$	$E_{H\ ave}$ / $E_{H\ ave}$	Gradient over 4 m (%)	Players	Camera
Major events	0.5 to 1.5*	0.8	20	50	40
National events	0.5 to 1.5*	0.7	20	50	40
2nd league events	0.5 to 2	0.6	25	50	40

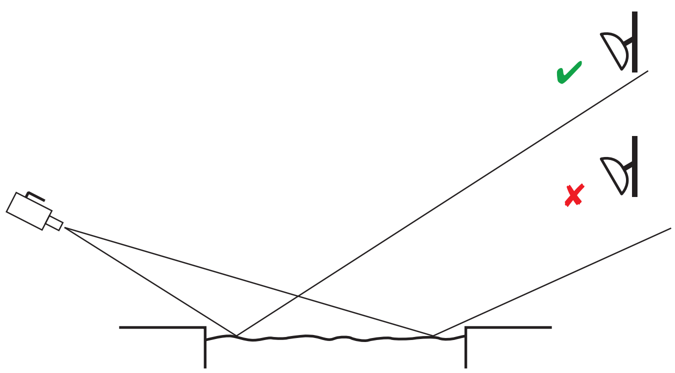
* The target value for typical grass surface should be 1.0; for lighter surfaces it should be between 0.5 and 1 (e.g. for ice, target value should be 0.5); for dark surfaces it should be between 1.0 and 1.5

Notes: (1) Illuminance values includes the intereflected component where applicable; (2) HDTV is 'unforgiving' in displaying unevenness and hot spots.

7a.2.3 Unwanted reflections or 'skip light'

Reflections of bright sources such as floodlights or sunlight/daylight in the playing surface can cause bright images that will affect the camera picture. These are affected by the position of the source relative to the cameras and the surface reflection. Analytical software can be used to predict where these might occur so preventative action can be taken at the design stage. This is referred to as 'skip glare' by broadcasters. With knowledge of the main camera locations, simple geometry can also be used at the preliminary design stage to limit backlight locations see Figure 2. The surfaces likely to cause skip glare should be matt finish.

Figure 7a.2 Avoiding reflections from surface



7a.2.4 Colour temperature of the lighting

In the case of outdoor installations the colour temperature of the artificial lighting shall be between 5000 K and 6000 K where floodlighting is used during daylight and into dusk. It should be noted that broadcasters require a constant colour temperature wherever possible and do not like a mix of significantly different colour temperatures. The broadcaster will almost invariably require the least amount of daylight possible within an indoor venue in particular if it affects the playing area. Broadcasters generally call for a total daylight blackout with no compromises on permissible daylight levels.

Within the reference area of an installation the colour-temperature shall not deviate from the average value by more than the stated maximum and minimum limits given in Figure 3 below.

7a.2.4 Colour rendering of the lighting

The colour rendering index R_a of the lighting should be greater than 80.

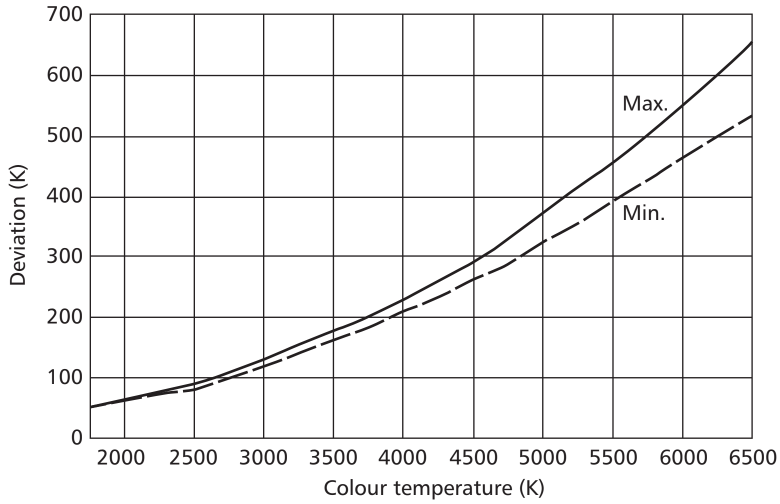


Figure 7a.3 Colour temperature tolerances within the reference area

7a.2.6 Light level on surrounding spectators' areas

For television camera shooting it is desirable that the areas bordering the playing field should be illuminated to a certain extent, but that this falls off beyond the first 12 rows. This will ensure adequate contrast between the sporting action and its background. This is generally expressed as a ratio between the average vertical illuminance at 1.5 m height over the first 12 rows of seating towards the principle camera and the average vertical illuminance at 1.5 m height over the playing area (PA) towards the principle camera. Recommendations are given in the following table.

Event level	Main cameras $E_{cam\ ave\ (Stand)} / E_{cam\ ave\ (PA)}$
Major events	<0.25
National events	<0.25
2nd league events	<0.35

Depending on the production style some sports might require special attention, such as 'theatrical treatment', where the light in the stands is reduced to the minimum, to obtain a more dramatic atmosphere.

7a.2.7 Glare rating

Glare rating (GR) from CIE 112: *Glare Evaluation System for Use within Outdoor Sports and Area Lighting* is designed to minimise the effects of glare for the player. However it is often used by broadcasters and a GR<40 will help to ensure there is no camera flare. The calculation is made in the same way as for competitors. Mitigation measures to minimise glare, spill light reflected light include suitable louvers, hoods, shields barn doors etc.

7a.3 Position of floodlights

Camera flare can be minimised by ensuring floodlights are not placed in direct view of them. The floodlight locations should be agreed at the earliest stage in the design of a venue as it can have structural implications. Angle *x* in Figure 1 should be limited as indicated in the following table.

Requirement	Major events	National events	2nd league events
Luminaire aiming angle*, in elevation	≤65°	≤70°	≤70°
No luminaire shall be aimed directly at a stationary camera within cone of stated angle	50°	50°	50°

* luminaire aiming angle = the angle of the peak intensity (not necessarily coïncident with the front [glass] surface or physical axis)

7a.4 Additional requirements for super-slow-motion broadcasting

Super-slow-motion (SSM) cameras operate at shutter speeds above 150 fps and are now typically used between 300–600 fps to produce slow motion clips of the action. Cameras with speeds above 300 fps are usually called 'ultra-slow-motion' (USM).

Traditional discharge lamps operating on electromagnetic gear produce a 100 Hz flicker, which is detectable to the camera at these high frame rates. With the development of SSM/USM cameras it is now necessary to specify specific values. This should be carried out in conjunction with the broadcaster.

7a.4.1 Flicker factor

Flicker factor is defined as:

$$\mathrm{FF} = \frac{E_{\mathrm{H\,max}} / E_{\mathrm{H\,min}}}{E_{\mathrm{H\,max}} + E_{\mathrm{H\,min}}} \times 100$$

where FF is the flicker factor (%), $E_{\mathrm{H\,min}}$ is the minimum horizontal illuminance in time at point on the calculation grid (lux) and $E_{\mathrm{H\,max}}$ is the maximum horizontal illuminance in time at the corresponding point on the calculation grid (lux).

For super-slow-motion broadcasting up to frame speeds of 1000 fps:

- Max. FF <1%: flicker free
- Max. FF < 6%: barely visible and acceptable
- Max. FF ≤ 10%: visible, may be acceptable
- Max. FF > 10%: visible, not acceptable.

Flicker can be controlled by:

- Using a lighting system that has a declared flicker within the specification
- Mixing light using a 3-phase electrical supply. In this case three calculations should be made over the field of play and surrounding areas for each phase. The three readings at each calculation point should be compared and should not vary by more than the specification. This approach may be appropriate for SSM (<150 fps) but not necessarily for USM (300–600 fps) cameras.
- Electronic ballasts.

7a.4.2 Measurement of flicker factor

A meter can be used to directly measure the flicker factor. This should be carried out in the same way as the measurement of horizontal illuminance over the same grid points. The flicker factor for the installation will be the maximum of the measured values.

Light falling on the spectator areas as specified in section 6.3.6 is also subject to the same flicker requirement as the spectator areas form a background to the camera image.

7a.5 Considerations for other users

Together with the consideration for broadcasters the lighting must also fulfil the needs of participants, spectators and judges. Positioning lighting to achieve the broadcast requirements may result in glare for these other users. Individual sports will therefore have 'restricted luminaire location zones', which should be avoided. In general, floodlights should not be aimed within 10° of the line of sight of judges with a fixed location or the usual line of sight of participants. The governing body for individual sports should be able to offer specific advice for their particular sports.

