Outdoor and Amenity Lighting

This module deals with design aspects, specific applications, equipment, lighting calculations, maintenance and economics for outdoor and amenity lighting. Within this module the basics of floodlighting are covered, however there is a separate module on floodlighting and its applications.

1 Design Aspects

Awareness of the benefits of lighting our towns, cities and communities at night is growing. Lighting can both create an attractive nightscape and make places safer to live in.

It is increasingly recognised that lighting design for an area can be approached in a co-ordinated way. For example a series of buildings along a stretch of river could be lit with co-ordination. This requires a lighting strategy incorporating many different issues. When a strategy is well implemented it bring an improvement in the night-time environment due to greater control on the implementation of urban lighting.

Fig 1 Presidential Residence, Finland.

As the amount of lighting increases, especially in urban areas, it is important that control is kept on its application. Also there is concern about the impact that ill-planned lighting is having on astronomy and its intrusion on landscapes that are naturally dark at night.

At present, only some aspects of lighting fall within the scope of planning legislation. However there are separate guidelines or standards covering many applications of outdoor lighting. (See References)

There are many reasons for lighting the outdoor environment. Some reasons are more tangible than others. Safety, security and promotion are more tangible than other reasons and therefore lighting criteria can more easily be devised for them. Below are design reasons for lighting:

Safety
Lighting makes for safe movement of traffic, shoppers and pedestrians. It also creates a feeling of well being for residents in their own living area.

Security
Lighting is a powerful deterrent to night-time crime. It protects people and property and significantly reduces the fear of crime. Good lighting attracts visitors to an area increasing natural surveillance and deterring opportunist crime. In addition, the use of CCTV surveillance in town and city centres can be extended by the use of appropriate lighting.

Fig 2 Lighting creating ambience.

Promotion
Lighting is an effective means of publicity for commerce, industry and for a town or city in general. It can increase the pride of local residents as well as promoting tourism.

Ambience
The way we perceive our night-time surroundings is very much dependent upon how they are lit. Lighting can generate feelings of invitation and warmth, intimacy or spaciousness, or even excitement and drama.

Amenity
This adds pleasantness to an area. It serves the needs of the pedestrian but goes beyond purely functional lighting. It should reveal the footpath as well as providing sufficient spatial illuminance for other pedestrians to be seen clearly. This will ensure the area gives a feeling of security. The scale of the lighting should also be at a human level and not create a confining impression.

Fig 3 Lighting creating spectacle at a leisure facility.

Identity
Each district has its own individual identity or character. Lighting can reveal and enhance this by emphasising a particular style of architecture or planning.

Orientation
Lighting of roads and landmarks (eg churches, bridges, etc.) can help us find our way in an unfamiliar area at night. However this is unlikely to be the primary reason for lighting.

Spectacle
The urban light spectacle is a way of extending our enjoyment of sports and leisure facilities providing entertainment, amusement and recreation.

2 Heritage issues

There is growing public concern and demands for closer protection of our historical and architectural heritage. Far more structures are now 'listed' for preservation, or fall within Conservation Areas and consequently are subject to more stringent and far reaching controls over what may or may not be done to 'improve' or 'enhance' a structure. The principal categories of these controls, relating to the proposed use of exterior lighting, are:

- Listed Building approval and/or
- Ancient Monument approval
- Conservation Area Consent

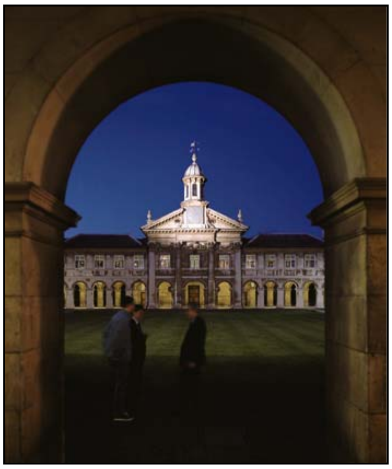


Fig 4 Emmanuel College, Cambridge.

In all these cases the existing local authority powers and legal requirements are substantially more detailed and extensive than those of Town and Country Planning Act 1990. The Act is primarily with the 'material effect' that an installation may have upon the external appearance of the building, that is the visual impact of the luminaires, wiring, conduits, etc. The question of the effect of lighting is vague and less certain when it comes to legal enforcement. There is little case law and precedent relating to levels of illumination and its intrusive nature.

When dealing with the more stringent requirements associated with listed buildings the situation is more specific. Not only must the physical parameters and visual impact of the equipment be considered, but also the illumination produced by the installation must complement the structure and not detract from the character and appearance of its setting, particularly in conservation areas. (Fig 4)

There will almost certainly be constraints upon the materials used, their colour and the method of mounting or attachment to the structure. With the later, a major problem can be the total refusal to allow drilling or fixings which damage the fabric of the structure, or which are visually intrusive. Even where drilling is allowed there can be limitations on the use of 'Rawlplug' that could cause cracking of brick or stonework. An alternative method of using resin filled holes into which the bolts are fixed can be an acceptable solution, known as resin bolts. Coloured mineral insulated cable now can be selected to blend with building surfaces.

Fig 5 Recessed Ground Box during installation.

The positions of the luminaires should be chosen to be discreet, for example the use of natural contours, vegetation or sunken cavities that are landscaped to conceal projectors (Fig 5). Combine or conceal fittings within existing structures or features. Use everyday accepted street furniture like street lighting columns, ornamental bollards, fences, and directional signs as a means of mounting the desired fittings in a less obtrusive manner. Fixing of luminaires and distribution cables must not damage or stain any part of the building fabric and should be easily reversible. Specialist advice should be sought before fixing equipment or cables to structures.

3 Lighting and crime

Fig 6 People feel more secure in well lit areas.

There have been a number of studies on the relationship between exterior lighting and crime particularly in streets and areas around housing. Probably the most rigorously analysed study of general lighting effects on crime carried out to date is the Dudley Project (Painter and Farrington 1997). The results clearly demonstrated:

- The incidence of crime in the light-enhanced area fell by 41% by contrast with a 15% reduction in the comparison area.
- The prevalence of crime (i.e. the proportion of people victimised) fell by 23% in the light-enhanced area, by contrast with a 3% reduction in the comparison area.
- Incidence and prevalence fell in all crime categories.
- The proportion of people who personally knew a victim of crime fell in the light-enhanced area relative to the comparison area.
- People in the light-enhanced area became somewhat more satisfied with their area, whereas those in the comparison area became somewhat less satisfied.

Studies have shown, perhaps not surprisingly, that people feel more secure in areas that are well lit.

There is another dimension to crime prevention and recording in town and city centres and that is by using close circuit television, CCTV. Good lighting can greatly improve the quality of pictures taken either through still or video security cameras at dusk and the hours of darkness. Studies have been made for indoor surveillance by Thorn Lighting 'Lighting for CCTV' (R Hargroves and J Hugill 1994). The results of this study are not directly transferable to outdoor conditions. There is however some common sense guidance that can be given:

Illuminance – CCTV camera performing well under range of actual illuminances
Uniformity – high and no rapid changes with distance
Modelling – adequate vertical illuminance at face level with moderate contrast
Colour – wide spectrum light sources (avoid monochromatic SOX lamps)

4 Avoiding Light Pollution

Poorly designed and installed outdoor lighting may lead to needless pollution of the environment. Waste or spill light is a waste of energy and money, at a time when we need to ensure that energy is used efficiently. Waste energy contributes to global warming and other ecological problems and it is not only the polluter who pays in terms of higher bills.

In rural areas outdoor lighting is a concern for all those interested in preserving the natural night-time environment and minimising any adverse effects on plants and wildlife. However, there is an increasing need for security lighting in rural areas, both for homes and on farms and commercial properties that are vulnerable to theft and vandalism. If such lighting is over-bright and poorly directed it can be highly intrusive in such an environment, and justifiably can be the subject of complaint. For many people living in rural locations, the introduction of outdoor lighting, where none previously existed, is often viewed as 'urbanisation' of the countryside, and undesirable. (Fig 7)

Fig 7 In rural areas lighting should not be intrusive.

Sunsets and sunrises, dark skies, moonlit and star-studded nights are part of the rich variety of the countryside. The sky glow from major towns and cities brightens and colours the background sky even when viewed from places far away, reducing the visibility of stars. Illuminated skies blur the separation between country and town, reducing the feeling of remoteness in rural areas and introducing a suburban character deep into the countryside.

Adding lighting to environmentally sensitive areas, such as the green belt, wildlife sites, national parks, sites of special scientific interest, areas of outstanding natural beauty and cross-country footpaths needs special consideration. In such locations care must be taken to keep lighting to a minimum necessary and to eliminate upward or stray light. This is essential if the quality of the night-time environment is to be preserved.

The Institution of Lighting Engineers has issued '**Guidance Notes for the Reduction of Light Pollution**'. This gives easy ways to reduce the problems of unnecessary obtrusive light as follows:

1. Switch off lights when not required for safety, security or enhancement of the night-time scene. In this respect one can introduce the concept of a curfew with further limitations on lighting levels between agreed hours e,g, advertising and decorative floodlighting – off between 23.00 h and dawn.

2. Direct light downwards wherever possible to illuminate its target, not upwards. If there is not alternative to up-lighting, then the use of shields and baffles will help reduce spill light to a minimum.

3. Use specifically designed lighting equipment that once installed minimises the spread of light to, or above the horizontal. (Fig 8)

4. Do not 'over' light. It is a cause of light pollution and a waste of money.

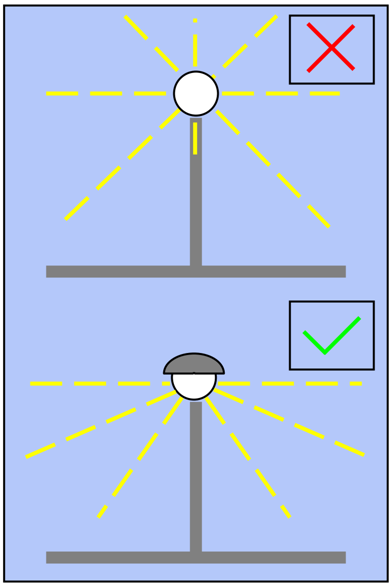


Fig 8 Choose luminaires that minimise upward light.

5. To keep glare to a minimum, ensure that the main beam angle of all lights directed towards any potential observer is kept below 70°. It should be noted that the higher the mounting height, the

lower can be the main beam angle. In places with low ambient light, glare can be very obtrusive and extra care should be taken in positioning and aiming. (Fig 9)

6. Wherever possible use floodlights with asymmetric beams that permit the front glazing to be kept at or near parallel to the surface being lit.

7. For domestic and small scale security lighting, there are two solutions:
(i) Passive infra-red detectors can be used to good effect, if correctly aligned and installed. A 150W (2000 lumen) tungsten halogen lamp is more than adequate. 300/500W lamps create too much light, more glare and darker shadows.
(ii) All-night lighting at low brightness is equally acceptable. For a porch light a 9W (600 lumen) compact fluorescent lamp is more than adequate in most locations.

8. For road lighting, light near to above the horizontal should be minimised. (Note UWLRs in the following Table).

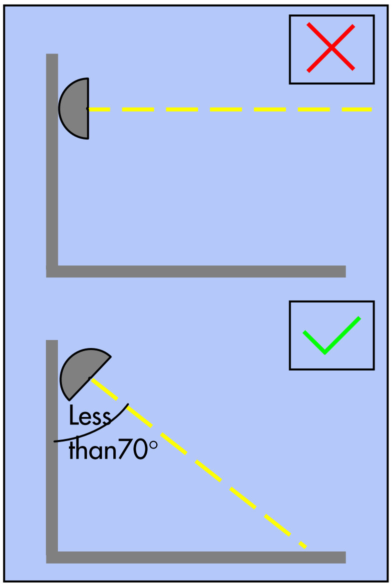


Fig 9 Aim peak intensity below 70° from the vertical.

Recommended Obtrusive Light Limitations for Exterior Lighting Installations

Environmental Zones	Sky Glow UWLR (Max %)	Light into Windows Ev (lux)		Source Intensity I (kcd)		Building Luminance *** L (cd/m²)
		Before curfew	After curfew	Before curfew **	After curfew	Average before curfew
E1	0	2	1*	0	0	0
E2	5	5	1	50	0.5	5
E3	15	10	5	100	1.0	10
E4	25	25	10	100	2.5	25

Environmental Zones
E1 In 'National Parks', 'Areas of outstanding natural beauty' or other 'Dark landscapes'.
E2 Areas of 'low district brightness' e.g. in a rural location, but outside a Zone E1
E3 Areas of 'medium district brightness' e.g. in an urban location
E4 Areas of 'high district brightness' e.g. in an urban centre with night-time activity

UWLR Upward Waste Light Ratio = Max. permitted % of luminaire flux that goes directly into the sky.
Ev Vertical illuminance in lux
I Intensity in candelas
L Luminance in candelas per square metre
- Acceptable from public road lighting installations **only**

Curfew Time - 23.00h till dawn.

** **Source Intensity –** This applies to each source in the potential obtrusive direction, outside of the area being lit. The figures given are for general guidance only and for some medium to large sports lighting applications with limited mounting heights, may be difficult to achieve. However if the recommendations for reducing light pollution are followed then it should be possible to lower these figures to under 10 kcd (kilocandela).

*** **Building Luminance –** This should be limited to avoid over-lighting and relates to the general district brightness.

5 Quantity of Light

It is helpful that the CIBSE Outdoor Environment Guide gives maintained illuminance values for many specific applications but this is not what we see. Illuminance is a measure of the quantity of light that falls on a surface. A dark and light surface next to each other could be receiving the same amount of illuminance but the brightness would be quite different. (Fig 10) The light surface would look brighter. Surface reflectance is very influential in our perception of the brightness of surfaces. Brightness is subjective whereas luminance which we can measure can be considered to be objective. Consequently in determining quantities of light for outdoor applications there is a mixture of references to luminance, reflectance and illuminance. (Fig 11) For a matt surface these three quantities are related by:

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

where:
E is illuminance (lux)
L is luminance (cd/m^2)
R is reflectance (as a decimal)
For a matt surface the value is not dependent on the direction of view whereas for a smooth shiny surface the luminance is dependent on the direction of the source and view.

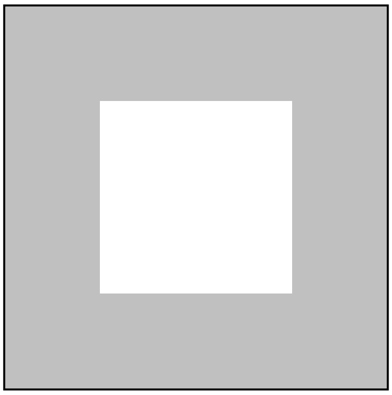


Fig 10 The smaller square of higher reflectance is brighter.