References

CIE 67: *Guide for the Photometric Specification and Measurement of Sports Lighting Installations* (Vienna: International Commission on Illumination) (1986)

CIE 81: *Guide for the Lighting of Sports Events for Colour Television and Film Systems* (Vienna: International Commission on Illumination) (1989)

CIE 112: *Glare Evaluation System for Use within Outdoor Sports and Area Lighting* (Vienna: International Commission on Illumination) (1994)

CIE 169: *Practical Design Guidelines for the Lighting of Sport Events for Colour Television and Filming* (Vienna: International Commission on Illumination) (2005)

Part C – Maintenance and operation of sports lighting

8 Maintenance and operation

8.1 Maintenance

The illuminance provided by a lighting installation will decrease as the lamps age and dirt is deposited on the luminaire and room surfaces. The luminaire's luminous distribution will also be affected by dirt deposits. Planned maintenance is therefore essential if the design parameters are to be met throughout the life of an installation.

Depreciation can be kept within technically and economically acceptable limits by ensuring:

- that luminaires are safe, reliable and constructed to relevant international standards;
- that luminaires are selected to suit location conditions; and
- that a programme of luminaire cleaning and lamp replacement is implemented.

8.2 Depreciation of lighting installations

Planned maintenance is essential for all lighting installations. An agreed maintenance factor should be applied to take into account all light depreciation factors (see appendix 2).

The maintenance of indoor installations and the depreciation of interior surfaces is dealt with in detail in the SLL *Code for Lighting*, which should be consulted.

Luminaires may be difficult to reach, especially those with mounting heights up to 10 m. Servicing arrangements must be considered when the building is planned. In certain cases it may be possible to provide a catwalk to permit the servicing of luminaires from the ceiling void.

The maintenance of outdoor installations is more demanding than that of indoor systems, primarily because the luminaires operate under more severe conditions and are usually less accessible.

8.3 Construction of equipment

Exterior luminaires and associated exposed equipment must be able to withstand the environment for many years. Unprotected metalwork should be manufactured from highly corrosion-resistant grades of material and/or be protected against corrosion by appropriate surface finishes. This is of particular importance in high-moisture or marine applications where the saline environment provides highly corrosive conditions.

Those parts of the luminaire that have to be removed or opened for access to the interior should suitably restrict the ingress of moisture and dirt (see section 10.1). In floodlights utilising unjacketed lamps, a high ingress protection rating (IP65/IP66) is necessary to prevent contamination of the lamp and a shortened lamp life.

Luminaire reflectors are primarily of brightened and polished aluminium. These surfaces are usually anodised for protection against corrosion but may still become subject to deterioration.

8.4 Servicing equipment

The accumulation of dirt in any moisture present can also lead to severe corrosion and seizure of mechanical parts if the equipment is not serviced for long periods. Luminaire light-emitting surfaces should be cleaned and the lamps replaced at the intervals stated in the maintenance plan. Reflectors should not be cleaned unless absolutely necessary.

If reflector cleaning is unavoidable then it should be undertaken with extreme care and in accordance with the manufacturer's recommendations. Abrasives or dry cloths should not be used as these can easily damage reflecting surfaces.

The regularity and effectiveness with which equipment can be serviced generally depends on the cost of maintenance, which should be considered when determining the maintenance plan. Effective maintenance is more likely if luminaires can be easily reached and cleaned.

8.5 Operation

The most powerful constraints on any design are usually financial. It is necessary to establish realistic economic and energy budgets commensurate with the design objectives. The methods of financial assessment employed by the designer must be acceptable to the client, since grants, tariffs, accounting methods and other factors can vary. Fortunately, simple methods of analysis are usually sufficient.

A new lighting installation may be justified because of increased lighting specifications for the sport concerned. Where there is existing equipment it may be necessary to decide whether it is better to upgrade, refurbish or replace with a new scheme.

The cost of owning and operating an installation can be divided into:

- capital costs (lamps, luminaires, associated equipment installation and wiring); and
- operating costs (fixed annual costs, running costs, maintenance costs).

8.5.1 Energy use

Sports lighting should be designed to be energy efficient and in accordance with Building Regulations Approved Documents L2a and L2b, 2006 in England and Wales, or the regulations in force in other areas.

8.5.1.1 Lamp energy efficiency class

A lamp energy efficiency class (LEEC) may be assigned to a lamp in accordance with its energy efficiency index. This information is defined in the Lamps Directive 98/11/EC and measured in accordance with BSEN 50285.

8.6 Management of lighting systems

Energy costs may be controlled by investment in energy management systems, ranging from locally installed detectors or photocells to full computer monitoring of lamp usage, lamp survival and overall system operating efficiency. With building management systems it is possible to programme system illumination levels and occupancy in conjunction with the facilities.

8.6.1 Flexibility of switching

A sports lighting installation may need to operate at various illuminance switching or dimming levels. Consideration should be given to:

- switching systems to light individual playing areas;
- remote switching to enable staff to control and programme usage;
- timers to control usage; and
- photocell-controlled systems in conjunction with natural daylight where appropriate.

By utilising switching programmes, substantial savings on energy can often be achieved.

8.6.1.1 Occupancy detectors

These control luminaires in the event of areas being unoccupied. They can also be used for non-sporting activities, in which case the sensitivity will need to be adjusted accordingly. It is possible with certain types of heating systems to link both luminaires and heaters to occupancy detectors (see SLL *Code for Lighting*).

It should be noted that certain types of discharge lamps are not suitable for control by movement detectors.

8.6.2 Constant illuminance

Designing for a maintained illuminance means that initially, when lamps are new and luminaires and surfaces are clean, the illuminance will be substantially higher than the design level. How much higher will depend upon the characteristics of the installation and the intended maintenance programme.

Lighting systems that can be regulated may be linked to photocells that will hold the lighting at the design maintained illuminance. As the system ages the controls will also be able to increase the power to the lamp. Eventually the system will operate at full load in order to produce the maintained illuminance, and this is when maintenance should be carried out.

The installation can also be adapted for change over use. If the function of an area changes, requiring a lower task illuminance, the system can be adjusted to control the lighting to the revised level.

To achieve full versatility, a constant-illuminance installation requires the use of electronic control gear coupled with a lighting control and lamp monitoring system.

8.6.3 Documentation

The original design layouts, objectives and records of calculated and achieved illuminances should be kept for reference.

At regular intervals it is advisable to recheck illuminances at key positions on the playing surface. This will enable assessments to be made as to whether or not the scheme is operating within the design recommendations for the sport.

With careful monitoring of maintenance and running costs, an accurate assessment of the true operating expenditure can be formulated.

8.7 Hours of use

The usage of sports facilities can vary throughout the year depending upon the individual sport; ie badminton and football are mainly autumn and winter sports while athletics and tennis are primarily summer sports.

It may prove beneficial to install an hours-run meter on the user side of the main installation supply switch to enable a true estimate to be made of the hours of lighting use. This could also be used to record lamp life and will prove useful when monitoring scheme performance. Listed below (Tables 4 and 5) are typical variations in hours of usage per annum for various sports lighting facilities.

Table 4 Approximate hours of lighting in a year of 365 days

Daily lighting from 1 h before sunset to	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total per annum
18:00	81	51	23							36	83	94	368
19:00	112	79	50	2					22	67	113	125	570
20:00	143	107	80	32	7			20	52	98	143	156	838
21:00	174	135	110	62	38	23	28	51	82	129	173	197	1192
22:00	205	163	141	92	69	53	59	82	112	160	203	218	1557
23:00	236	191	172	122	100	83	90	113	142	191	233	249	1922
Midnight	267	219	203	152	131	113	121	144	172	222	263	280	2287

Table 5 Approximate hours of usage for sports facilities per annum

Exterior sports applications	hours	Interior sports applications	hours
Major-sports stadia (eg football and athletics)	60	Swimming pools	4200
Minor-sports stadia (eg rugby and hockey)	100	Sports halls and ancillary areas	4500
Outdoor sports grounds	300	Individual sporting facilities	500
Outdoor multi-use areas	1000	Indoor arenas (events)	3000

Part D: Equipment

9 Lamps

The selection of a suitable light source for the sports application will require many considerations:

- luminous efficacy (the amount of light emitted per unit of electrical power (lm/W);
- colour rendering;
- colour appearance (correlated colour temperature), particularly important in CTV applications;
- lamp lumen depreciation; and
- lamp survival.

The type of lamp selected should have the best balance of properties for the application since this will affect the overall impression, suitability and operating parameters (initial and running costs) of the installation. The technical selection data and information on lamps should be sought from manufacturers.

9.1 Lamp types

The following types of lamp are commonly used in sports lighting:

- exterior applications: metal halide, high-pressure sodium and tungsten halogen (ie photo-finish applications); and
- interior applications: tubular fluorescent, compact fluorescent, metal halide and high-pressure sodium.

A general overview of lamp types, luminous efficacy and selection criteria including possible environmental considerations is provided and discussed in the LIF *Lamp Guide*.

9.2 Apparent colour of emitted light

The colour appearance of a lamp refers to the apparent colour of the light emitted and is quantified by its correlated colour temperature (see SLL *Code for Lighting*). The choice of colour appearance is influenced by psychology and aesthetics. However, correlated colour temperature is particularly important for television and film recording applications.

9.3 Colour rendering

Colour is important to most sports; very noticeable colour distortion can be caused by using unsuitable lamps. To provide an objective indication of the colour rendering properties of a light source, the general colour rendering index (*Ra*) has been introduced.

The minimum colour rendering requirements of a sport may vary with its class of play and should be considered when selecting a lamp type. For CTV applications, lamps with very high colour rendering index should be used to ensure that the environment, objects, clothing and skin tones are rendered naturally.

10 Luminaire selection

In addition to being safe, luminaires may have to withstand a variety of physical conditions (such as climatic considerations, moisture, dust, UV, wide ranges of ambient temperature, vibration and exposure to vandalism). The degree of exposure of the luminaire will be different for exterior and interior sports environments.

The method of fixing and the architectural appearance may be required to be in sympathy with the architecture and environment of the location or interior style. Accessibility to lamps and associated electrical equipment should be considered to allow safe and easy maintenance and installation.

For interior applications, further guidance on the selection of luminaires is provided in section 3.6 of the SLL *Code for Lighting*. For exterior applications the type of applicable luminaire will generally be either a fixed- or variable-elevation floodlight.

Floodlights are available in a variety of beam configurations ranging from asymmetric fan-shaped distributions to precise parabolic beams used for major

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Floodlights are available in a variety of beam configurations ranging from asymmetric fan-shaped distributions to precise parabolic beams used for major stadia. Of particular importance is the floodlight's facility to contain obtrusive light effectively. This may be achieved by the inclusion of internal baffles, the fixing of external louvres or the use of cowl accessories. Floodlights whose main beam is emitted with a forward throw relative to the front glass will offer reduced fixture elevations to assist further in control of obtrusive light.

The future disposal and recycling requirements of lamps, luminaires and associated lighting equipment is now a legal requirement.

All luminaires offered for sale in the European Community must be affixed with a manufacturer's CE mark, thus declaring that a product conforms to essential EC technical directives. It is a primary consideration that all luminaires should be safe. This is assured by using only equipment meeting the required luminaire standards and approval marks (see Figure 31).

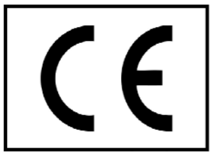


Figure 31 CE conformity mark.

10.1 Protection classification

Luminaires are classified by an international classification system (see BSEN 60529) that specifies the degree of protection offered against dust, moisture and external impact. It consists of two numerals:

- the first relates to the ingress of solid objects (ie IP2X); and
- the second relates to the ingress of moisture (ie IPX5).

A third numeral (KI value) relates to the external impact resistance in joules.

In most instances the IP classification of exterior luminaires will be higher than those used for interior applications. Although the IP system is designed as a safety specification it has implications for the depreciation in light output due to dirt (ingress) and therefore on applied maintenance factors (see sections 8.3 and A2.2).

10.2 Electrical classification

This specifies the protection against electric shock with which the luminaire has been designed.

Table 6 Electrical classification (see BS 7671).

Electrical class	Description
Class I	A luminaire with an earth terminal. The usual protection is by a metal enclosure bonded to this terminal.
Class II	A luminaire without an earth terminal. Protection is by two separate barriers of insulating material.
Class III	Luminaires where protection from shock is derived from its use on safety-type extra-low-voltage supplies.

Note: Class 0 luminaires have no earth terminal and have reduced protection against shock. By law, class 0 equipment is not permitted in the UK.

10.3 Resistance to impact

In ball sports, the likely consequence of balls impacting against luminaires should be considered. In some cases this will require the addition of some form of protection such as a suitable wire or polycarbonate guard.

Lighting installations may at some time come under attack from vandalism. This usually results in front glass breakage and lamp or reflector damage. For high-wattage HID light sources it is necessary to use toughened front glasses in order to withstand high working temperatures and thermal shock (ice and rain onto hot glass). Toughened glass should shatter into small pieces when broken. Glass and lamp replacement should be undertaken as soon as possible after breakage to ensure that reflectors and internal fixings do not suffer corrosion and loss in performance.

10.4 Accessories

For many luminaires there is a range of accessories that may be relevant to sports lighting. This may typically include floodlight louvres or shielding to restrict glare and overspill. Accessories that are designed to restrict the light output from the luminaire may also reduce the maintained illuminance over the playing surface. The use of accessories should be taken into account when performing illuminance calculations. Aiming devices are generally available to ensure the accurate setting of floodlights during installation.

10.5 Luminaire performance data

The determination of illuminance requires extensive calculation and is normally undertaken using specific lighting design computer software. A general appreciation of luminaire intensity distribution may be presented in graphical form to provide an approximation as to its distribution shape and suitability for use in a lighting project.

Computer software will require provision of photometric data in a suitable file format (eg TM14, Eulumdat, NAIES). Photometric data are generally available direct from luminaire manufacturers or supplied pre-installed or downloadable via the Internet for use on lighting design software packages. The accuracy of lighting calculations will be dependant upon the reliability of data and quality of interpolation within the photometric data intensity matrix (see EN 13032-1 for minimum requirements).

In interior sports applications, luminaire performance data may also be provided in utilisation factor (UF) tabular form (see EN 12665).

Luminaire photometric data are generally freely available from manufacturers to enable independent assessment of luminaire photometric performance and verification of lighting design parameters.

Appendices

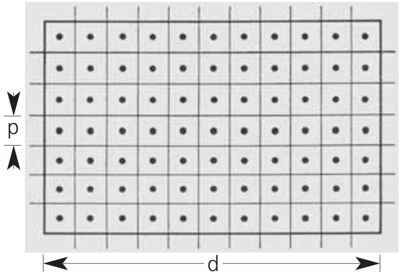
A1 Appendix 1

Determining average illuminance and uniformity ratio for sports installations

Maintained illuminance and uniformity ratios are provided for sports areas stated in this guide. To determine these values it is necessary to calculate point illuminance values over a regular grid pattern covering the entire reference area.

The greater the number of grid points considered, the more accurate will be the calculated or measured illuminance for the sports area. The grids are generally rectangular and the grid interval in each axis should be a whole number. Illuminance is calculated or measured at the central point of each grid rectangle (Figure 32).

Figure 32 Calculation grid.



For calculation purposes the grid interval should be that necessary to achieve the accuracy needed to verifying the specified illuminance. However, the measurement grid is used only for checking the installation, and for this purpose a reduced number of grid points may suffice for comparison against computed values.

The grid reference level is generally at ground level ($Z = 0$) for determining horizontal illuminance or 1 m above ground level ($Z = +1$m) for determining vertical illuminance, unless stated otherwise. The average illuminance is the mean arithmetic value obtained from all grid points within the regular grid area. To determine the validation between the calculated and the measured average illuminances, comparison should be based upon initial illuminance levels (MF = 1.0). The maximum grid interval necessary to achieve a suitable calculation accuracy may be determined from the equation:

$$p = 0.2 \times 5^{\log d}$$

where p is the grid size; and d is the dimension of the longest reference axis.

The number of points in the larger dimension is given by the nearest odd whole number of d/p. This result is then used to calculate the nearest odd whole number of grid points in the smaller dimension. This should produce a cell spacing ratio near to unity.

In a symmetrical track situation the larger dimension d is given by one quarter the distance of the overall inner track limit (Figure 33).

Where multiple sports are played on a single sports area, each playing area should be calculated separately using the aforementioned method to determine appropriate grid sizes.

Uniformity ratios over the sports areas (E_{min}/E_{av} and E_{min}/E_{max}) are based upon illuminances taken over the aforementioned calculation and measurement grid points.

Where information on illuminance fall-off at the boundaries of the area is required, the calculation grid should be extended outside the main grid (Figure 34).

The illuminance values obtained at the additional grid points outside the reference area should not be included in the calculation of average illuminance or uniformity ratios.

Note: Some sports governing bodies may require the calculation of average illuminance and uniformity based upon grid points located along the boundary of the reference area. This does not provide a true calculation or measurement of average illuminance over the sports area in relation to the maintained illuminance recommended by this guide.