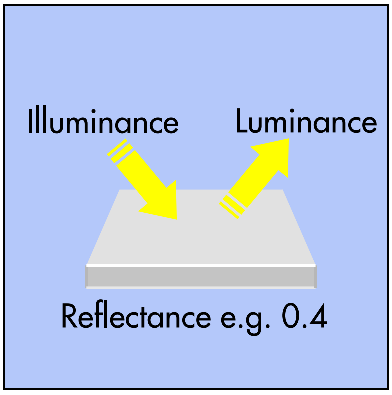


Fig 11 Illuminance onto a surface, luminance off a surface.

Architectural or promotional lighting is particularly subjective and will depend upon the relative brightness of the surroundings or character of the area. Specific luminance levels have been recommended which relate to the Environmental Zones.

Luminance Levels for Architectural and Promotional Lighting

Environmental Zone	Average Luminance (cd/m^2)	Maximum Luminance (cd/m^2)
E1 (e.g. Countryside)	0	0
E2 (e.g. Urban fringe)	5	10
E3 (e.g. Town)	5 – 10	60
E4 (e.g. City)	10 - 25	150

Also the ratio between the average and the maximum will determine the degree of contrast in the subject. This is referred to as the luminance contrast ratio.

The Effect of Luminance Contrast Ratio

1:1	Not Noticeable
1:3	Just Noticeable
1:5	Low Drama
1:10	High Drama

In the case of a building facade lit to an average level of 10 cd/m^2, the highlighting of a small portion to a luminance of 30 cd/m^2 will only be noticeable. Increase the luminance to 50 cd/m^2 and the effect becomes more dramatic.

Remember that these ratios relate to the amount of light reflected from the surfaces. If the building facade is red brick with a reflectance of 0.3 and a feature is a white plaque with a reflectance of 0.9, and they are lit to the same illuminance, there will be a brightness ratio of 1:3.
To make things easier suggested illuminances can be given for a range of typical materials for use in preliminary design based on the use of a 'white' light source e.g. Tungsten Halogen or Metal Halide.

Illuminance Levels for Architectural and Promotional Lighting

			District brightness Illuminance (lux)		
Approximate Reflectance	Typical Material	Surface Condition	Low E2	Medium E3	High E4
0.8	White brick	Clean	15	25	40
		Fairly clean	20	35	60
		Fairly dirty	45	75	120
0.6	Portland stone	Clean	20	35	60
		Fairly clean	35	55	90
		Fairly dirty	65	110	180
0.4	Middle stone	Clean	30	50	80
	Medium concrete	Fairly clean	45	75	120
		Fairly dirty	90	150	240
0.3	Dark stone	Clean	40	60	100
		Fairly clean	55	90	150
		Fairly dirty	110	180	300
0.2	Granite	Clean	55	90	150
	Red brick	Fairly clean	80	140	230
		Fairly dirty	160	280	450

Influence of colour on Illuminance

A neutral coloured surface will reflect a proportion of all the spectral colours of the light falling upon it. A coloured surface is coloured because it reflects only some of the spectral colours strongly. This is important when considering the effects of lamps that do not have a balanced spectral output. For instance, red brick may have a reflectance of 0.3 as far as white light is concerned, but its reflectance to red light could be 0.5 or higher. Conversely, it reflectance for blue light may be 0.2 or less.

Fig 12 'Warm' stone lit by a warm light source.

When selecting light sources the materials to be lit need consideration. A safe and simple design approach is to use warm colour appearance light sources with warm coloured materials (Fig 12) and use cool colour appearance light sources with cool coloured materials. For example, red brickwork would be sympathetically lit by high pressure sodium lamps with a colour temperature of about 2000K, but could look rather dull with metal halide lamps with a colour temperature of over 5000K.

6 Setting the Scene

Viewing position

To start an outdoor lighting design it should be known what is the principal viewing position or approach to the building or area being lit. It may not be possible, practical or economical to attempt lighting so the scene is effective from all directions. It can be agreed with the client what the principle direction of view is. In the case of a building facade where there is an opportunity to light from some distance away, lighting from the main direction of view will create a flat appearance to the building. Whereas setting the lighting to come onto the building at a glancing angle will produce strong shadows and marked highlights, consequently the building will be given the appearance of depth.

Fig 13 Church seen from the principle viewing approach.

Creating an effect

Outdoor lighting does not need to attempt to duplicate the daytime appearance of the building or object since the main direction of light is usually reversed. The best decorative lighting installations are those which exploit these differences rather than minimise them.

The lighting of columns provides a good example of lighting to create an effect. A row of columns can be lit from the front, side and the rear to give a silhouette. (fig 14 & 15) A turret with columns could be lit internally so that light is emitted from within. (fig 16) It is better to use light to bring out form than to flatten out to a two dimensional appearance.

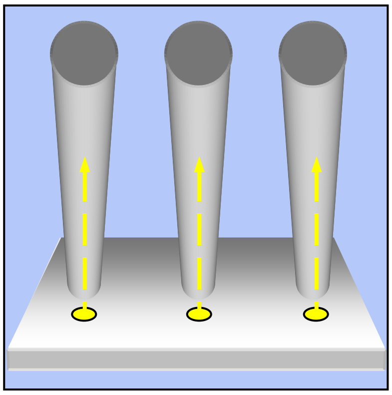


Fig 14 Front lit columns.

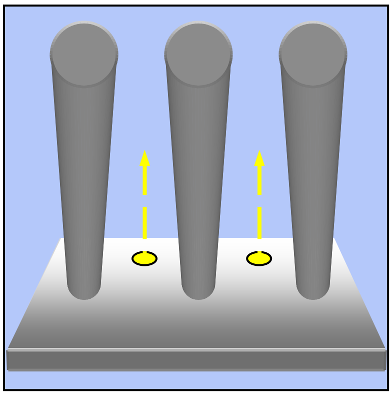


Fig 15 Rear lit columns.

Fig 16 Lighting by emission.

The appearance of building surfaces when lit at night will depend on the surface reflective properties. It is a matter of what the luminance is, or the brightness that appears to the observer. Considering illuminance falling on a surface alone may be quite misleading. Reflections from specular surfaces such as glass, gold leaf, aluminium, stainless steel, mosaics, glazed bricks and tiles, can present difficulties. Lighting from ground or low level the dominant reflection of light will be upwards. (Fig 17) When confronted with buildings of this type the position of luminaires needs careful consideration. There may be window mullions or columns with matt surfaces that could be lit in preference to the areas of specular surfaces. Matt surfaces have the advantage of reflecting light in all directions so when buildings are lit from a low or ground level the apparent brightness when viewed at ground level can be relatively high. (Fig 17) Even with buildings with a very high proportion of specular surface there are solutions. For example, luminaires may be able to be installed at the top of the building directing narrow beams of light downwards. Alternately, low power luminaires could be placed at suitable positions at different levels of the building directed downwards or sideways.

Buildings or object that are particularly dirty present a difficulty. The obvious approach if cleaning is not going to happen is to increase the amount of light used. If it is an object that is to be lit then consideration could be given to lighting in silhouette. When obtaining a specification in situations where an existing building or object is not going to be seen then a question that needs to be asked is: how clean is it?

Colour

The **colour appearance** of a light source can evoke a warm or cool atmosphere depending on the choice of colour temperature of the source. Lamps of low colour temperature are seen as warm and lamps of high colour temperature appear cool. Lamps of good **colour rendering** will make a scene look natural whereas lamps of poor colour rendering will distort some colours making the appearance of a scene unnatural.

The use of coloured light for buildings or landscapes is largely a matter of personal taste. Insensitive or inappropriate use of colour can cause great dissatisfaction. Multi-coloured lighting might be appropriate in parts of a city centre but would destroy the tranquillity of a country town. (Fig 18)

Using different light sources can produced colour shadows and a distinction can be made between two part of a building by using only a slightly different light source. The spectral distributions of light emitted by typical 'white' lamps show quite notable differences from warm to cool, so that you can produce subtle contrasts in colour. Light sources that slightly enhance building materials generally works better. In general, colours in the outdoor environment at night are required to be recognisably natural, and for this reason a 'white' source is normally used.

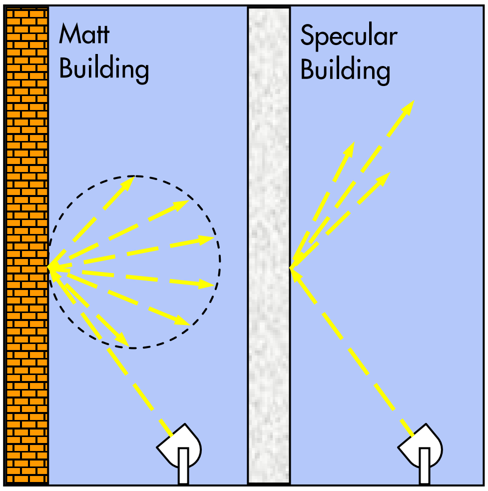


Fig 17 Effect of building surfaces on lighting.

Fig 18 Creative use of colour at Wembley Conference Centre.

Modelling

The principles given in the module on Lighting Theory apply to outdoor lighting. Establishing a principle viewing position can be quite important. For something like a sculpture, a viewing position can be agreed then a typical treatment is to use a key light at about 45°, if that is possible, with a less intense softer fill in light from the other side (fig 19). An even more three dimensional effect can be given by introducing back lighting, although care is needed not to cause glare to observers at the preferred viewing position. Just using a key light alone can look harsh and stark.(fig 20) In the situation where there is an object that people are expected to walk around then lighting from three direction could be appropriate given slightly stronger emphasis in one direction. (fig 21)

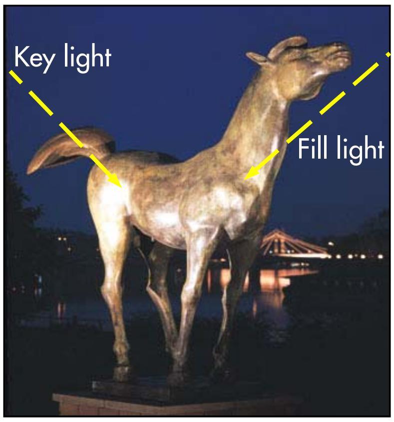


Fig 19 Key and soft fill light.

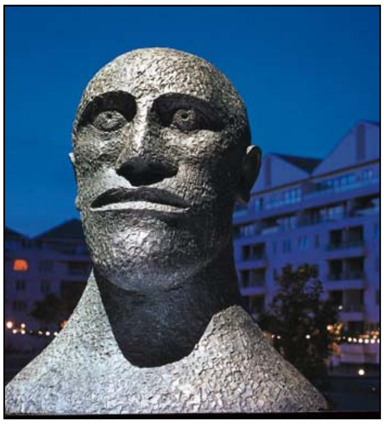


Fig 20 Only key light.

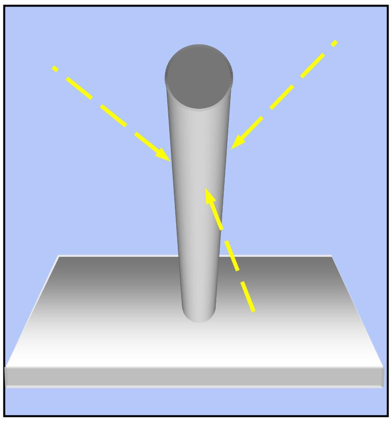


Fig 21 Three directional lighting.

Shadows

The shadows of a lit object can in some circumstances be part of the overall effect. Where different coloured light sources are being used shadows from one light source can be lit and coloured by another light source. (Refer to Lighting Theory module Assignment question 12.) Shadows can help to define the three-dimensional form of an object or building and create a contrast between highlights in the field of view. (Fig 22) Light directed at a fairly shallow angle, close offset, can provide strong shadows to a three-dimensional structure. These strong shadows can be soften by lighting from the opposite direction to fill in the shadows. The illuminance only needs to be a tenth to a third of the key light. (Fig 23) Light directed at shallow angles onto a surface can cast minute shadows in the building material, this technique can be used to reveal texture. (Fig 24)

In amenity areas large areas of shadows should be avoided as this reduces people's sense of security within the space. It increases the potential for fear of crime and crime itself. (See section 3)

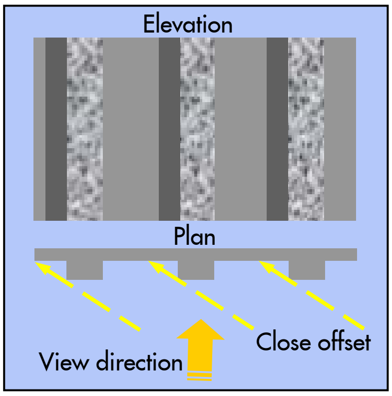


Fig 22 Shadows defining form.

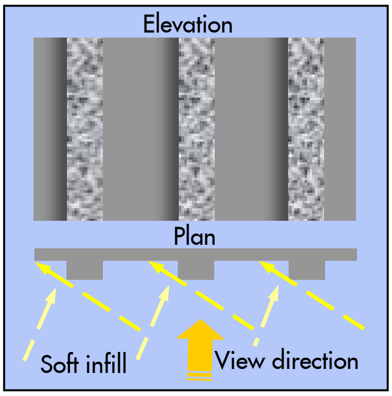


Fig 23 Softening shadows.

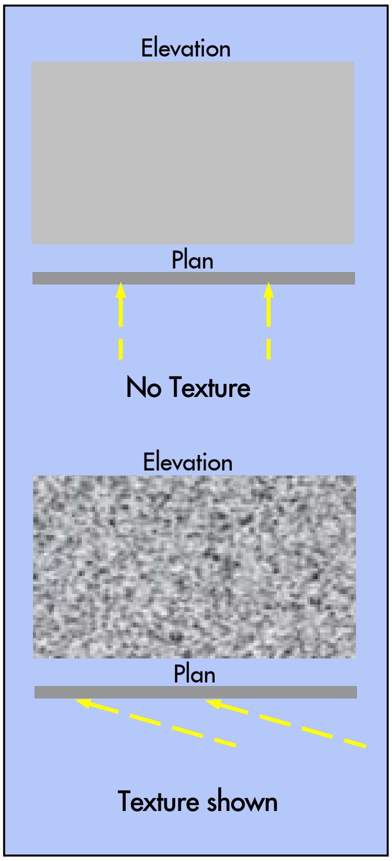


Fig 24 Revealing texture.

District Brightness

The degree to which an object is accentuated depends upon the contrast between the object and its background. To achieve a desired emphasis the luminance of the object has to be related to the district brightness. For example, a country church may need little more than moonlight levels to make its presence felt whereas a building lit to this level in the centre of a city would hardly be noticed. The three main bands of district brightness are rural, suburban and town or city centre. Illuminance levels for this range of district brightness areas are given in the table on page 7.

Questions 1

1. What is the broad purpose of amenity lighting?
2. What parameters may need to be considered before lighting a listed building?
3. How might you expect good lighting to affect crime and the fear of crime in streets and around housing?
4. What aiming for a floodlight would you recommend to minimise glare and control light pollution?
5. For architectural outdoor lighting what is the maximum luminance recommended in a town?
6. Suggest three methods of lighting a building that has a mainly specular surface.
7. What is the effect to modelling of using only a key light?

7 Amenity lighting

Attractiveness, delightfulness and pleasantness are all ways of expressing amenity and these expressions lend themselves to the purpose and objectives of amenity lighting. However, such objectives are not easy to use as a basis from which a lighting decision can be made.

Fig 25 Amenity lighting at Leeds City Centre.

Sometimes the term 'amenity lighting' is characteristic of lighting that is provided where before it was nearly pitch dark. Generally reference to amenity lighting infers that in an exterior area at night:

- the lighting should assist people and vehicles in moving about safely
- that it may aid the performance of outdoor work and
- may have some prestige value.

The distinction between amenity and prestige is blurred.

A fairly high diversity of illuminance is acceptable for most amenity lighting but it is important that the equipment and its placing should relate to the human form and not dominate. Light sources placed below eye level and projecting light downwards, generally, achieve a more pleasing effect. Although they do not represent a very efficient way of lighting an external area due to the increased cabling and maintenance costs involved, such investment should be weighed against the benefit of the quality of the visual environment.

Amenity lighting levels

Illuminance recommendations for outdoor and amenity lighting are generally specified as horizontal or vertical maintained illuminance. A significant step in illuminance is a doubling and so often these values occur: 5, 10, 20, 50, 100, 200, 500, 1000, 2000 lux.

For example for parks and gardens the CIBSE Outdoor Environment Lighting Guide gives:

Area, location, or task	Maintained illuminance (lux)
Secondary pathways	5
Main pathways	10
Trees/bushes	10
Steps	50
Focal points (large)	100
Focal points (small)	200

Fig 26 Tree lighting in park.

When it has been stated that brightness is the real thing that counts why is illuminance being used to specify lighting levels? Illuminance is easier to calculate and measure, it does not depend on the surface properties of what is being lit. Most of the time lighting based on this will look acceptable. However there are going to be occasions when relying on illuminance as a criterion is not going to work. So where might using illuminance not work? In situations where the materials being lit are markedly different in reflectance or surface properties.

The values of maintained illuminance are average over the area, location or task. The uniformity of lighting if it is specified is quite likely to be given as a diversity, that is 'maximum : minimum'. The table below gives typical values. A main pathway in a park could have an average illuminance of 10 lux, a maximum of 50 lux and minimum of 1 lux. This would correspond to a diversity of 50:1.

Typical diversity for outdoor lighting

Area, location, or task	Diversity
Non-critical areas: Parks, gardens, amenity lighting	50:1
Working areas, most building facades. Sports training areas	20:1

A study was undertaken by the Bartlett School of Architecture and Thorn Lighting (Lighting Journal 32,1991) on amenity lighting. From this study the following design recommendations have been developed. These recommendations provide a useful framework that will enable the designer to produce a better, more attractive night-time environment for pedestrian shopping areas and similar residential areas.

- The general lighting should provide a wash of light over the area. The average illuminance on the horizontal plane 1.5 m above the ground level (E_H) should not be less than 20 lux with a uniformity (minimum/average) of not less than 0.3.
- The average illuminance on the vertical plane 1.5 m above ground level (E_V) should not be less than 0.8 E_H average, with a uniformity of not less than 0.2.
- The accent lighting used to highlight features of visual interest should provide illuminance levels on the relevant vertical planes that are about $5E_V$ average.
- Covered walkways should have lighting that is continuous throughout their length and that light vertical surfaces. The illuminance on the walls should be about $5E_V$ average.
- The daytime appearance of the lighting equipment is an important consideration and the lanterns and columns should form an integrated part of the whole design.

The above recommendations are meant to form a basis for design and not a rigid requirement. Lighting for pedestrian areas must form a balance between good seeing conditions over the entire area and a light pattern that provides an attractive and welcoming environment.

Fig 27 Create an attractive environment with light.

8 Tasks

A selection of lighting tasks is given below with brief guidance on approaches to lighting. Refer to CIBSE, ILE and other guides for specific task specifications. The Outdoor Environment CIBSE Lighting Guide (LG6) is often the best starting point for the type of lighting being covered.

City centres

Many cities and towns restrict or exclude most motor traffic from an area in the centre, reserving the area for pedestrians and possibly cyclists. Planning authorities, anxious to secure busy and prosperous city centres have realised the benefits of improved traffic circulation systems, car parking facilities and pedestrian traffic segregation.

The major retail shops and stores have virtually re-grouped to form extensive shopping areas that are assessed from a main thoroughfare, square or walkway. The area is usually traffic free, predominantly open to the sky, but may be connected to the neighbouring streets by

Fig 28 City area reserved for pedestrians.

covered linkways and circulation spaces.

Fig 29 Consider hazards such as steps and escalators.

Lighting equipment should be chosen which is in keeping with the public nature of the area. An impression of brightness, warmth and unity is desirable, particularly throughout the circulation spaces. Colour should be natural and people pleasantly modelled and not inconvenienced by glare.

Light can be used to improve safety and security in all parts of the precinct. The illuminance should be increased where there are hazards, such as steps and escalators, or seating areas and other focal points. Such areas of higher ambient illuminance introduce variety to the scene and further interest is added if flower displays, shrubs, advertising bollards, trees and other features are design to receive lighting emphasis.

The night-time appearance of a precinct is affected considerably by the type of luminaire and equipment used. Unobtrusive systems are desirable in some precincts, whereas in others the luminaires and columns can be used to enhance and extend the visual impression of the space by being a feature of the scene both by day and night.

Area, location or task	Maintained illuminance (lux)	Notes
Open pavement	20	1.5m above ground (min/ave> 0.3) Vertical illuminance 15 lux
Covered pavements, overhangs and steps	75	Vertical 1.5m above ground.
Illuminance set to ensure that facial expressions are easily recognised so that pedestrians feel secure.		

Buildings

When it comes to lighting building facades the complete facade should be illuminated to some extent in order to show the entire building outline to the viewer. This maintains the proportions of the architecture and allows the more prominent and desirable features to be given emphasis. If possible a building needs to look more than just an illuminated front. Its solidity can be emphasised by adding light at a lower illuminance to the side, or at the very least to the return corners, allowing the illuminance to decay gradually to the rear of the end wall. It may be necessary to illuminate a sloping roof to achieve a coherent picture, otherwise chimney stacks may appear as if they are suspended in mid-air.

Fig 30 Light revealing features in the architecture.

It may be desirable in some cases to soften the strong modelling effect of uni-directional light. This may be achieved by illumination in the form of fill-in light from a completely opposite direction to the main flow of light. Any fill-in light should be only one tenth the value of the main illuminance.

There are broadly four basis architectural styles for building facades:

- Facades that are basically flat
- Facades with predominantly vertical characteristics
- Facades with predominantly horizontal characteristics
- Facades with external recesses

Facades that are basically flat

For example undecorated fronts of factory units and spec-built office blocks. The achievement of any shadow effects may only be possible by placing the luminaires at exceptionally close-offset positions, unless for security surveillance a high level of uniformity is required, a certain unevenness in the brightness patterns across the façade could produce a degree of visual interest.

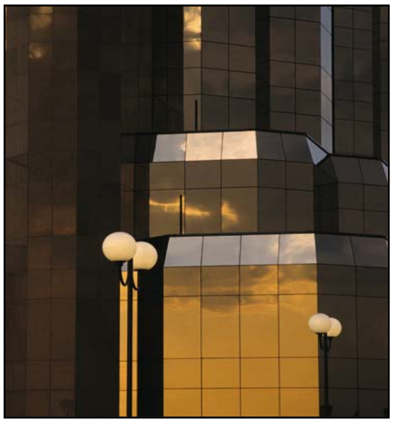


Fig 31 Flat facade.

Facades with predominantly vertical characteristics

This is characteristic of both medieval and classic architecture. The style can be emphasised by applying illumination from the left and right side of the facade using medium beam floodlights. Generally, due to fairly light coloured surface material, the shadow formed by sharply oblique lighting are too strong and create too distinct a contrast. In-fill lighting from the opposite direction using wide-beam floodlights will reduce the contrast and soften the appearance.

Fig 32 Vertical facade.

Facades with predominantly horizontal characteristics

A great many modern high office and hotel blocks have a markedly horizontal emphasis. Often such designs include horizontal elements that project slightly, like window ledges or continuous bands that run across the facade from one side of the building to the other.

Floodlights placed close to the facade and aimed upward will produce bands of dark shadow above the projection. The wider the shadow band the more likely it will be that the surface area of the facade above the projecting ledge will appear to be floating on air and the building will appear as dismembered sections. Supplementary lighting may be placed upon the ledge to soften or eliminate the shadow, or alternatively, the floodlights have to be moved away from a close-offset position so that a greater distance exists between the facade and the light source.

Fig 33 Horizontal facade.

Facades with external recesses

A facade is often designed to incorporate features such as balconies or galleries that may project forward or be recessed into the facade. In both cases the floodlights must be located some distance in front of the building in order to prevent excessively dark shadows being formed.

If lack of available space in front of the facade prevents this, supplementary illumination will have to be placed inside the balcony space or incorporated within the object creating the shadow as in fig 34. A technique that can be considered is to place small exterior low voltage tungsten halogen luminaires on ledges of the facade whilst hiding the transformer for the lamp within the building at close quarters.

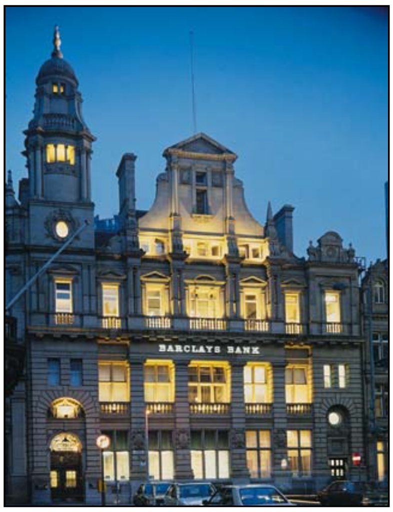


Fig 34 Facade with recesses.

Parks and Gardens
A small amount of lighting can attractively reveal the beauty of flower beds, of trees, shrubs and water features and help to foster a communal feeling. Ponds and fountains may have features like statues or small bridges that could be attractively lit. One of the main objectives is to enhance the general scene and to eliminate dark shadowy areas that may detract from the visual impression or may be considered a safety hazard, although everything in sight does not have to be illuminated. Main features of interest can be selected for emphasis.

Where visitors are likely to follow a prescribed route a sequence of lighting scenes can be presented. On pathways for security it is important that people can see each other at a distance and that their facial features can be seen close by. One way of doing this is to use decorative lanterns on 4-6 m columns to reveal people in silhouette at a distance and give front or side lighting when someone is nearby. Where security is less of an issue lower level luminaires can be considered like bollards or recessed wall lights. For flowerbeds and shrubs there are several approaches to lighting, for example garden spike luminaires, bollards and fibre optics.

Trees
For lighting purposes it is useful to consider three basic groups of trees, open, solid and transparent:

Open: Trees whose main character comes from the structure of their branches. (Birch, Ash, Rowan.)
Responds well to lighting upwards from underneath. Use floodlights sunk into ground or sunken luminaires. (Mica)
Solid: Trees with more complete canopies having dense foliage. (Most Conifers, Beech, Chestnut)
Responds well to frontal floodlighting to the side of the principal direct of view.
Transparent: At certain times of the year the leaves of some species are transparent. (Lime, Horse Chestnut)
If lit from behind can glow with colour.

Tungsten Halogen or Metal Halide lamps can be used for natural colour of leaves, blossom and fruit.
Evergreens respond to light from Metal Halide lamps.
Silhouette trees in front of building by lighting facade to reveal form and pattern. Light sources can be placed to cast multiple shadows onto buildings.

Also the use of coloured lamps or coloured filters with luminaires in the right setting can add interest and vibrancy to a park or garden.

Area, location or task	Maintained illuminance (lux)
Main pathways	10
Secondary pathways	5
Steps	50
Trees/bushes	10
Focal point (large)	100
Focal point (small)	200


Fig 35 Revealing flower beds.


Fig 36 Lighting a pathway.


Fig 37 Trees need special consideration.


Fig 38 Use of a coloured lamp in a garden.

Water Features
Water is a very attractive element of the landscape and can be used to create a sense of tranquillity or vibrancy. Still water is a perfect medium for the reflection of floodlight buildings, sculpture and trees. Fountains and cascades sparkle and glitter when suitably lit whilst distorted reflections of light from moving water can create interest on walls and other surfaces.

The beauty of a floodlit tree-filled island viewed from the banks of the mainland is greatly enhanced by reflections in the water. Submersible tungsten halogen lamp floodlights positioned near to its banks and mounted below the surface of the water may be used, or proof floodlights may be mounted just above water level. The second method has the advantage that light losses caused by absorption and scattering of the light are minimised. To obtain a balanced picture of patterned foliage each floodlight should have side wings or lateral lourves that can be adjusted individually. Taller trees in the centre of the island will need additional light and symmetrical beam floodlights may be mounted on the far banks to provide this.

Vertical jets of water can be lit by symmetrical beam submersible floodlights positioned so that the light is projected through, or along the water streams. The beam angle of the luminaire is critical and should be calculated in relation to the height of the jet in relation to its width. A tall 25m jet could use a narrow angle beam with a high peak intensity. Low voltage equipment is useful for this not only for electrical safety reasons but also because of the choice of beam angles and intensities available. Fibre optic terminals with a light harness and light generator are increasingly a preferred option.

Swimming and ornamental pools will benefit from underwater lighting. They are generally lit below the surface from the side walls with special luminaires having narrow or fan shaped beams.

Fibre optics is a very versatile media to transfer light from a light generator to many light terminals around a pool. Electrical safety and ease of maintenance is particularly beneficial. For example, pools do not need to be drained for lamp replacement. There is a reduction in running costs because of easy access to the light source which is mounted outside the pool. Maintenance is reduced through the long life of the metal halide discharge lamps compared with tungsten halogen lamps. The light terminals are more discrete than submersible floodlights and also the precision of the light beams reduces light pollution. The Thorn Lighting Aquarius range opens up many possibilities in this area of lighting.

All equipment should be inspected frequently, particularly for security of fixings, corrosion and chafing of supply cables. The use of residual current circuit breakers should be considered for all supplies to underwater lighting systems.

Fig 39 Vertical jets of water lit with colour.

Fig 40 Using colour change on fibre optic light generator.

Fig 41 Statue and foaming jets lit by fibre optics.

Fig 42 Fountains in Paris lit by Aquarius fibre optics.

Statues and Sculptures
Lighting at night gives an exciting opportunity to create an alternative look to that given by daylight. In most situations of lighting statues a natural appearance looks best. A statue or sculpture may be intended for viewing from within a restricted angle or from all sides. In any case modelling is always important and lighting is required that reveals the form and details of the sculpture and makes it stand out from its surroundings. Works in light coloured materials are normally revealed best when brighter than the background, but dark statues, like bronzes, are often better in silhouette. Experiments should be made on site to get the best lighting effect.