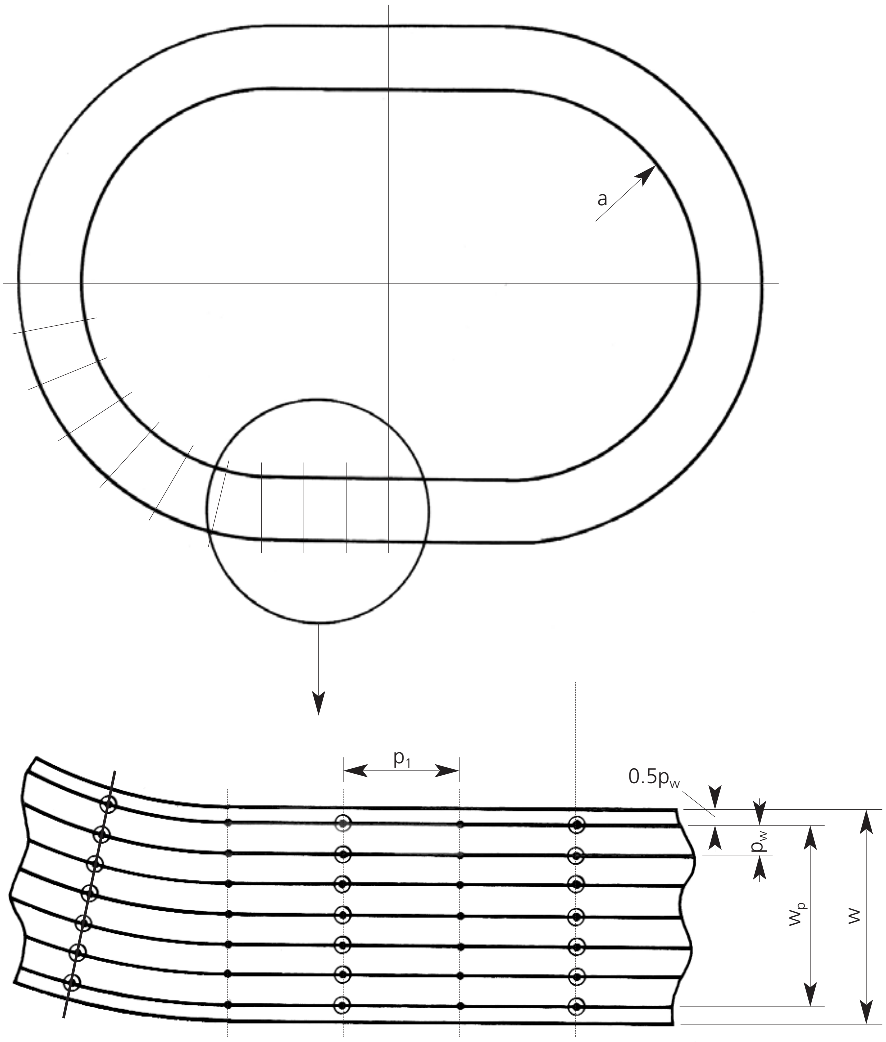


Figure 33 Track grid interval.

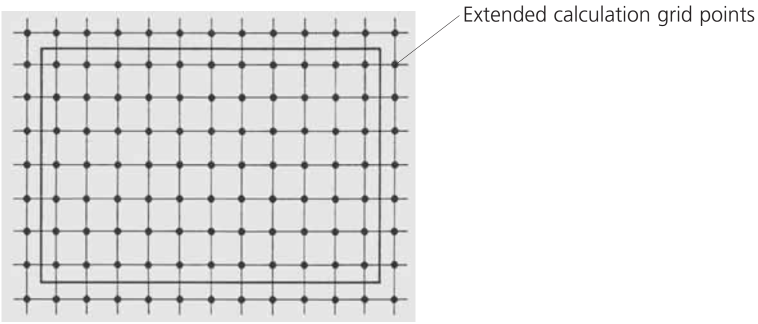


Figure 34 Illuminance fall-off at boundary.

A2 Appendix 2 Lighting depreciation factors

Lighting schemes based on an applied maintained illuminance should ensure that the lighting does not fall below that specified for the sport concerned during the period up to planned maintenance.

The overall maintenance factor (MF) is the product of all applied lighting depreciation factors. Those lighting depreciation factors that primarily affect installation performance are:

- luminaire maintenance factor (LMF): the light loss due to accumulation of dirt deposits on luminaires and light-emitting surfaces; and
- lamp lumen maintenance factor (LLMF): lamp lumen depreciation with age (hours of use).

The lamp survival factor (LSF) should also be considered when designing the optimal lighting scheme.

A2.1 Light loss from luminaires

The extent to which the optical performance of a luminaire is affected in service depends on:

- climatic conditions;
- the degree of air pollution;
- the corrosion resistance of the optical surfaces;
- the location and orientation of luminaires; and
- the regularity and effectiveness of cleaning and maintenance.

Three considerations are necessary to ensure that the fall in luminaire light output is kept within technically and economically acceptable limits:

- the equipment must be well constructed;
- lamps must be replaced after failure; and
- the luminaires must be cleaned regularly.

Maintenance factors must relate to:

- the cleanliness of the location;
- the cleaning characteristics of the luminaire; and
- the cleaning cycle.

As a luminaire ages there will also be gradual loss of performance of reflectors, perhaps accompanied by a loss of transparency of other materials. The light output lost due to luminaire depreciation cannot usually be regained by cleaning.

A2.2 Depreciation factors due to accumulation of dirt on light-emitting surfaces

An estimation of the depreciation factor due to dirt accumulation for an outdoor luminaire may generally be obtained from Table 7, which considers the cleanliness of the location, the cleaning cycle and the degree of luminaire ingress protection. Annual cleaning of luminaires is recommended. For seasonal sports (football, rugby, hockey, cricket) it is common for a six-month cleaning interval to be used if pre-season cleaning is undertaken.

A guide to pollution categories is as follows.

High pollution: large urban areas surrounded by heavy industry.
Medium pollution: semi-urban residential and light industrial areas.
Low pollution: rural areas.

Table 7 Depreciation factors due to dirt on the luminaire

Cleaning interval (months)	Pollution category					
	High		Medium		Low	
	IP5X	IP6X	IP5X	IP6X	IP5X	IP6X
6	0.90	0.92	0.91	0.93	0.93	0.94
12	0.89	0.91	0.90	0.92	0.92	0.93
18	0.87	0.90	0.88	0.91	0.91	0.92
24	0.84	0.88	0.86	0.89	0.90	0.91
36	0.76	0.83	0.82	0.87	0.88	0.90

A2.3 Lamp lumen depreciation

Light output diminishes with time as lamps age and eventually fail. The rate of fall in light output depends upon the lamp type, the operating conditions and the switching cycle.

Lumen depreciation is normally depicted in graphical form shown as percentage depreciation against hours of use.

A2.4 Lamp survival

It is normal to present lamp survival graphically as a percentage life expectancy of a large batch of lamps against hours of use for a specific switching cycle.

A2.5 Supply voltage variation

Lighting calculations and measurements are based upon an electricity supply of rated voltage and current. Fluctuations in the mains voltage will greatly affect the lumen output of lamps.

A2.6 Lamp replacement interval

Eventually, lamp lumen output will diminish to an extent whereby it is not possible to achieve a maintained illuminance by cleaning the luminaire and its light-emitting surfaces. At this stage either a partial or bulk lamp replacement is appropriate.

If spot lamp replacement is employed during the maintenance period, illumination over the playing surface should remain acceptable throughout the bulk lamp-replacement period.

A3 Appendix 3 Aiming floodlights and commissioning sports floodlighting installations

A3.1 Checking equipment

After erection of masts and fixing of floodlights, the lighting scheme enters its final stage prior to commissioning. It is advisable to re-check that all equipment (masts and floodlights) is located correctly since any installation errors will be difficult to determine at commissioning.

A3.2 Floodlight aiming

There are two principal methods used for aiming floodlights:

- floodlights are adjusted to stated angles of horizontal (azimuth) and vertical alignment; and
- floodlights are sighted to predetermined aiming points on the playing surface.

The decision over which method is deployed will be influenced greatly by the degree of accessibility to floodlights and masts.

When a floodlighting scheme is being prepared, the design calculations will probably be based upon grouping floodlights at a single point at each masthead. In large floodlight arrays this may result in aiming errors unless position corrections are applied. For small floodlight arrays, collective floodlight grouping should produce insignificant aiming errors.

Azimuth angles are a measure of the floodlight's rotation about its fixing point on the mast relative to a horizontal reference plane. Elevation angles relate to the angle between the floodlight's peak intensity and the downward vertical. Most floodlights are fitted with a side protractor scale to enable simple setting of the elevation angle.