There are three basic methods that can be used:

- **spotlighting from above** (Fig 43)
  A natural modelling effect will be created if the key light is balanced with fill light of about one tenth the intensity of the main beam. It can be very effective to additionally provide a high back light of the same intensity as the key light.
- **spotlighting from below** (Fig 44)
  Luminaires can be buried into the ground. These can be positioned so the statue or sculpture has light at an incident angle of 45° to 60°. Care is needed to create some stunning effects rather than something grotesque. These luminaires can either have directional low voltage lamps or an asymmetric reflector. Consideration should be given to the use of matt black louvres across the lens to avoid glare in the people's eyes.
- **close offset highlighting**
  Small discreet luminaires on the plinth or elsewhere on the structure could be installed. The intensity of these luminaires should be balanced with that of any others aimed at the object. This can particularly enliven the appearance of a dark statue seen in silhouette when highlighting particular features of the statue.

Obelisks can be lit by the 'spotlighting from below' technique. If it is of a simple design, narrow beam spotlights could be set closer with the beam directed up the length of the obelisk. The effect of any ledges or protrusions need to be taken into account when positioning luminaires and spill light should be kept to a minimum.

Fig 43 Key light from above.

Fig 44 Lighting from below.

Fig 45 Close offset lighting could be used to good effect.

9 Luminaires and Equipment

This section is a broad survey of luminaires, equipment and their applications with brief comments. The luminaires are selected to represent a type or group, specific product names and specifications can be found in the current Comprehensive Catalogue or product catalogues. The applications selected are just a few to give examples of what the luminaires and equipment can be used for.

Recessed Outdoor Luminaires

A wide variety of recessed luminaires are now available, for ground, wall and ceiling mounting. The ground recessed luminaire shown on the top right is ideal for paved, concrete or grassed areas where raised lighting would be obtrusive. Various combinations, coloured filters, lenses and directional grilles can be attached allowing the creation of many different visual effects.

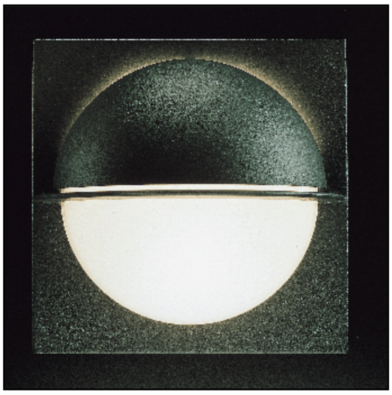
Recessed luminaires can be used for defining pathways and routes for pedestrians. Statues, sculptures, decorative brickwork, shrubbery and trees can be enhanced by these luminaires and precise directional control is possible to prevent light pollution. They are less susceptible to vandalism than bollards that might be considered for pathway lighting. An aspect to take into account is the surface temperature of the luminaire. Young children particularly could be vulnerable to getting a burn from touching some luminaires. There are low temperature luminaire versions available to avoid this possibility.

Recessed wall luminaires can be an attractive alternative to bulkhead type luminaires. It needs to be established that a cavity can be made for the luminaires and that provision can be made for electrical connections. The shape of the luminaire, round, square or rectangular, could be selected to complement the architecture.

Typical applications are for stairs and external walkways in the vicinity of buildings. The downward facing louvre directs light down to the ground, reducing glare. It is important in amenity areas that peoples faces are recognisable so other means of lighting at a high level would be beneficial.

Bulkheads & Bollards

There is a wide range of bulkhead luminaires, many with attachments, making it easy to select a product that complements the architectural style of the location. Luminaires that appear functional through to decorative are available. This elegant bulkhead designed for wall or bollard mounting controls well the amount of upward light.



In this setting the choice of a white finish blends with the stone cladding of the building. The bollards may well create an invisible boundary for some people to keep off the grass besides providing a safe and well defined route to and from the building.

Bollards are typically used to light pathways and approaches to entrances. There is sufficient choice to be able to make a luminaire selection that blends with the surrounding architecture. Points to consider are the height of the bollard, the lighting performance, the ingress protection and degree of vandal resistant offered.

If necessary, and the numbers were sufficient, some luminaires could be painted to a colour to suit other elements within the project. This can help in integrating the appearance of the overall design.

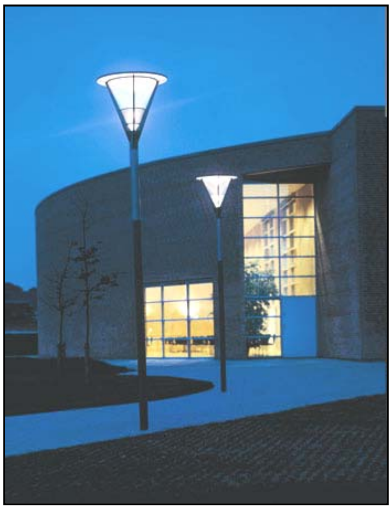
Decorative Lanterns

Amenity lighting for a long time has been associated with spheres of various types, singularly mounted on a column or several spheres mounted on brackets to a column. Spheres mounted on wall brackets sometimes compliment these. This type of lighting is good at lighting the elevation of buildings and people's faces as well as the ground. They have the effect of making a place feel more pleasant and safe. Opal spheres with no other optical control emit a lot of upward light that is wasted and causes light pollution. Clear spheres with internal louvres provide better light control reducing upward light and glare. They are also less obtrusive during daylight hours, you can see through them to the surroundings.

At Hartlepool Historic Quay lanterns reminiscent of Victorian gas lanterns are used to blend in with the character of the place. High pressure sodium lamps bring warmth to the brick and stonework of the buildings. There is a trend growing to use 'white' light to show people and objects more naturally, such as with ceramic metal halide lamps.

There are now many attractive high performance decorative lanterns to choose from. This elegant design of the Avenue XL shields the lamp from view whilst reflecting the majority of the light off the top canopy. The control gear is not contained within the column but in the top of the canopy.

The Avenue range of post top lanterns can easily complement contemporary buildings. The struts supporting the canopy can mimic the glazing bars on the building or other structural elements.



This decorative lantern, Fidji, relies upon reflected light from the top canopy, the light source is mounted lower down between the tripod column. There are many imaginative designs and styles of decorative lantern and it is matter of knowing what is on offer. It is important that the scale of the lantern is appropriate for the intended situation, the size of the lantern and the height of the column need to look right.

This shows the quite unusual Candle luminaire. It is an indirect lighting column that uses optical film technology. Most of the column is luminous when the lamp is on. A 150W Metal Halide HIT lamp is used. It is possible to incorporate colour filters.

Road Lighting

Road lighting is in several broad categories including major traffic routes, residential routes and amenity lighting. The Alpha 2000 is a stylish high performance lantern suited to major traffic routes where the design and installation is concerned primarily about road user safety. The Alpha 2000 has a special optical system. The system consists of a moulded plastic component housing an aluminium reflector, a glass or polycarbonate front and an adjustable lampholder. The lampholder allows longitudinal, vertical and horizontal adjustment, providing an enormous variety of lighting performances. This type of lantern is used in amenity areas as well because of its style.

This rectangular luminaire (CA 5000) has outstanding lighting performance with no upward light and very little spill light. Its applications extend from car parks and private roads to main traffic routes in city centres.

The Beta series of lanterns are for minor roads, residential and security lighting. Typically using high pressure sodium lamps of 50W to 100W, or low pressure sodium lamps of 35W and 55W. The Beta 99 shown here has a GRP canopy and vandal-resistant bowl with an ingress protection of IP65.

Floodlighting

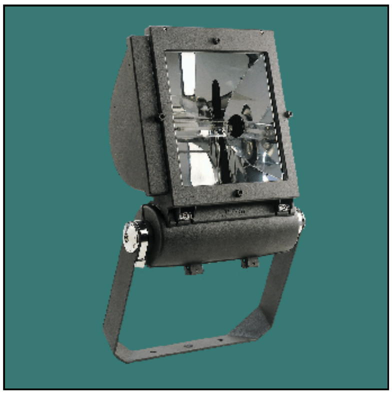
Broadly floodlighting can be divided into area floodlighting, precision spotlighting and precision floodlighting. Predominantly high pressure sodium and metal halide lamps are used as light sources. The main interest in this module is area floodlighting. The Areaflood 7 is a classic design suited to small scale floodlighting using 70W discharge lamps offering a wide range of attachments to the luminaire.

This black version has a black spill light shield. This could perhaps be used on buildings in a trading estate next to residential properties.

This version has a black louvre that cut down glare from most viewing angles. It inevitably reduces the light output and affects the lighting performance of the floodlight.

The Contrast ranges provide three distinct design conscious shapes that caters for a wide range of lamp types and wattages. Many diverse schemes can be handled using the same style of luminaire, particularly so because of the vast range of attachments available including anti-glare louvres, protective grilles, barn doors, colour filters and visors. Visually well integrated schemes are easy to achieve because there is a family of products.

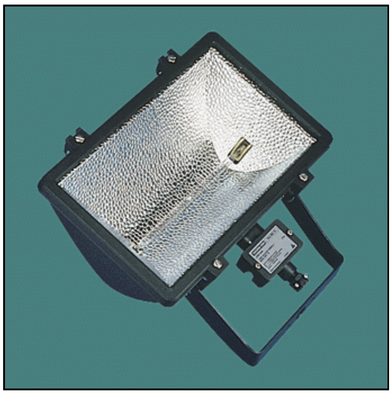
Front glasses and refractors will often be needed to broaden the beam. When used with Contrast R these can be rotated to give alignment of the beam profile to suit the application thus minimising waste light.



Refractors that attach to the front of Contrast C vary predominantly the vertical angle of the beam.

Additionally sand blasted glass attachments can be used to soften the beam of the Contrast R and C.

Contrast Pinspot is a mains voltage floodlight for use with halogen and metal halide lamps. A wide selection of glasses and attachments, which can be used in combination, allows for a variety of beam distributions. They are ideal for the lighting of sculptures, plants, trees or signage, or the emphasis of architectural detail. They are so small that they are inconspicuous mounted on buildings to light architectural detail. There is a selection of mains voltage and low voltage tungsten lamps available that give excellent colour rendering and precise beam control.



There are many applications, often in the realm of security, that benefit from the instant white light of tungsten halogen. The Haline range offers a wide wattage range from 500W to 1500W.

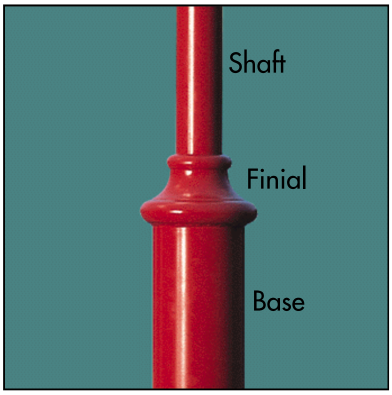
This shows the apron area outside a CAA Hangar at Stansted Airport being lit by area floodlights with high pressure sodium lamps.

Columns

Several ranges of columns for road lighting, floodlighting and amenity lighting are manufactured by Thorn Lighting.

Thorn Cityscape columns are made from aluminium. There are advantages to using aluminium over galvanised steel. It will not corrode and does not need painting, making them completely maintenance free.

Aluminium column can be painted if required for aesthetic reasons. The paint will not bubble, crack, stain or streak due to corrosion. Also aluminium columns are lightweight, enabling easy handling and erection. The risk of injury in a collision with an aluminium column is reduced dramatically.

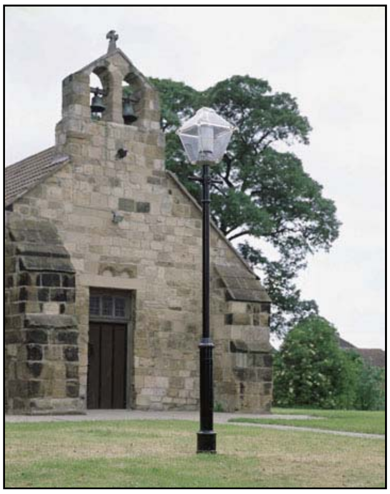


The Cityscape decorative columns and brackets collection is available in 3, 4 and 5 m columns for use with the Cityscape range of amenity lighting lanterns. There is also a complementary range of non-illuminated aluminium bollards.

There is a range of 4-5 m group B aluminium and steel columns and brackets for use with side entry group B lanterns for residential roads, post top lanterns for residential roads, footpaths, car parks and amenity areas. The columns can also be used for low-level floodlighting. The picture shows Gamma 6 lanterns on aluminium columns.

There is a range of group B parallel sided, hot dip galvanised, tubular steel columns and associated brackets and attachments. It is preferable that the columns are painted on site for further protection and appearance.

Heavy-duty steel columns are also available for more onerous use, for example, with multiple floodlights illuminating a car park. The range varies from 4m to over 16m.



Fibre Optics

Lighting with fibre optics has opened up many new opportunities for display lighting that has produced some exciting results. In principle light from a lamp is controlled and directed into a bundle of optical fibres that transmit the light by means of internal reflection along the fibres to optical terminals that emit the light. Broadly there are three parts to this system, the **light generator** or **projector**, the **optic fibre harness** and **optical terminals**. Metal halide lamps are a popular choice of light source for the system. The optical terminals emit light without UV or heat so they can be used to light at close range or for lighting sensitive items.

The GL6 Projector uses a xenon metal halide lamp with an extremely short arc dimension of around 1mm. The optical system can control the light output and focus it precisely into the fibre optical harness. The main advantages of this system are realised in applications that require side lighting or very long end light fibres. For these two types of application, PMMA is the best fibre material due to its low attenuation level along the length of the fibres. The projector has a filter holder for fixed colour filters and has the option of a colour wheel with eight colour positions.

This is just one example of a cairn terminal. It is a guide light with four windows for use on footpaths, car parks and other amenity areas. It is easily visible at over 100 m by pedestrians as a light marker.

Another distinct form of fibre optics is side lit plastic fibres used for decorative effect, and in some situations can be used as an alternative to cold cathode type lighting. Lengths can range between 5 and 40 m.

Systems for exterior applications include fountain lighting. The Aquarius range is specifically designed for use with fountains, water jets and pools.

Questions 2

1. What lighting diversity is acceptable in non-critical amenity areas?
2. Outline a typical approach to floodlighting a facade with predominantly vertical characteristics.
3. Where lighting statues or sculptures from below what would need to be given careful consideration?
4. If decorative lanterns with spheres are to be used in an amenity area how can upward light pollution be substantially reduced?
5. What features need considering when selecting a bollard to light a pathway?
6. What are the features and advantages of aluminium columns over steel?
7. How is light transmitted along optical fibres?

9 Design considerations

Having decided on the lighting effect required from the key viewing positions and thus where the light should come from to achieve the best modelling results, the more practical aspects of outdoor lighting have to be resolved. The flow chart in fig 46 gives the major steps and considerations.

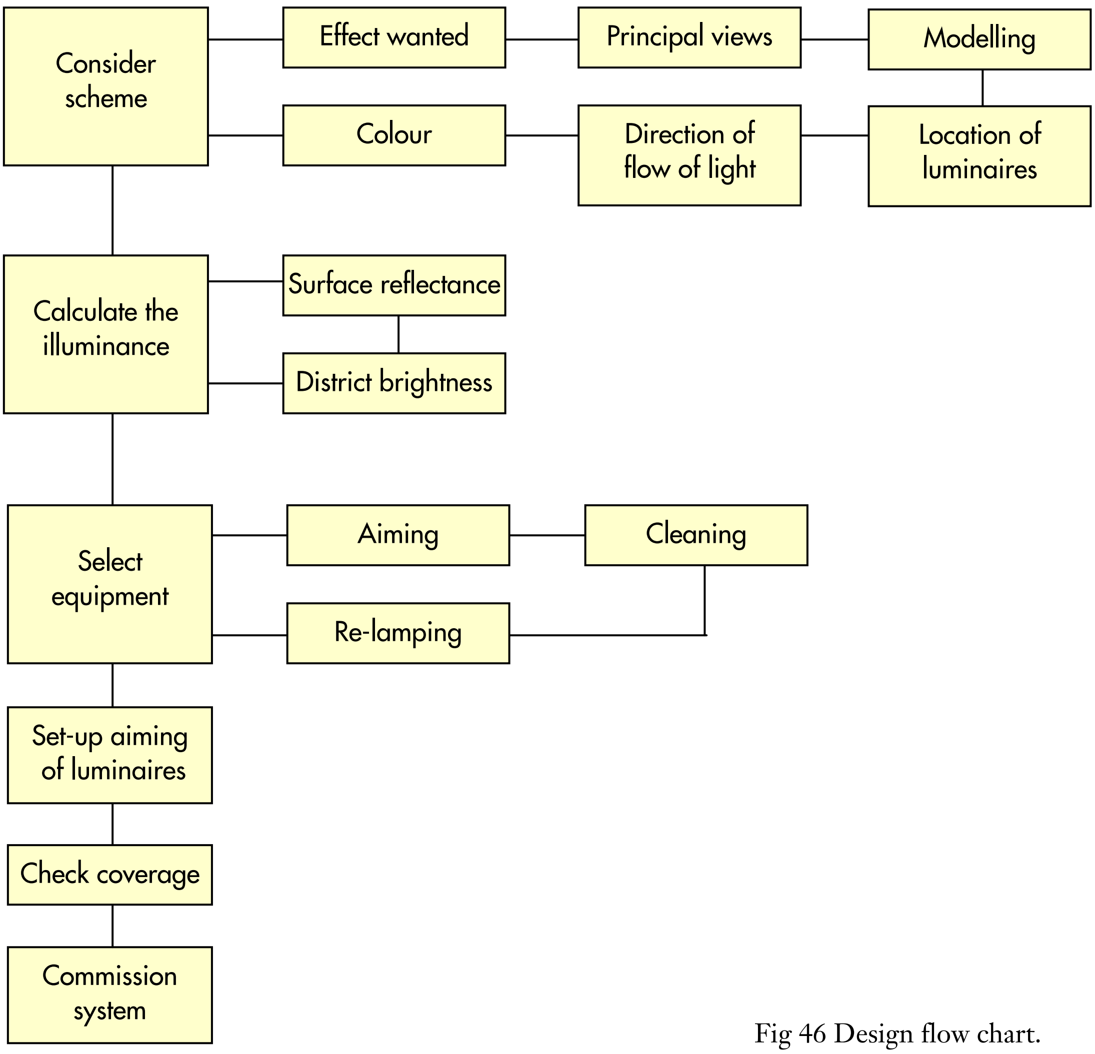


Fig 46 Design flow chart.

It should be noted that the illuminance required to achieve certain brightness contrasts on the facade depend upon a number of factors:

- building surface material reflectance
- district brightness
- location of the building relative to the general surroundings and
- the dimensions of the building

Fig 47 One way of lighting a square and buildings.

Fig 47 shows one approach to lighting a square and surrounding buildings. A number of buildings are lit primarily by luminaires placed on ledges below and between windows. Additionally the clock tower and fountains are lit. Another approach would be to light the square using floodlights mounted on top of the buildings, allowing spill light to do some, but not all, of the building lighting. This could be combined with column mounted lanterns that give the impression of being the source of lighting for the square, whilst look attractive during the day and night. Where buildings in a square are much closer in an amenity area and there is a requirement to light the buildings and the square, a simple design approach is to light the opposite buildings by floodlights mounted on top of the opposite building. Reflected light from the buildings, if of high enough matt reflectance, could provide suitable amenity lighting levels. This technique is possible if the buildings are unoccupied during the hours of darkness.

Facades, or even selective areas of surface material that may only achieve reflectance values less than 20% generally cannot be floodlit economically and it may be more practical to accentuate a section of bright trim with high reflectance rather than attempt to make dark stone appear visually bright.

Material	Reflectance
White marble, white or cream terracotta, white plaster	0.80 – 0.70
Plain concrete, light grey or buff stonework	0.65 – 0.45
Medium limestone, sandstone, common tan brick	0.45 – 0.20
Common red brick, sandstone, dark stonework	0.25 – 0.10

10 Lighting calculations

This section deals with the presentation of data for amenity luminaires, floodlights and fibre optics together with the methods for calculating illuminance at a point and average values. (Detailed floodlighting calculations are not covered nor are luminance design techniques for street lighting.)

Illuminance at a point

Most amenity lighting luminaires, for example street lanterns and bollards, have data for hand calculations in the form of an **isolux diagram**. (Fig 48) This diagram applies to a single luminaire at the stated height and attitude, that is the angle a street lantern may be tilted. Contours give the illuminance on a horizontal plane in lux/klm or lux/1000 lm. This means that by multiplying a contour value by F/1000, where F is the bare lamp flux in lumens, the actual illuminance in lux is calculated.

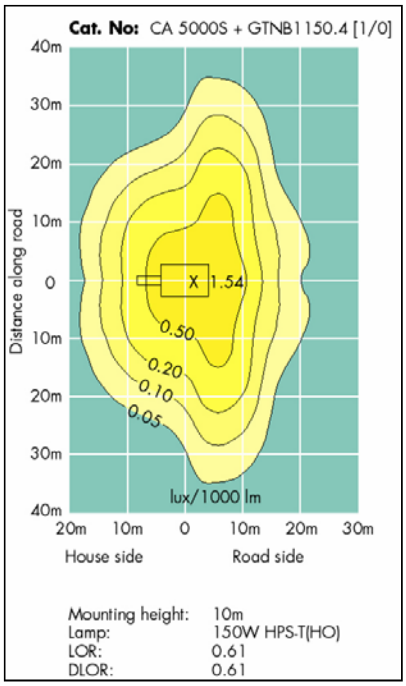


Fig 48 Isolux diagram.

An '×' on the isolux diagram shows the position of maximum illuminance, again with an associated value in lux/1000 lm. The dimensions on the diagram are in metres measuring from directly below the optical centre of the luminaire. For the purpose of orientation with street lanterns the grid may be labelled with 'House Side' and 'Road Side'. For values of illuminance on the grid or between the grid the nearest isolux contours can be read to interpolate a value of lux/1000 lm.

The calculation at a point can be calculated using the **isolux diagrams**. The illuminance in lux is derived from the contour values by use of the formula:

$$\text{Maintained illuminance (lux)} = \text{contour value} \times \frac{\text{initial bare lamp flux (lm)}}{1000} \times \text{MF}$$

The mounting height of the lantern that this illuminance applies to is given below the isolux diagram on the data.

Conversion factors to the contour values of the isolux diagram and road distances can be applied to calculate the illuminance for alternative mounting heights of the lantern.

Multiply contour values by:

$$\frac{(\text{Stated mounting height in m})^2}{(\text{New mounting height in m})^2}$$

Multiply road distance by:

$$\frac{\text{New mounting height in m}}{\text{Stated mounting height in m}}$$

Then use the formula given above for maintained illuminance at a point.

If more than one lantern contributes to the illuminance at a point the total illuminance can be determined by summing the contributions from all the lanterns. This can be done by copying the isolux diagram on to transparencies at the right scale and overlaying them on a plan of the area to be illuminated and seeing the contributions from more than one lantern.

In situations where the luminous intensity is known for a luminaire then the **inverse square law** can be used to calculate illuminance at a point. The calculation was covered in detail in the Lighting Theory module.

Worked example
Calculate the maintained illuminance using the isolux diagram in fig 48, the maintenance factor can be taken as 0.9:

a) At a point 10m roadside and 20m along the road. The lantern is mounted at 10m.
b) At a point 10m roadside and 20m along the road. The lantern is mounted at 8m.

a) The point 10m roadside and 20m along the road corresponds to the 0.2 lux/1000 lm contour. The initial lamp lumens are 17500 lm.

$$\text{Maintained illuminance (lux)} = \text{contour value} \times \frac{\text{initial bare lamp flux (lm)}}{1000} \times \text{MF}$$

Maintained illuminance = $0.2 \times \frac{17500}{1000} \times 0.9 =$ **3.2 lux** (Note: any point on the 0.2 lux/1000 lm contour corresponds to 3.2 lux. Likewise the 0.1 lux/1000 lm corresponds to 1.6 lux)

b) Since the mounting height is different to the height specified with the isolux diagram the conversion factors will need to be applied:

Multiply contour values by:

$$\frac{(\text{Stated mounting height in m})^2}{(\text{New mounting height in m})^2} = \frac{10^2}{8^2} = \frac{100}{64} = 1.56$$

Multiply road distance of grid by:

$$\frac{\text{New mounting height in m}}{\text{Stated mounting height in m}} = \frac{8}{10} = 0.8$$

At a point 10m roadside and 20m along the road now corresponds on the existing grid to 12.5m and 25m. This point is midway between the 0.05 and 0.10 contours, that is 0.075, but this value needs multiplying by the conversion factor of 1.56 to give 0.075 × 1.56 = 0.12 lux/1000 lm

Then use the formula given above for maintained illuminance at a point.

$$\text{Maintained illuminance (lux)} = \text{contour value} \times \frac{\text{initial bare lamp flux (lm)}}{1000} \times \text{MF}$$

$$\text{Maintained illuminance} = 0.12 \times \frac{17500}{1000} \times 0.9 = \mathbf{1.9\ lux}$$

Average illuminance

The average maintained illuminance produced by a lighting installation, or the spacing between luminaires to produce a desired average illuminance, can be calculated using an **utilisation factor**. It is assumed that the spacing between lanterns or luminaires in a row and the spacing between rows are uniform.

For road and amenity lighting lanterns and luminaires the utilisation factor is denoted by the symbol U_1 for light falling on the road side and U_2 for light falling on the house side of the lantern when it is mounted a shown in fig 49.

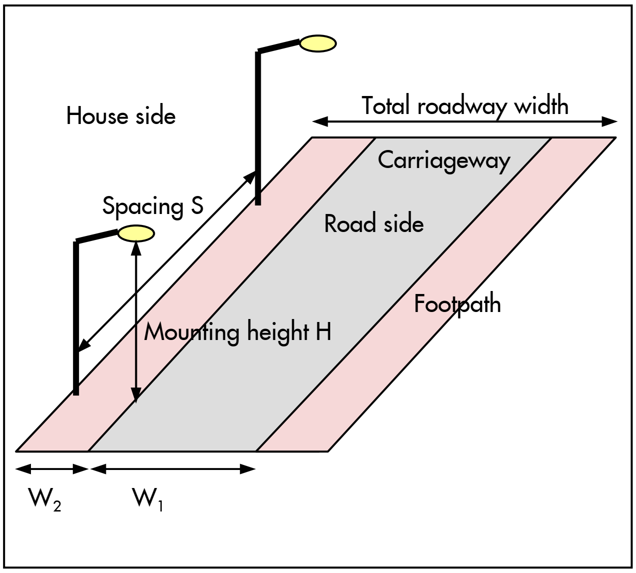


Fig 49 Road layout terminology.

Average Illuminance Calculation

The first step in calculating the average illuminance is to determine the utilisation factors to be applied. The sample table of utilisation factors in fig 50 shows that they vary according to the ratio W_1/H and W_2/H, where:

W_1 is the road side width between the lantern and the near side of the far footway or boundary line

W_2 is the house side width between the lantern and the near footway or boundary line

H is the mounting height

When the ratios W_1/H and W_2/H have been calculated the corresponding utilisation factors can be read from the table.

The formula for calculating the maintained illuminance is:

$$E = \frac{1000\,(U_1 + U_2) \times F \times MF}{(W_1 + W_2) \times S}$$

where:

E is the average maintained illuminance (lux)

U_1 is the road side utilisation factor

U_2 is the house side utilisation factor

F is the initial lamp flux (klm)

MF is the maintenance factor (see section 11)

W_1 is the road side width (m)

W_2 is the house side width (m)

S is the lantern spacing (m)

Utilisation Factors

Cat. no. CA5000S + GTNB1150.4 [1/0]

W_1/H or W_2/H	Road side U1	House side U2
0.2	0.05	0.05
0.4	0.12	0.09
0.6	0.19	0.12
0.8	0.25	0.15
1.0	0.30	0.17
1.5	0.35	0.20
2.0	0.37	0.21
3.0	0.39	0.22
4.0	0.39	0.22

Fig 50 Example of utilisation factors.

The formula can be re-arranged to give the spacing required to produce a particular average maintained illuminance:

$$S = \frac{1000\,(U_1 + U_2) \times F \times MF}{(W_1 + W_2) \times E}$$

These formulae apply to what is known as **single sided** and **double sided** arrangements of lanterns, that is a single row of lanterns or two rows where the lanterns are located alternatively on one side of the road and then the other. (Fig 51) If a **double sided** arrangement is to be used i.e. lanterns are mounted opposite each other or either side of the road, then the sum of the utilisation factors ($U_1 + U_2$) should be doubled. In the case of a **staggered** arrangement, the spacing is taken to be the distance between successive lanterns along the road rather than lanterns in a row.

Worked example

a) CA5000S [1/0] with 150W HPS-T(HO) lamp lanterns are to be installed along one side of a service road. The straight road is 12m wide and columns at 10m are equally spaced at 38m centres along a 200m stretch. Assume that the optical centre aligns with the edge of the road and that a maintenance factor of 0.9 is taken. Calculate the average maintained illuminance.