Where a lighting scheme does not provide details of the individual aiming adjustments, it may be necessary to derive angles of azimuth and vertical settings from basic trigonometry. Where floodlights are aimed via direct sighting, either a telescopic sight or a special aiming device will be required to aim each floodlight to a precise point on the playing surface.

Figure 35 Floodlight aiming.

A3.2.1 Large floodlight arrays

In a floodlighting installation in a large stadium, consideration should be given to provision of lighting switching steps for various levels of stadium use. The arrangement of floodlight groups should be in such a way that logical visual appearance is achieved. The impression that some floodlights may have failed should not be conveyed when switching from one arrangement to the next.

Large floodlight head frames may be tilted forward to a fixed inclination (typically 15º) to reduce the possibility of floodlights on upper rows from shining onto those floodlights directly below. An inclined head frame may also provide a more aesthetically pleasing appearance.

A3.3 Commissioning the installation

The commissioning of lighting involves a visual assessment at night, the measurement of illuminances and validation against design objectives and calculations. During the assessment, good climatic conditions are required and any extraneous light from surroundings should be kept to a minimum and recorded. Before measurements are taken, all lamps should be run-up sufficiently to ensure stable operation and full output. It is advisable to conduct a visual assessment of the lit sports surface prior to undertaking illuminance measurements. A visual assessment should determine:

- the acceptability of the brightness and contrast over the playing surface for the appropriate sports; and
- the acceptability of the visual impression of glare while viewing the sports surface.

A3.3.1 Measurement of illuminance

All measurements of illuminance should be recorded using a suitable portable light meter with a valid certificate of calibration (see BS 667). The instrument should use an appropriate means of aligning the photocell to the plane of measurement. Large reading errors may result if the photocell is out of alignment from the reference plane by only a few degrees.

Measurements of horizontal plane illuminance are taken at ground level. Measurements of vertical plane illuminance are taken at 1 m above ground level in the appropriate reference direction.

Care should be taken not to cast shadows or reflect light from clothing onto the photocell during measurement. To avoid this it is advisable to use a remote photocell sensing unit connected to the light meter by a long extension cable.

The measurement record should include the following:

- date and time of measurement/commissioning;
- nomenclature of the sports ground;
- full installation details (the sport's surface dimensions, mast locations, floodlight quantities, aiming discrepancies);
- lighting equipment information (lamp type, control gear settings, dimming and switching provision, number of lamps operating);
- installation age, condition and hours of use since last cleaning;
- the number of hours the lamps have been burning;
- apparent differences in lamp colour temperature;
- operating voltage at control gear terminals taken during illuminance measurements;
- weather conditions; and
- light meter type, serial number and date of last calibration.

Correction factors may need to be applied to the measured illuminance values depending upon the installation details appertaining to the measurement record.

In the final comparison between the measured and designed average values, a variation of not more than 10% may result (excluding illuminance meter uncertainties) due to:

- manufacturing tolerances (luminaires, lamps, mast heights etc);
- installation tolerances (reference area size, mast locations, floodlight positioning and aiming); and
- tolerances in photometric measurements.

Additional tolerances can be caused by voltage variation relative to nominal control gear settings.

Lamp manufacturers generally provide graphical information per lamp type and wattage, relating variation in Supply Voltage (Vs) against Lamp Lumen Output (Lm) to enable applicable corrections to be applied where appropriate.

A4 Appendix 4 Relevant sport governing bodies

The list below is for guidance only and may not be representative of all international sport governing bodies. Links to the web sites of national governing bodies are generally possible via the specific web addresses listed below.

Sport	Governing body	Web site address
Archery	Intl. Archery Federation (FITA)	www.archery.org
Athletics	Intl. Amateur Athletics Federation (IAAF)	www.iaaf.org
Badminton	Intl. Badminton Federation (IBF)	www.intbadfed.org
Baseball	Intl. Baseball Association (IBA)	www.baseball.ch
Basketball	Intl. Federation of Basketball (FIBA)	www.fibaeurope.com
Bowls (indoor)	World Indoor Bowls Council	www.wibc.org.uk
Bowls (outdoor)	World Bowls Board	www.worldbowlsltd.co.uk
Bowling (nine and ten pin)	International Bowling Federation (FIQ)	www.fiq.org
Boxing	Intl. Boxing Association (AIBA)	www.aiba.net
Canoe slalom	Intl. Canoe Federation	www.canoeicf.com
Cricket	Intl. Cricket Council (ICC)	www.icc-cricket.com
Curling	World Curling Federation (WCF)	www.worldcurlingfederation.org
Cycle racing (track)	Intl. Cycling Union (UCI)	www.uci.ch
Equestrianism	Intl. Federation for Equestrian Sports (FEI)	www.horsesport.org
Fencing	Intl. Fencing Federation (FIE)	www.fie.ch
Football	Football Association (FA)	www.thefa.com
	Football League	www.football-league.co.uk
	Football Premiership	www.premierleague.com
	UEFA	www.uefa.com
	FIFA	www.fifa.com
Football (American)	National Football League (NFL)	www.nfl.com
Football (Gaelic)	Gaelic Athletic Association (GAA)	www.gaa.ie
Golf courses	R and A	www.randa.org
	English Golf Union	www.englishgolfunion.org
Greyhound racing	National Greyhound Racing Club	www.ngrc.org.uk
Gymnastics	FIG	www.fig-gymnastics.com
Handball	British Handball Association	www.britishhandball.com
Hockey	FIH	www.fihockey.org
Horse racing	Jockey Club	www.thejockeyclub.co.uk
Hurling	Gaelic Athletic Association (GAA)	www.gaa.ie
Ice hockey	Intl. Ice Hockey Federation (IIHF)	www.iihf.com
Ice sports	Intl.Skating Union (ISU)	www.isu.org
Lawn tennis	Lawn Tennis Association (LTA)	www.lta.org.uk
Netball	Intl. Federation of Netball Associations	www.netball.org
Rugby league	The Rugby Football League (RFL)	www.therfl.co.uk
Rugby union	Intl. Rugby Football Board (IRFB)	www.irb.com
Snooker/billiards	Intl. Billiards and Snooker Federation	www.ibsf.org
Speedway	British Speedway Promoters Association	www.british-speedway.co.uk
Squash	World Squash Federation (WSF)	www.worldsquash.co.uk
Swimming	FINA	www.fina.org
Table tennis	Intl. Table Tennis Federation (ITTF)	www.ittf.com
Volleyball	FIVB	www.fivb.org

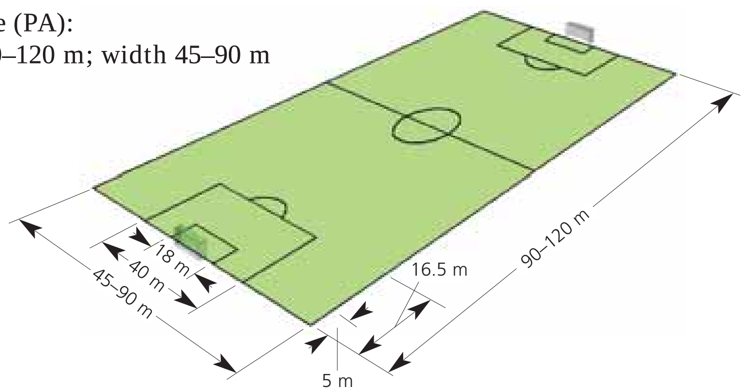
Web site addresses correct at time of printing

A5 Appendix 5 Typical play area dimensions

These details are provided for general information only.