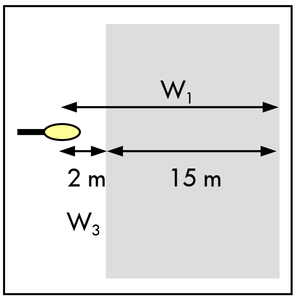
There is no house side utilisation factor to account for.
Initial lamp lumens = 17.5 klm
$W_1 = 12,\ W_2 = 0$

$W_1/H = \frac{12}{10} = 1.2\quad U_1 = 0.32,\quad U_2 = 0$ ……..see fig. 50

$$E = \frac{1000 \times U_1 \times F \times MF}{W_1 \times S} = \frac{1000 \times 0.32 \times 17.5 \times 0.9}{12 \times 38} = \mathbf{11\ lux}$$

b) CA5000S [1/0] with 150W HPS-T(HO) lamp lanterns are to be installed along one side of a service road. The straight road is 15m wide and columns at 10m are to be equally spaced along a 220m stretch. The optical centre is 2m away from the edge of the road and that a maintenance factor can be taken as 0.9. Calculate the lantern spacing to achieve an average maintained illuminance of 10 lux on the road.

The first 2 m band on the road side does not contribute illuminance on the road so the utilisation factor for this band needs subtracting from the U_1.



Initial lamp lumens = 17.5 klm
$W_1 = 17,\ W_2 = 0,\ W_3 = 2$

$W_1/H = \frac{17}{10} = 1.7,\quad W_3/H = \frac{2}{10} = 0.2$

$U_1 = 0.36,\quad U_3 = 0.05$ …… see fig.50

$$S = \frac{1000\,(U_1 - U_3) \times F \times MF}{(W_1 - W_3) \times E} = \frac{1000\,(0.36 - 0.05) \times 17.5 \times 0.9}{(17 - 2) \times 10} = \mathbf{32.6m}$$

The calculation technique of using utilisation factors can be applied to area car parks and amenity areas with reasonable accuracy provided there are three of four lanterns in line, as if along a road.

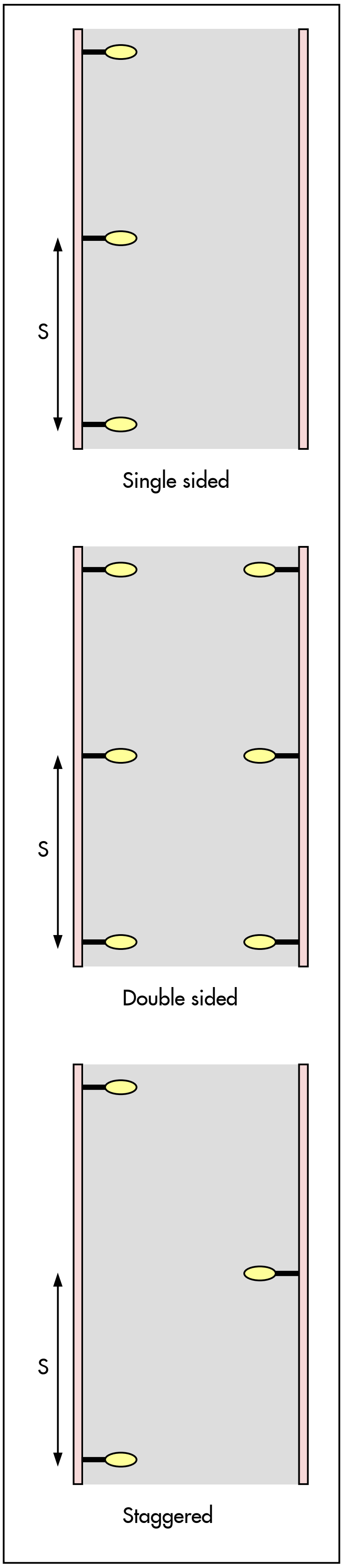


Fig 51 Road lantern arrangements.

Floodlighting data and calculations

There are several ways of presenting photometric data for floodlights. The simpler methods of presentation are dealt with here. For preliminary design work the **beam data** is particularly useful, fig 52 shows an example for an Areaflood 40.

Peak intensity (I) cd/klm	1110	
Beam factor to 10% peak (I)	0.74	
Beam angle to 10% peak (I)	Horizontal Vertical	2 × 50° 36°/66°
Beam angle to 50% peak (I)	Horizontal Vertical	2 × 39° 7°/13°
Beam angle to 1% peak (I)	Horizontal Vertical	2 × 67° 49°/89°

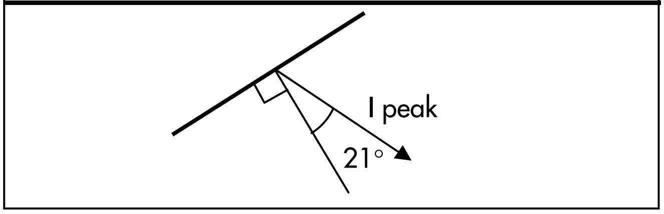


Fig 52 Beam data.

The **peak intensity** is in a direction 21° to the normal of the front glass of the floodlight expressed in cd/klm. To obtain the actual intensity in cd the value, in this case, 1110 needs multiplying by the bare lamp lumens divided by 1000.

The **beam factor to 10% peak** is the decimal of the lamp flux in the beam to where the intensity is 10% of the peak value. This can be thought of as how much of all light from the lamp goes into the beam. This can be referred to as BF for beam factor.

The **beam angle to percentage of peak** is measured in a horizontal and vertical plane with respect to the peak intensity. (Fig 53) The horizontal angle is doubled because the angle is either side of the central peak intensity. The first vertical angle is above the peak intensity and the second vertical angle is below the peak intensity.

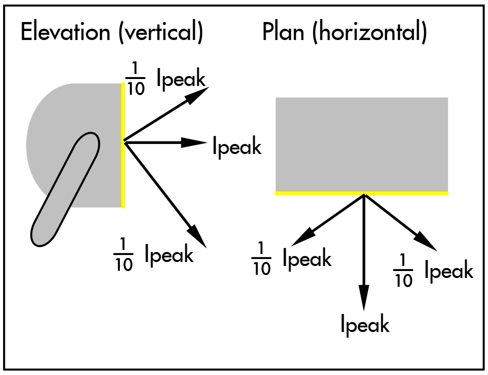


Fig 53 Beam angles.

The beam angle to 10% peak indicates the angular spread of the useful beam. The beam angle to 50% peak is useful for those occasions when beams from two of the same type of floodlights overlap with the intention of giving an even 'wash' of light. The beam angle to 1% peak is the boundary beyond which there is just spill light, that will make no useful contribution to the lighting scheme.

The **intensity curves** for a floodlight graphically shows the lighting performance. (Fig 54) The most of the data given in the **beam data** can be read from these curves. For the intensity in candelas multiply the intensity by the bare lamp lumens divided by 1000. The solid curve denotes the intensity in the horizontal plane. The dashed line denotes the intensity in the vertical plane, positive angles are above the peak intensity. All angles are measured with respect to the peak intensity, which may not be normal to the front glass of the floodlight, but should be defined.

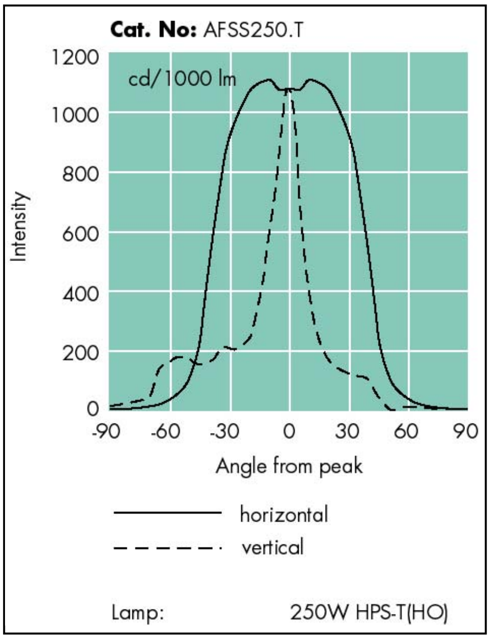


Fig 54 Intensity curves.

The lighting performance of a floodlight can be evaluated by looking at an **isolux diagrams** when it is available. The format is similar to that for amenity luminaires. For a specified mounting height, on a grid in metres contours of constant illuminance are shown in units of lux/1000 lm. To obtain an actual value of illuminance just multiply by the bare lamp lumens divided by 1000. The isolux diagram can be used to assess the illuminance created when the floodlight is mounted at other mounting heights, by using the same conversion factors given earlier for amenity luminaires:

Multiply contour values by:

$$\frac{(\text{Stated mounting height in m})^2}{(\text{New mounting height in m})^2}$$

Multiply grid distance by:

$$\frac{\text{New mounting height in m}}{\text{Stated mounting height in m}}$$

The boundary of the area to be lit will not necessarily coincide with the area covered by the floodlights, like in the case of a tall narrow building, or one with a complicated profile, a considerable amount of light may be wasted. (Fig 56) This situation can be accounted for by what is called the **Waste Light Factor**, **WLF** although it would be more appropriately called the **What's Left Factor**. More light may be wasted on a tower or chimney than on a rectangular building or advertising hoarding. The Waste Light Factor is the decimal of light that gets onto the object being lit, not the decimal of what light is wasted. Under favourable conditions a waste light factor of 0.9 might be assumed, but in difficult situations it may be reduced to 0.5 or lower. This factor when multiplied by the **Beam Factor, BF** gives the **Utilisation Factor, UF** :

$$UF = WLF \times BF$$

The lumen method of design can then be applied, as with interior lighting design:

$$E = \frac{N \times F \times UF \times MF}{A}$$

where:
E is the average maintained illuminance
N is the number of luminaires
F is initial bare lamp lumens per luminaire
UF is the Utilisation Factor
MF is the Maintenance Factor
A is the area to be lit

Even more simply at the first stage of design calculations it is common practise to use an estimated utilisation factor of 0.3. This figure is low for asymmetric and some symmetric projectors giving precise light control and too high for wide angles projectors that will project light beyond the boundaries of the area being considered.

If a rectangular area is to be lit the **Thorn Floodlighting Calculator** is a better choice for preliminary designs than using a UF of 0.3.

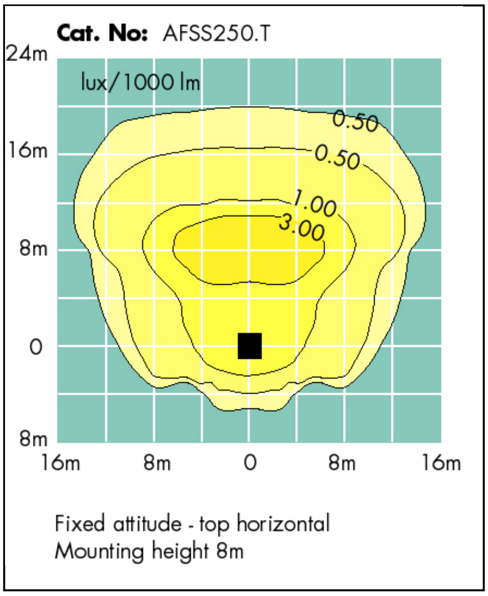


Fig 55 Floodlight isolux diagram.

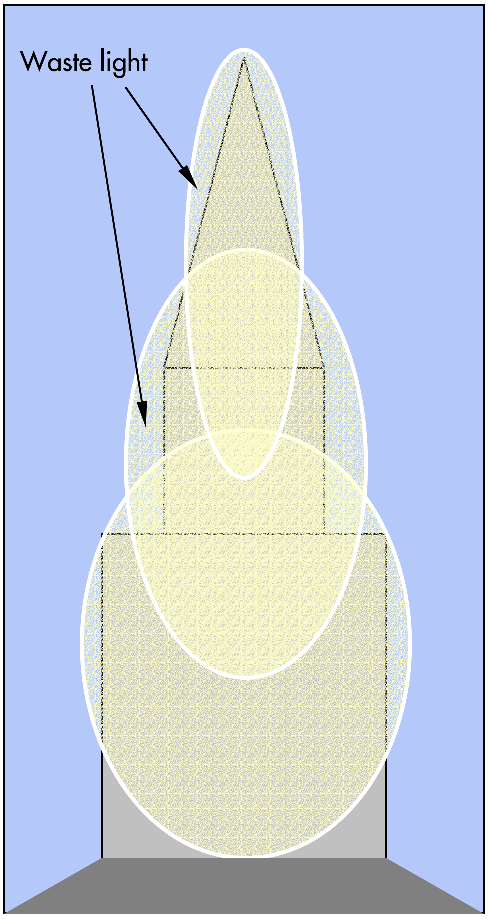


Fig 56 Waste light floodlighting facade.

A form of data presentation for floodlights and projectors that is gaining popularity is one that gives a series of template as circles or rectangles at a range of distances from the luminaire. The edge of the template is the boundary of the half peak intensity and a value of horizontal average illuminance is given inside the template. (Fig 57) These templates can be used in preliminary designs where the edges of templates are butted up to each other to give coverage of an area to be lit. In this way the adjoining half peaks add together to give an illuminance similar to that in the direction of the peak, if the same type of floodlight is being used side by side. It has to be recognised though that the templates represent an area that is at right angles to the direction of the peak luminous intensity and that the peak is directed to the centre of the template.

CONTRAST R Size 1 + Refractor No 1
Lamp 150W HPS-T

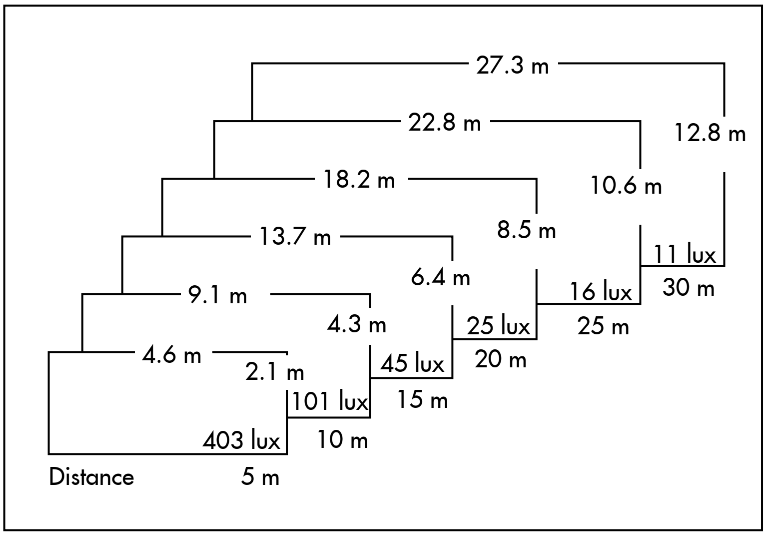


Fig 57 Illuminance templates.

It is not complicated to generate these templates for yourself from **beam data**. Fig 58 shows the geometry of a rectangular template. Using trigonometry to find W and H:

$$W = 2D \tan A$$
$$H = 2D \tan B$$

where A° is half the total horizontal plane angle to the half peak intensity and B° is the vertical plane angle above the peak intensity to the half peak intensity. (If the angles above the peak and below the peak are different, then the two angles could be averaged to give a value for B°.)

The series of distance between the luminaire and surface are typically for D in metres:

3, 6, 9, 12, 18
5, 10, 15, 20, 25, 30
10, 20, 30, 40, 50, 60

The average illuminance in the horizontal intensity plane can be expressed as $E = \frac{E_1 + E_2}{2}$

$$E_1 = \frac{I_{pk}}{D^2} \quad \text{and} \quad E_2 = \frac{I_{pk} \cos^3 A}{2D^2}$$

$$\text{So } E = \frac{I_{pk}}{2D^2}\left(1 + \frac{\cos^3 A}{2}\right)$$

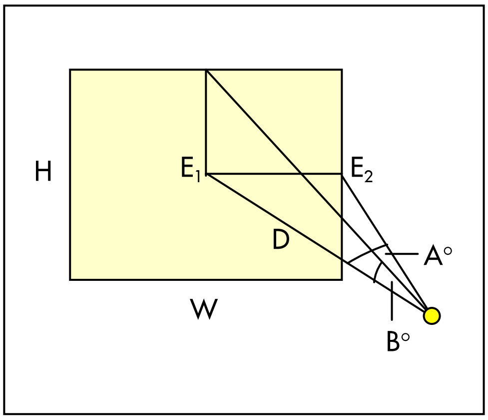


Fig 58 Geometry of template

In practise the peak intensity may well not be at right angles to the surface being lit. (Fig 59) The templates can still be used when the surface is tilted with respect to the peak intensity. However the area lit and the average illuminance need adjusting.

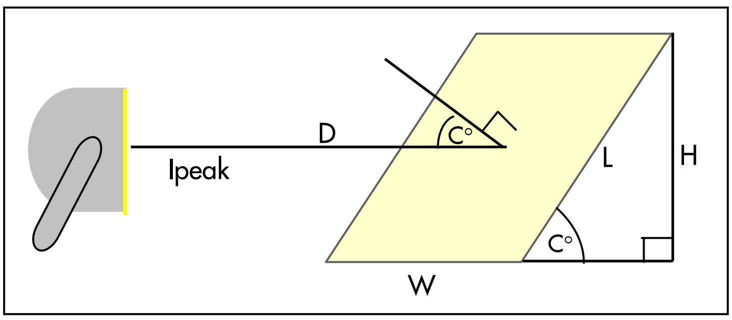


Fig 59 Effect of tilted surface

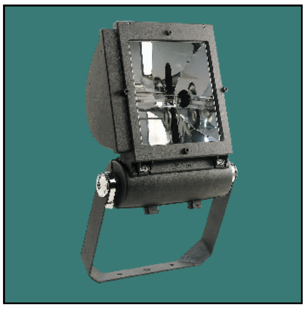
From geometry at the distance D the height lit increases from H to L and since $\frac{H}{L} = \cos C°$, L =

$\frac{H}{\cos C^\circ}$, so divide the template height by cos C° and multiply the template illuminance by cos C° compensates for a tilted surface.

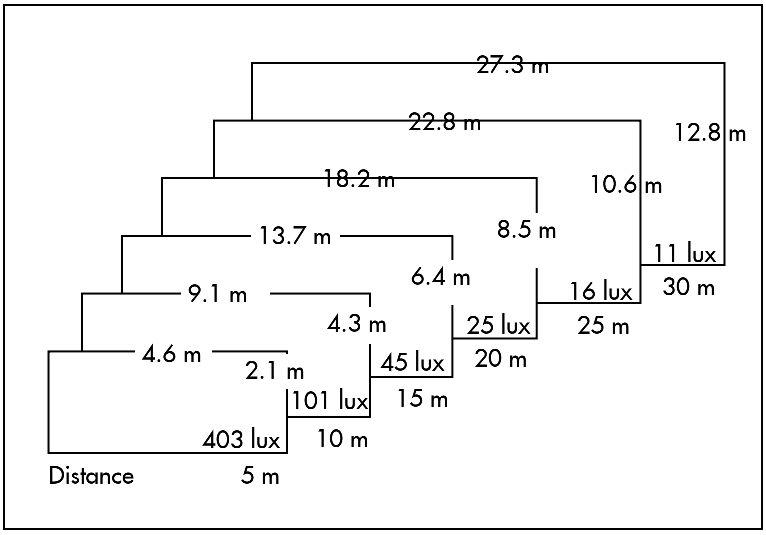
Initial lumens 15000 lm

CONTRAST R Size 1 + Refractor No 1
Lamp 150W HPS-T

I max cd/1000 lm	916
I max/2	
Horizontal	2 × 12°
Vertical	24°
Vertical	25°



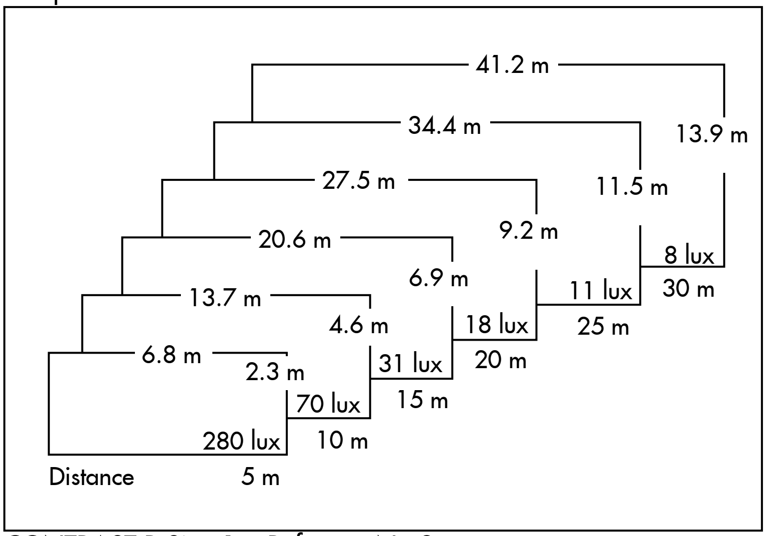
CONTRAST R Size 1 + Refractor No 1
Lamp 150W HPS-T



CONTRAST R Size 1 + Refractor No 2
Lamp 150W HPS-T

I max cd/1000 lm	639
I max/2	
Horizontal	2 × 13°
Vertical	34°
Vertical	35°

CONTRAST R Size 1 + Refractor No 2
Lamp 150W HPS-T

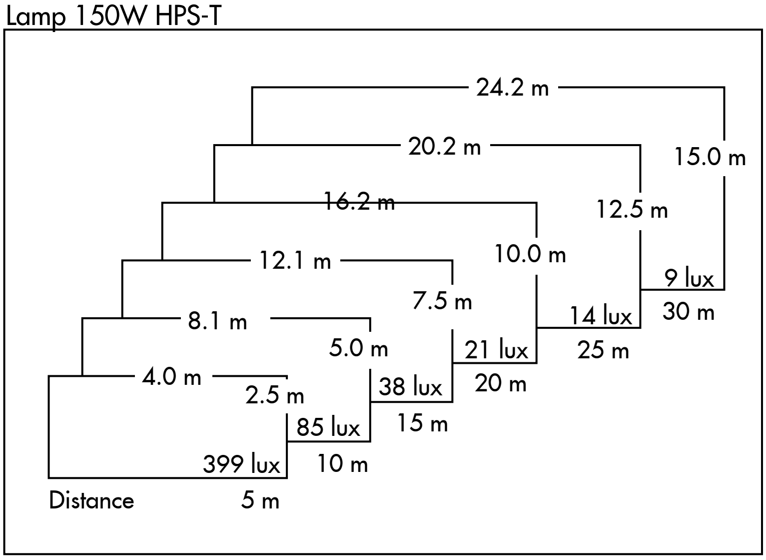


CONTRAST R Size 1 + Refractor No 3
Lamp 150W HPS-T

I max cd/1000 lm	775
I max/2	
Horizontal	2 × 14°
Vertical	22°
Vertical	22°

Note: Templates are rotated through 90° for convenience.

CONTRAST R Size 1 + Refractor No 3
Lamp 150W HPS-T



Worked example
Generate a set of templates for the beam data that has already been shown for the AFSS250.T.

Beam data

Peak intensity (I) cd/klm	1110	
Beam factor to 10% peak (I)	0.74	
Beam angle to 10% peak (I)	Horizontal Vertical	2 × 50° 36°/66°
Beam angle to 50% peak (I)	Horizontal Vertical	2 × 39° 7°/13°
Beam angle to 1% peak (I)	Horizontal Vertical	2 × 67° 49°/89°

Lamp 250W HPS-T (HO) initial lumen output 33000 lm

To find the best series of distances to use a few test calculations can be made evaluating E_1 where I_{pk} is 1110 × 33 = 36630 cd. This shows the distances 5, 10,15, 20, 25, 30 m to be the most practical.

From the beam data: $A° = 39°$ and $B° = \frac{7 + 13}{2} = 10°$

These equations can be used to find corresponding values of W and H.

$W = 2D \tan A$

$H = 2D \tan B$

D (m)	5	10	15	20	25	30
W (m)	8.1	16.2	24.3	32.4	40.5	48.6
H (m)	1.8	3.5	5.3	7.1	8.8	10.6

Next using $E = \frac{I_{pk}}{2D^2}\left(1 + \frac{\cos^3 A}{2}\right)$ to find E and adding it to the table.

$$E = \frac{18315}{D^2} \times 1.235 = \frac{22619}{D^2}$$

D (m)	5	10	15	20	25	30
W (m)	8.1	16.2	24.3	32.4	40.5	48.6
H (m)	1.8	3.5	5.3	7.1	8.8	10.6
E (lux)	905	226	101	57	36	25

This data can now be shown as a set of templates (Fig 60).

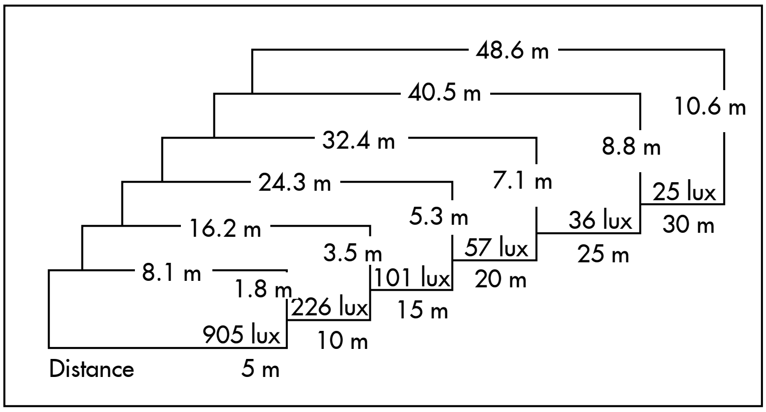


Fig 60 Templates for AFSS250.T.

Fibre Optics

The lighting calculations for fibre optics are placed in this module although they are used for both interior and exterior applications. Thorn Lighting produced a CD on Fibre Optics, the first theory and applications CD from Thorn catalogue number DCPTHLFOA. This could be viewed as an introduction to the topic.

Fig 61 Side emitting fibres.

A fibre optic system consists of a light generator or projector and a harness with fibre optic tails, whether these tails are end or side emitting tails. The exterior projector Cat. No.TFGL2 uses a 150W HIT lamp and the GL6 projector uses a 100W xenon metal halide lamp with an extremely short arc dimension all in a pre-focused housing including reflector and front glass. The GL6 projector is most suited to side emitting light harness and very long end light fibres.

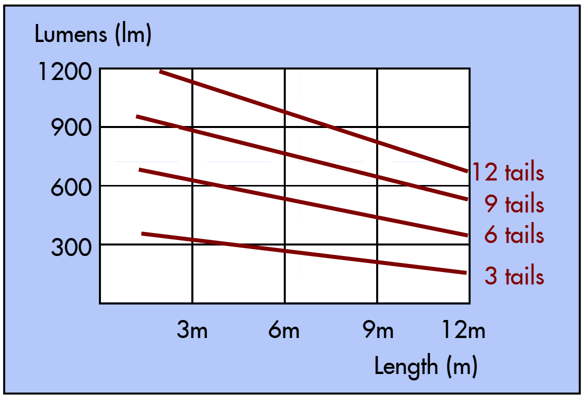


Fig 62 TFGL2 + 150W HIT + 4.5mm harness.

The lighting calculation is simple, although there is a slight difference in the method for end light harness for the two projectors. The method for the TFGL2 projector is given below:

1) The graph is selected that corresponds to the projector/harness combination.
2) From the graph the length of the harness chosen is looked up on the graph to where it crosses the sloping line for the number of tails used on the harness to read off the total number of lumens emitted by the harness.
3) The lumen output per tail is the total lumens divided by the number of tails. This value can be used as a multiplying factor for the published **intensity curves** and **cone diagrams**.

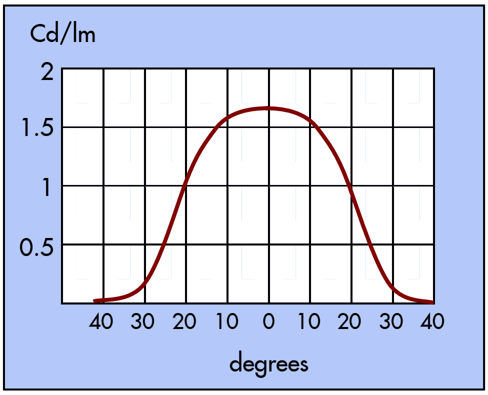


Fig 63 Intensity curve TFGL2 + 150W HIT

Worked example

Find the illuminance at 1.5m from the end of a tail where the surface is at right angles to the axis of the tail end. The equipment used is the TFGL2 Projector and Harness 6 × 6m – 4.5 mm tails.

The graph of fig 62 is used. The total lumen output for 6 tails of 6 m length = 500 lm. The lumen output per tail =

$$\frac{\text{Lumen output per harness}}{\text{No. of tails}} = \frac{500}{6} = 83 \text{ lumens per tail.}$$

The intensity curve for a tail with no attachment, just the ferrule is given in fig 63. This expresses the luminous intensity in terms of cd/lm. (As though the tail output was one lumen.) On the axis the peak value is 1.7 cd/lm. Applying the inverse square law: $E = \frac{I}{d^2} = \frac{83 \times 1.7}{1.5^2} = 63$ lux

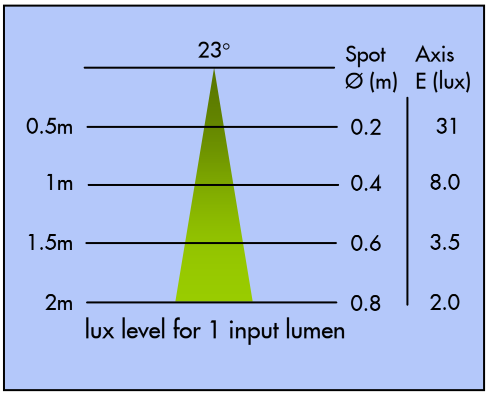


Fig 64 Example of cone diagram

Where a terminal is connected to the end of a tail the lighting performance can be evaluated by using the corresponding cone diagram that is expressed in terms of 'lux for 1 lumen input' and then multiplying by the 'lumens per tail' figure. (Fig 64)

The light output of fibre optic systems is generally low and for the lit effect to be successful the ambient lighting level needs to be low. In many applications the distance between the object and the terminal or end of the tail is relatively short.