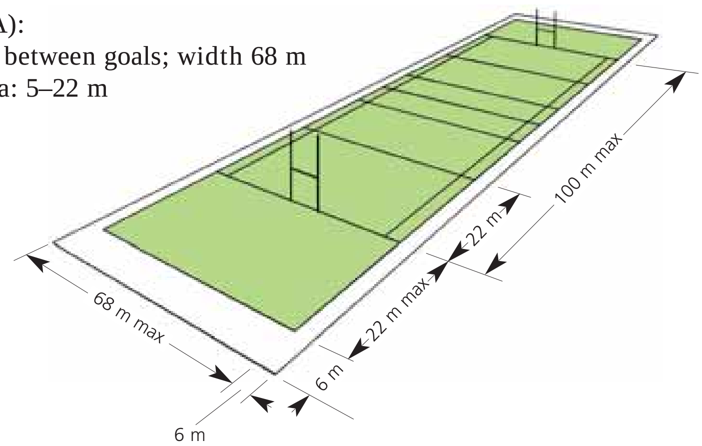
A5.1 Football

Pitch size (PA):
length 90–120 m; width 45–90 m



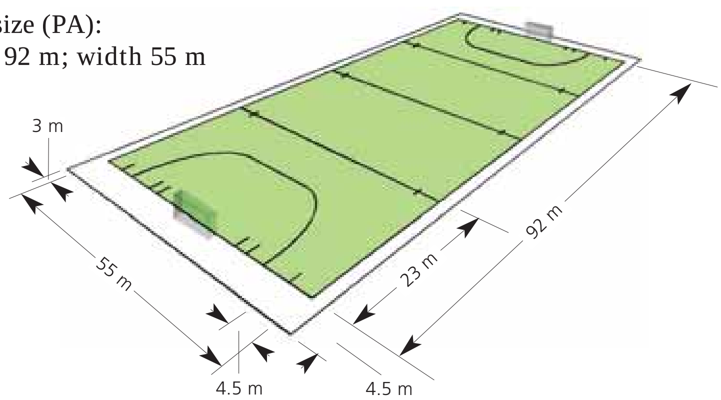
A5.2 Rugby

Pitch size (PA):
length 100 m between goals; width 68 m
Dead ball area: 5–22 m



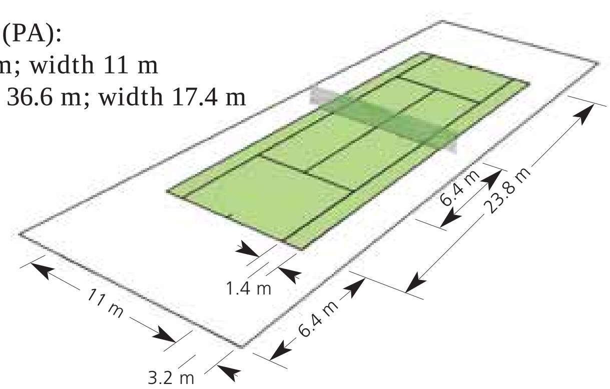
A5.3 Hockey

Pitch size (PA):
length 92 m; width 55 m



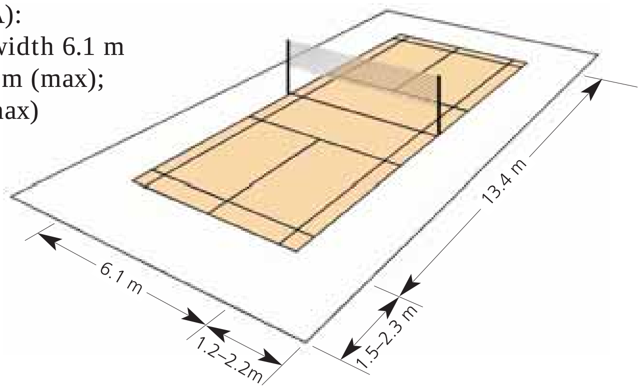
A5.4 Lawn Tennis

Single court (PA):
length 23.8 m; width 11 m
(TA): length 36.6 m; width 17.4 m



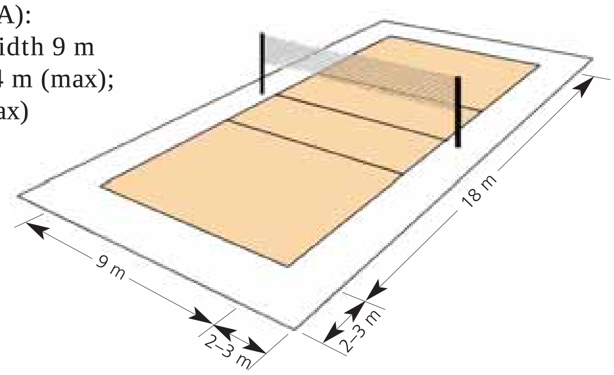
A5.5 Badminton

Single court (PA):
length 13.4 m; width 6.1 m
(TA): length 18 m (max);
width 10.5 m (max)



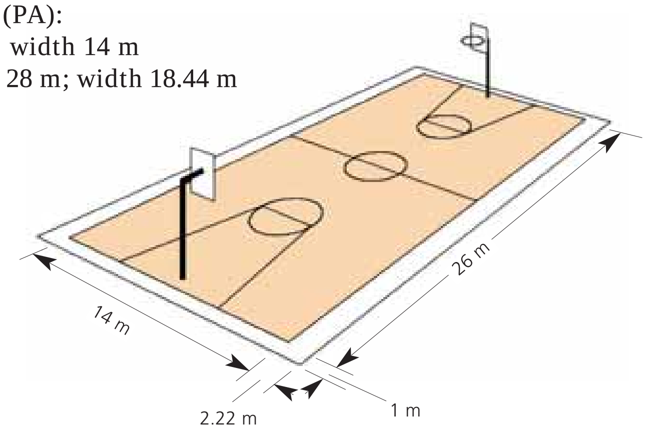
A5.6 Volleyball

Single court (PA):
length 18 m; width 9 m
(TA): length 24 m (max);
width 15 m (max)



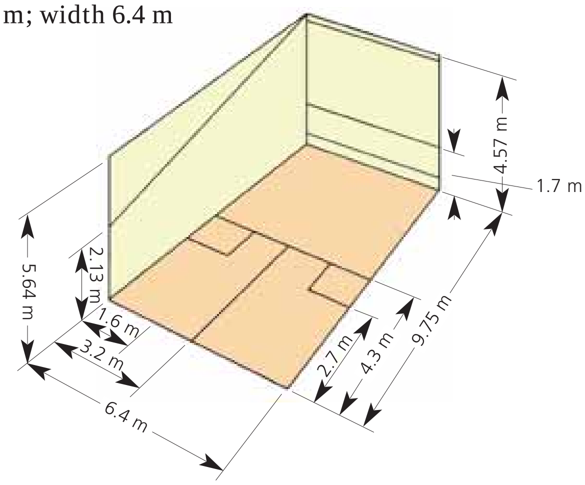
A5.7 Basketball

Single court (PA):
length 26 m; width 14 m
(TA): length 28 m; width 18.44 m



A5.8 Squash

(PA): length 9.5 m; width 6.4 m



Glossary

This glossary contains definitions and explanations for the specification of sports lighting to facilitate an understanding of this guide. The definitions are based upon:

- BSEN 12665:2002 *Lighting Applications – Basic Terms and Criteria for Specifying Lighting Requirements*; and
- CIE17.4 *International Lighting Vocabulary*, fourth edition, joint publication IEC/CIE:1987.

These documents should be consulted if more precise definitions are needed.

Adaptation

A process which takes place as the visual system adjusts to the luminance and colour of the visual field or the final state of this process.

Technically defined: The process by which the state of the visual system is modified by previous and present exposure to stimuli that may have various luminances, spectral distributions and angular subtenses.

Note 1: The terms light adaptation and dark adaptation are also used, the former when the luminances of the stimuli are of at least several candelas per square metre and the latter when the luminances are of less than some hundredths of a candela per square metre.

Note 2: Adaptation to specific spatial frequencies, orientations, sizes etc are recognised as being included in this definition.

Adaptation level

The state of adaptation of an individual at a particular time.

Ballast

A device connected between the supply and one or more discharge lamps which serves mainly to limit the current of the lamp(s) to the required value.

Note: A ballast may also include means of transforming the supply voltage, correcting the power factor and, either alone or in combination with a starting device, provide the necessary conditions for starting the lamp(s).

Brightness

Attribute of the visual sensation associated with the amount of light emitted from a given area. It is a subjective correlate of luminance.

Technically defined: brightness, luminosity (obsolete): Attribute of a visual sensation according to which an area appears to emit more or less light.

Colour rendering (of a light source)

Effect of a light source on the colour appearance of objects compared with their colour appearance under a reference light source.

The definition is more formally expressed as: Effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant.

Colour temperature (T_c)

The temperature of a Planckian (black body) radiator whose radiation has the same chromaticity as that of a given stimulus.

Unit: kelvin (K)

Note: The reciprocal colour temperature is also used, unit K^{-1}.

Contrast

In the perceptual sense: Assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence: brightness contrast, lightness contrast, colour contrast, simultaneous contrast, successive contrast etc).

In the physical sense: Quantity intended to correlate with the perceived brightness contrast, usually defined by one of a number of formulae which involve the luminances of the stimuli considered, for example: $\Delta L/L$ near the luminance threshold, or L_1/L_2 for much higher luminances.

Correlated colour temperature (T_c)

The temperature of the Planckian (black body) radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

Unit: kelvin (K)

Note 1: The recommended method of calculating the correlated colour temperature of a stimulus is to determine on a chromaticity diagram the temperature corresponding to the point on the Planckian locus that is intersected by the agreed iso-temperature line containing the point representing the stimulus.

Note 2: Reciprocal correlated colour temperature is used rather than reciprocal colour temperature whenever correlated colour temperature is appropriate.

Cylindrical illuminance (at a point) (E_z)

Total luminous flux falling on the curved surface of a very small cylinder located at the specified point divided by the curved surface area of the cylinder. The axis of the cylinder is taken to be vertical unless stated otherwise.

Unit: lux (lx) = lumens per square metre

Technically defined: Quantity defined by the formula:

$$E_z = \frac{1}{\pi}\int_{4\pi\text{sr}} L.\sin\varepsilon.\mathrm{d}\Omega$$

where $\mathrm{d}\Omega$ is the solid angle of each elementary beam passing through the given point; L is its luminance at that point; and ε the angle between it and the given direction.

Diffused lighting

Lighting in which the light on the working plane or on an object is not incident predominantly from a particular direction.

Direct lighting

Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 90–100%.

Directional lighting

Lighting in which the light on the working plane or on an object is incident predominantly from a particular direction.

Disability glare

Glare that impairs the vision of objects without necessarily causing discomfort.

Note: Disability glare may be produced directly or by reflection.

For specification: Disability glare may be expressed in a number of different ways. If threshold increment is used the following values of TI should be used:

5%, 10%, 15%, 20%, 25%, 30%.

If glare rating is used then the following values of GR should be used:

10, 20, 30, 40, 45, 50, 55, 60, 70, 80, 90.

Discomfort glare

Glare that causes discomfort without necessarily impairing the vision of objects.

Note: Discomfort glare may be produced directly or by reflection.

For specification: If it is expressed using the unified glare rating the following values of UGR should be used:

10, 13, 16, 19, 22, 25, 28.

Emergency lighting

Lighting provided for use when the supply to the normal lighting fails.

Escape lighting

That part of the emergency lighting which is provided to ensure that the escape route is illuminated at all material times.

Flicker

Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

General lighting

Substantially uniform lighting of an area without provision for special local requirements.

Glare

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

See also: 'disability glare' and 'discomfort glare'.

Illuminance (at a point of a surface) (*E*)

Quotient of the luminous flux $\delta\Phi_v$, incident on an element of the surface containing the point, by the area δA of that element.

Equivalent definition: Integral, taken over the hemisphere visible from the given point, of the expression:

$L.\cos\theta.\delta\Omega$

(where L is the luminance at the given point in the various directions of the incident elementary beams of solid angle $\delta\Omega$; and θ is the angle between any of these beams and the normal to the surface at the given point).

Unit: lux (lx) = lumens per square metre

Note: The orientation of the surface may be defined, eg horizontal, vertical; hence horizontal illuminance, vertical illuminance.

For specification: Illuminance should be specified as maintained illuminance and should take one of the following values:

1.0×10^N lux, 1.5×10^N lux, 2.0×10^N lux, 3.0×10^N lux, 5.0×10^N lux, 7.5×10^N lux (where N is an integer).

The area over which the illuminance is to be calculated or measured shall be specified.

Illumination

Application of light to a scene or its surroundings so that they may be seen.

Illuminance gradient

Percentage difference of illuminance between adjacent measuring points (FIFA).

Illuminance uniformity

Ratio of minimum illuminance to average illuminance on a surface.

Note: Use is also made of the ratio of minimum illuminance to maximum illuminance, in which case this should be specified explicitly.

Indirect lighting

Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 0–10%.

Initial illuminance

Average illuminance when the installation is new.

Unit: lux (lx) = lumens per square metre

Intensity (luminous) (of a point source in a given direction) (*I*)

Luminous flux per unit solid angle in the direction in question, ie the luminous flux on a small surface, divided by the solid angle that the surface subtends at the source.

Unit: candela = lumen per steradian (lm/sr)

Technically defined: Quotient of the luminous flux (δΦ) leaving the source and propagated in the element solid angle (δΩ) containing the given direction, by the element solid angle:

$$I = \frac{\delta\Phi}{\delta\Omega}$$

Isolux curve (iso-illuminance curve)

Locus of points on a surface where the illuminance has the same value.

Lamp

Source made in order to produce an optical radiation, usually visible.

Note: This term is also sometimes used for certain types of luminaires.

Lamp cleaning interval

The illuminance provided by a lighting installation will decrease as the lamps age and dirt is deposited on the luminaire and room surfaces. The luminaire's luminous distribution will also be affected by dirt deposits. Planned maintenance is therefore essential if the design parameters are to be met throughout the life of an installation.

Depreciation can be kept within technically and economically acceptable limits by ensuring: that luminaires are safe, reliable and constructed to relevant international standards; that luminaires are selected to suit location conditions; and that a programme of luminaire cleaning and lamp replacement is implemented.

Lamp lumen maintenance factor (LLMF)

Ratio of the luminous flux of a lamp at a given time to the initial luminous flux.

Lamp survival factor

Fraction of the total number of lamps that continue to operate at a given time under defined conditions and switching frequency.

Light output ratio (of a luminaire)

Ratio of the total flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions.

Note: For luminaires using incandescent lamps only, the optical light output ratio and the light output ratio are the same in practice.

Light pollution

Non-preferred term, use obtrusive light

'Obtrusive light': That light which is projected in any combination of upward and outward path beyond the boundaries of the site or object being illuminated, and by reason of that projected light's direction, magnitude, duration and presence is contrary to the general environment and those interests of life and livelihood.

'Light pollution': an expression promoted by astronomers, relates to light either into the night sky, resulting in 'sky glow', or light presence affecting the performance of their instruments.

Louvre

Screen made of translucent or opaque components and geometrically disposed to prevent lamps from being directly visible over a given angle.

Luminance (*L*)

Luminous flux per unit solid angle transmitted by an elementary beam passing through the given point and propagating in the given direction, divided by the area of a section of that beam normal to the direction of the beam and containing the given.

It can also be defined as: 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.

Or: The illuminance produced by the beam of light on a surface normal to its direction, divided by the solid angle of the source as seen from the illuminated surface.

It is the physical measurement of the stimulus which produces the sensation of brightness.

Unit: candela per square metre (cd/m^2)

Technically defined: Quantity defined by the formula:

$$L = \delta\Phi/(\delta A.\cos\theta.\delta\Omega)$$

where $\delta\Phi$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $\delta\Omega$ containing the given direction; δA is the area of a section of that beam containing the given point; and θ is the angle between the normal to that section and the direction of the beam.

For specification: Luminance should be specified as maintained luminance and should take one of the following values:

1.0×10^N cdm^{-2}, 1.5×10^N cdm^{-2}, 2.0×10^N cdm^{-2}, 3.0×10^N cdm^{-2}, 5.0×10^N cdm^{-2}, 7.5×10^N cdm^{-2} (where N is an integer)

The area over which the luminance is to be calculated or measured shall be specified.

Luminaire

Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

Note: The term lighting fitting is deprecated.

Luminous efficacy of a source (η)

Quotient of the luminous flux emitted by the power consumed by the source.

Unit: lumens per watt (lm/W)

Note 1: It must be specified whether or not the power dissipated by auxiliary equipment such as ballasts etc, if any, is included in the power consumed by the source.

Note 2: If not otherwise specified, the measurement conditions should be the reference conditions specified in the relevant IEC standard. See 'rated luminous flux'.

Luminous flux

Quantity derived from radiant flux (radiant power) by evaluating the radiation according to the spectral sensitivity of the human eye (as defined by the CIE standard photometric observer). It is the light power emitted by a source or received by a surface.

Unit: lumen (lm)

Note 1: In this definition, the values used for the spectral sensitivity of the CIE standard photometric observer are those of the spectral luminous efficiency function $V(\lambda)$.

Note 2: See IEC 50 (845)/CIE 17.4: 845-01-22 for the definition of spectral luminous efficiency, 845-01-23 for the definition of the CIE standard photometric observer and 845-01-56 for the definition of luminous efficacy of radiation (see ISO/CIE 10527).

Technically defined: Luminous flux Φ is given by

$$\Phi = K_m \int_0^\infty \{\delta\Phi_\varepsilon(\lambda)/\delta\lambda\} V(\lambda)\delta(\lambda)$$

where $\delta\Phi_\varepsilon(\lambda)/\delta\lambda$ is the spectral distribution of radiant flux; and $V(\lambda)$ is the spectral luminous efficiency.

Luminous intensity (of a point source in a given direction) (I)

Luminous flux per unit solid angle in the direction in question, ie the luminous flux on a small surface, divided by the solid angle that the surface subtends at the source.

Unit: candela = lumen per steradian (lm/sr)

Technically defined: Quotient of the luminous flux ($\delta\Phi$) leaving the source and propagated in the element solid angle ($\delta\Omega$) containing the given direction, by the element solid angle:

$$I = \frac{\delta\Phi}{\delta\Omega}$$

Maintained illuminance

Value below which the average illuminance on the specified area should not fall. It is the average illuminance at the time maintenance should be carried out.

Unit: lux (lx)

Maintenance factor

Ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the average illuminance obtained under the same condition for the installation considered conventionally as new.

Note 1: The term depreciation factor has been formerly used to designate the reciprocal of the above ratio.

Note 2: Maintenance factor of an installation depends on lamp lumen maintenance factor, lamp survival factor, luminaire maintenance factor and (for an interior lighting installation) room surface maintenance factor.

Mounting height

Distance between the working plane and the plane of the luminaire.

Obtrusive light

That light which is projected in any combination of upward and outward path beyond the boundaries of the site or object being illuminated, and by reason of that projected light's direction, magnitude, duration and presence is contrary to the general environment and those interests of life and livelihood.

Rated lamp life (ave)

The lamp operating hours at the period of 50% failures for a batch of lamps.

Rated luminous flux (of a type of lamp)

The value of the initial luminous flux of a given type of lamp declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions.

Unit: lumens (lm)

Note 1: For most lamps, in reference conditions the lamp is usually operating at am ambient temperature of 25°C in air, freely suspended in a defined burning position and with a reference ballast, but see the relevant IEC standard for the particular lamp.

Note 2: The initial luminous flux is the luminous flux of a lamp after a short ageing period as specified in the relevant lamp standard.

Note 3: The rated luminous flux is sometimes marked on the lamp.

Reflectance (*r*)

Ratio of luminous flux reflected from a surface to the luminous flux incident on it.

Note: The reflectance generally depends on the spectral distribution and polarisation of the incident light, the surface finish and the geometry of the incident and reflected light relative to the surface.

Response time

Time required for the change of detector output to reach, after a step variation of a steady detector input, a given final percentage of its final value.

Room index

An index related to the dimensions of a room and used when calculating the utilisation factor and other characteristics of the lighting installations:

$$\text{Room index} = LW/[h_m(L + W)]$$

where L is the length of the room; W the width of the luminaires above the working plane; and h_m the height of the luminaires above the working plane.

Safety lighting

That part of emergency escape lighting that provides illumination for the safety of people involved in a potentially dangerous process or situation and to enable proper shut down procedures for the safety of the operator and other occupants of the premises (known as 'high-risk task area lighting' in BS 5266-7/EN 1838).

Semi-cylindrical illuminance (at a point) (ESZ)

Total luminous flux falling on the curved surface of a very small semi-cylinder located at the specified point, divided by the curved surface area of the semi-cylinder. The axis of the semi-cylinder is taken to be vertical unless stated otherwise. The direction of the curved surface should be specified.

Unit: lux (lx)

Spacing (in an installation)

Distance between the light centres of adjacent luminaires of the installation.

Spacing-to-height ratio

Ratio of spacing to the height of the geometric centres of the luminaires above the reference plane.

Note: For indoor lighting the reference plane is usually the horizontal working plane; for exterior lighting the reference plane is usually the ground.

Spherical illuminance (at a point) (E_o)

Total luminous flux falling onto the whole surface of a very small sphere located at the specified point divided by the total surface area of the sphere.

Unit: lux (lx)

Technically defined: Quantity defined by the formula

$$E_o = \int_{4\pi\text{sr}} L.\mathrm{d}\Omega$$

where $\mathrm{d}\Omega$ is the solid angle of each elementary beam passing through the given point; and L is its luminance at that point.

Standby lighting

That part of the emergency lighting which may be provided to enable normal activities to continue.

Stroboscopic effect

Apparent change of motion and/or appearance of a moving object when the object is illuminated by a light of varying intensity.

Note: To obtain apparent immobilisation or constant change of movement, it is necessary that both the object movement and the light intensity variation are periodic and that some specific relation between the object movement and light variation frequencies exists. The effect is only observable if the amplitude of the light variation is above certain limits. The motion of the object may be rotational or translational.

Upward light output ratio (of a luminaire)

Ratio of the upward flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions.

Note: For luminaires using incandescent lamps only, the optical light output ratio and the light output ratio are the same in practice.

Uniformity ratio (of illuminance on a given plane)

Ratio of the minimum illuminance to the average illuminance on the plane.

Utilisation factor

Ratio of the luminous flux received by the reference surface to the sum of the rated lamp luminous fluxes of the lamps in the installation.

Veiling reflections

Specular reflections that appear on the object viewed and partially or wholly obscure details by reducing contrast.

Visual acuity

Capacity for seeing distinctly fine details that have a very small angular subtense at the eye.

Note: Quantitatively, it can be expressed by the reciprocal of the angle, in minutes of arc, subtended at the entrance pupil by the extremities of the detail separation which is just visible.

Technically defined: Qualitatively – Capacity for seeing distinctly fine details that have very small angular separation. Quantitatively – Any of a number of measures of spatial discrimination such as the reciprocal of the value of the angular separation in minutes of arc of two neighbouring objects (points or lines or other specified stimuli) which the observer can just perceive to be separate.

Visual field

Area or extent of physical space visible to an eye at a given position and direction of view.

Note: The visual field may be either monocular or binocular.

Visual performance

Performance of the visual system as measured for instance by the speed and accuracy with which a visual task is performed.

Bibliography

CIBSE/SLL publications

Available from: CIBSE, 222 Balham High Road, London SW12 9BS, UK.

Code for Lighting (2006; printed extracts 2002)

LG12: 2004 *Emergency Lighting Design Guide*

LG11: 2001 *Surface Reflectance and Colour – its specification and measurement for lighting designers*

Guide to Obtrusive Light (2002, available on the CD version of the *Code for Lighting*)

TM14 *Standard file format for transfer of luminaire photometric data* (1988)

British and European standards

Available from: BSI, 389 Chiswick High Road, London W4 4AL, UK

BS 667:2005 *Illuminance meters. Requirements and test methods*

BSEN 5266 *Code of Practice for Emergency Lighting*

BSEN 5499 *Code of Practice for Safety Signs*

BS 7671:2001 *Requirements for Electrical Installation. IEE Wiring Regulations, plus Amendments*

BSEN 12193:1999 *Light and Lighting – Sports Lighting*

BSEN 12665:2002. *Basic Terms and Criteria for Specifying Lighting Requirements*

BSEN 13032-1:2003. *Measurement and Presentation of Photometric Data for Lamps and Luminaires – Part 1: Measurement*

BSEN 50285:1999 *Energy efficiency of electric lamps for household use. Measurement methods*

BSEN 60529:1992 *Specification for degrees of protection provided by enclosures (IP Code)*

BSEN 60598-1:1997 Luminaires. *General Requirements and Tests*

BS EN 60589-2-5: 1998 Luminaires. *Particular Requirements – Floodlights*

CIE publications

CIE169:2005 *Practical Design Guidelines for the Lighting of Sport Events for Colour Television and Filming*

CIE 150:2003 *Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations*

CIE 117:1995 *Discomfort Glare in Interior Lighting*

CIE 112:1994 *Glare Evaluation Systems for Use with Outdoor Sports and Area Lighting*

CIE 97:1992 *Maintenance of Indoor Electric Lighting Systems*

CIE 83:1989 *Guide for the Lighting of Sports Events for Colour Television and Film Systems*

CIE 67: 1986 *Guide for the Photometric Specification and Measurement of Sports Lighting Installations*

CIE 62:1984 *Lighting for Swimming Pools*

CIE 58:1983 *Lighting for Sports Halls*

CIE 57:1983 *Lighting for Football*

CIE 45:1979 *Lighting for Ice Sports*

Other publications

Guide to Safety at Sports Grounds; fourth edition (London: HMSO) (2003)

ILE *Guidance Notes for the Reduction of Obtrusive Light* (Rugby, ILE) (2005)

Health and Safety at Work Act 1974

The Clean Neighbourhoods and Environment Act 2005

LIF *Lamp Guide* (available at www.lif.co.uk)

Stockmar A W *Eulumdat – ein Leuchtendatenformat fur den europaischen Beleuchtungsplanar* Tagungsband Licht 1990 pp 641–644

LM-63-02 *Lighting measurements testing and calculation guides. ANSI approved standard file format for electronic transfer of photometric data and related information* (New York: Illuminating Engineering Society of North America) (2002)

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