Computer programs

Illuminance values and other parameters can be calculated easily with a computer with a suitable program, such as **Optilume Flood** or **Optilume Street and Amenity**. **Optilume Flood** is suitable for lighting horizontal areas and vertical surfaces, like building facades. **Optilume Street and Amenity** enables the lighting design of amenity areas and street lighting design both on the basis of illuminance and luminance. These programs and others are powerful tools but the results need to be well understood and interrupted. At the planning stage it is often better to obtain illuminance plots for individual luminaires or groups of luminaires than attempt to simulate the complete installation. Tabulated illuminance values (luxplots) provide lots of detail, but can be difficult to interpret. Graphical presentations such as shading diagrams are much easier to understand. Too much importance should not be placed on variations of illuminance. It should be keep in mind what degree of uniformity is acceptable or even desirable.

The **Lightscape** software program can give mathematically accurate visual representations achieved with 'rendering techniques' of lit object. The generation of such images is generally very time consuming and hence costly but can be beneficial for the right project. Outdoor project may not need the calculation of an inter-reflected component so faster calculation times can be expected. Images of this type always look computer generated partly because they look too clean.

A more frequently used approach is to use a photographic image of an installation and scan it. This stored scanned image is then changed with a Photo Editor software program, such as **Adobe Paintbrush**. To make changes to the image that gives a good representation of expected light patterns from luminaires is a skilled task requiring considerable lighting engineering experience. In this process in effect a flat 2D image of a 3D scene is being changed discreetly by colour, brightness and contrast over the entire image or small areas of chosen shapes.

With all computer visual simulations it is important to convey to the client that they are an 'impression' of the appearance, not a guarantee, 'this is how it will look'. Judgements based upon the images are often very different from those based upon the real exterior. Such images may well 'sell' a scheme, something that numbers are alone unlikely to do.

11 Maintenance and economics

Maintenance
Cleaning and lamp replacement routines should be followed to maintain an installation. Maintenance programmes should include lamp replacement, luminaire cleaning and fault clearance.

The procedure related to which lamps are replaced is a matter of policy, cost and lamp type used. The cost of replacing lamps on demand (spot lamp replacement) should be compared with that of group replacement. In making the comparison the following factors are amongst some that should be considered:

- the lamp survival
- the lamp lumen depreciation
- ease of access e.g. extent of signing and coning required
- interference with traffic
- the frequency of luminaire cleaning.

Maintained Illuminance
Adoption of a predetermined maintenance routine can enable the prediction of a design illuminance that will be met or exceeded during the life of the installation, known as maintained illuminance. This requires the assessment of an overall maintenance factor that can be used in conjunction with initial lamp lumens for lighting design calculations. The maintenance factor is made up of components associated with the luminaire and lamp. The table, below that is from BS5489 part 2 and 3, gives the maintenance factor for the luminaire, luminaire maintenance factor. The factors for the lamp are the **lamp lumen maintenance factor** and the **lamp survival factor**. These may be obtained from manufacturer's data. The final maintenance factor is the product of these factors.

$$MF = LMF \times LLMF \times LSF$$

where:
MF is the total maintenance factor
LMF is the luminaire maintenance factor
LLMF is the lamp lumen maintenance factor
LSF is the lamp survival factor

	Degree of protection of lamp housing								
	IP2* minimum			IP5* minimum			IP6* minimum		
Cleaning interval	Pollution Category			Pollution Category			Pollution Category		
Months	High	Medium	Low	High	Medium	Low	High	Medium	Low
12	0.53	0.62	0.82	0.89	0.90	0.92	0.91	0.92	0.93
18	0.48	0.58	0.80	0.87	0.88	0.91	0.90	0.91	0.92
24	0.45	0.56	0.79	0.84	0.86	0.90	0.88	0.89	0.91
36	0.42	0.53	0.78	0.76	0.82	0.88	0.83	0.87	0.90

High pollution occurs in the centre of large urban areas and in heavy industrial areas.
Medium pollution occurs in semi-urban, residential and light industrial areas.
Low pollution occurs in rural areas.

In the arena of commercial consideration maintenance factors can be arbitrarily picked to be an unrealistically high figure or even one. By doing this the lighting performance may rapidly go below the specification after installation, which may not please the client!

Economics
Although not easily assessed in monetary terms, the benefits to the community of outdoor urban lighting are very great. Lighting schemes should be designed to utilise light as efficiently as possible and so avoid waste and light pollution.


Fig 65 Consider operating costs.

The total cost of a lighting installation is the sum of the **capital cost** and the **operating costs**. Some or all, of the following costs apply to most installations and there are occasionally additional charges.

Capital costs may include:
- design fees
- electrical installation
- initial lamps, luminaires, control gear, accessories
- columns or towers, fixings
- meter housing, equipment protection, time or other switches
- electrical connection
- commissioning fee

Operating costs may include:
- electrical energy
- replacement lamps
- routine maintenance, inspection, repair, repainting
- supervisory, clerical, transport, plant and overhead charges
- rental, insurance
- removal, storage and re-erection of equipment (temporary and seasonal installations)

Many different types of electricity tariff are available from many different energy suppliers and could make significant differences to the operating costs. At the outset of large projects tariff advice could be sought. There are often unpublished tariffs that can be made available and customers can even negotiate their individual contract.

It is convenient when comparing the economics of alternative lighting systems to assess all costs on an annual basis. Capital costs may be expressed as yearly costs by amortising the capital cost over the expected life of the installation. This is done by dividing the total capital cost by the expected life of the installation in years. Most operating costs are incurred annually. Where components are replaced only once every two or three years, the appropriate proportion of their replacement costs can be allocated to the charges for the year. A simple comparison between the annual cost of different systems is obtained by adding the yearly amortisation charge to the operating cost. More refined costing methods may be justified for large projects.

There are considerable differences in the periods of time during which different types of exterior installations are in use. Some typical hours of use are given below:

Annual use of outdoor lighting installations

Type of installation	Number of days per annum	Average hours of use per day	Total hours of use per annum
Security lighting	365	11	4000
Decorative floodlighting			
All year, all night	365	11	4000
All year, part night	365	6	2200
Summer only, part night	200	6	1200

In comparing alternative lamp/luminaire combinations for floodlighting it is initially quicker to evaluate for each proposal the total annual cost per 1000 beam lumens rather than repeating complete designs to satisfy illuminance and uniformity requirements. Some experience is needed to know that the selected lamp/luminaire combination is capable of achieving the illuminance and uniformity required before a complete design is undertaken.

For the smaller project simple methods can be used to give economy:

- Selection fittings with low power compact fluorescent lamp rather than tungsten halogen lamps.
- Selecting discharge lamps giving high overall efficacy.
- Controlling the hours of use by timers or photocells.
- Making sure light in not wasted spilling outside the area to be lit.
- Do not over light.

Following all this guidance should result in a well maintained and economical lighting scheme.

Questions 3

1. Under what circumstance in calculating average illuminance with utilisation factors for a road will the spacing between columns be halved?
2. For the beam data in fig 47 what is the beam factor and what are the corresponding horizontal and vertical angles with respect to the peak intensity?
3. For the data shown in fig 52 if the peak intensity is directed 60° to the surface about 25m away what is the width and height of the area covered. Also what is the average illuminance?
4. Find the illuminance at 1.2m from the end of a tail where the surface is at right angles to the axis of the tail end. The equipment used is the TFGL2 Projector and Harness 3m long with 9 tails – 4.5 mm.
5. What is the luminaire maintenance factor for a luminaire with an IP 65 rating that is in a semi-urban area and it is expected to be cleaned every two years?
6. How are capital costs amortised over the expected life of an installation?

12 Terminology

Amenity lighting is light for the enjoyment and/or use of an area or location. It may include street or precinct lighting as well as floodlighting.
Building lighting is the general exterior illumination of a building or structure.
Feature lighting involves singling out a discrete area for lighting.
Coherence between elements in a scene can be achieved by a carefully thought out design theme. Once a theme is established it will guide the development from the overall lit effect to the selection of appropriate equipment with regard to scale, material and colour.
Floodlighting is literally the flooding of an area with light with no intention of showing or revealing the area in any particular way. The term is generally used to describe any form of large scale lighting.
Functional lighting is intended to enable a task to be performed and is not designed to serve any decorative purpose.
Glare gives visual discomfort or disability due to the relative high brightness of the light source or area. This dependent on the size of the source, its position and background brightness as seen by the observer.
Highlighting differs from spotlighting in that it usually involves a larger area lit to a high level than adjacent areas to give emphasis.
Light Pollution is light that serves no useful purpose spilling into the night sky creating what is known as sky glow. This may be due to spill light, where the light source covers a greater angle than the object to be lit.
Modelling is the application of light in such a way as to make apparent any three dimensional form. It usually involves lighting at some angle oblique to the viewing position so that both highlights and shadows are formed.
Promotional lighting is for advertising purposes, either overtly in the form of advertising messages and signs or more subtly by making the viewer aware of the existence of what is being promoted.
Sparkle is small discreet point of high brightness that attracts but does not create glare.
Spotlighting is the application of a small area of bright light to single out a specific aspect of the scene.
Texture of a surface is revealed by lighting at a shallow oblique angle to the surface.
Uniformity ratio is the minimum illuminance to the average illuminance. In some instances, the ratio of the minimum to the maximum illuminance is quoted. The ratio usually applies to values on the work plane over the working area.

References
BS 5489: Road Lighting
CIBSE LG6: Outdoor Lighting
Lighting the Environment – A guide to good urban lighting (CIBSE/ILE)
Guidance Notes for the Reduction of Light Pollution (ILE 1994)
A Guide for Crime and Disorder Reduction through a Public Lighting Strategy (ILE 1999)
Lighting and Crime (ILE 1999)

13 Answers to Questions

Questions 1

1. The broad purpose of amenity lighting is to provide a pleasant lit area that contributes to people's enjoyment and feeling of safety.
2. Before lighting a listed building these parameters may need considering:
   - External appearance of building
   - Visual impact of luminaires
   - Wiring methods and appearance
   - Methods of fixing
3. Good lighting is likely to reduce crime and the fear of crime in streets and around housing.
4. Below 70°.
5. 60 cd/m^2.
6. a) Light those parts that are matt from ground level
   b) Light from top of building down
   c) Light with luminaires placed at suitable positions at different levels directed downwards or sideways.
7. Strong shadows and harsh modelling.

Questions 2

1. 50:1
2. Light from one side with medium beam floodlights with in-fill lighting from the other side with medium beam floodlights.
3. Careful consideration that the lit effect is not grotesque and that glare would not be caused to onlookers.
4. Light pollution can be reduced by fitting an internal louvre.
5. Features to considering when selecting a bollard:
   - Style
   - Colour
   - Lighting performance
   - Height
   - IP Rating
   - Vandal resistance
6. Aluminium columns:
   - Do not corrode and do not need painting
   - Are lightweight and easy to handle
   - Easily crumple so risk of injury in a collision is reduced.
7. Light is transmitted along optical fibres by means of internal reflection.

Questions 3

1. When lantern arrangement is staggered.
2. Beam factor = 0.74, Horizontal angles 2 × 50°, Vertical angles 36° above, 66° below.
3. Width = 22.8m, Height = 21.2m, Average illuminance = 8 lux
4. 118 lux.
5. Luminaire maintenance factor = 0.89.
6. Divide the total capital costs by the expected life of an installation.

14 Summary

Design Aspects

Design reasons for lighting:

Safety	Security
Promotion	Ambience
Amenity	Identity
Orientation	Spectacle

Heritage issues

There can be many constraints on the lighting of buildings in heritage or conservation areas affecting:
Luminaire appearance
Visual impact of luminaires on the building/area
Wiring and conduit
Fixing methods
Illumination levels

Lighting and crime

Good lighting in streets and areas around housing tends to reduce crime and the fear of crime according to studies.

When lighting areas with CCTV provide the necessary:
Illuminance – CCTV camera to perform well under range of actual illuminances
Uniformity – high and no rapid changes with distance
Modelling – adequate vertical illuminance at face level with moderate contrast
Colour – wide spectrum light sources (avoid monochromatic SOX lamps)

Avoiding Light Pollution

Poorly designed and installed outdoor lighting may lead to needless pollution of the environment. Waste or spill light is a waste of energy and money. Waste energy contributes to global warming and other ecological problems.

Implement the '**Guidance Notes for the Reduction of Light Pollution**' issued by the Institution of Lighting Engineers.

Quantity of lighting

Illuminance falls on a surface, luminance is emitted from a surface.
For a matt surface:

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

where:
E is illuminance (lux) L is luminance (cd/m^2) R is reflectance (as a decimal)

Luminance Levels for Architectural and Promotional Lighting

Environmental Zone	Average Luminance (cd/m^2)	Maximum Luminance (cd/m^2)
E1 (e.g. Countryside)	0	0
E2 (e.g. Urban fringe)	5	10
E3 (e.g. Town)	5 – 10	60
E4 (e.g. City)	10 - 25	150

The ratio between the average and the maximum will determine the degree of contrast in the subject. This is the luminance contrast ratio.

The Effect of Luminance Contrast Ratio

1:1	Not Noticeable
1:3	Just Noticeable
1:5	Low Drama
1:10	High Drama

Setting the scene

In preliminary design work consider:
Principal viewing position
Creating an effect
Colour
Modelling
Shadows
District Brightness

Amenity lighting

Amenity lighting should be made attractive and pleasant.

A fairly high diversity of illuminance is usually acceptable but it is important that the equipment and its placing should relate to the human form and not dominate.

Illuminance is generally specified as horizontal or vertical maintained illuminance. A significant step in illuminance is a doubling and so often these values occur: 5, 10, 20, 50, 100, 200, 500, 1000, 2000 lux.

Lighting for pedestrian areas must form a balance between good seeing conditions over the entire area and a light pattern that provides an attractive and welcoming environment.

Tasks

Refer to CIBSE, ILE and other guides for specific task specifications. The Outdoor Environment CIBSE Lighting Guide (LG6) is often the best starting point for the type of lighting being covered.

Luminaires and Equipment

Luminaires and equipment suitable for outdoor and amenity lighting include:
Recessed outdoor luminaires
Bulkheads and bollards
Decorative lanterns
Road lighting
Floodlighting
Columns
Fibre optics

Design considerations

The flow chart in fig 46 on page 26 gives the major steps and considerations.

Lighting calculations

Illuminance at a point using isolux diagram:

$$\text{Maintained illuminance (lux)} = \text{contour value} \times \frac{\text{initial bare lamp flux (lm)}}{1000} \times \text{MF}$$

Conversion factors to the contour values of the isolux diagram and road distances can be applied to calculate the illuminance for alternative mounting heights of the lantern.

Multiply contour values by:

$$\frac{(\text{Stated mounting height in m})^2}{(\text{New mounting height in m})^2}$$

Multiply road distance by:

$$\frac{\text{New mounting height in m}}{\text{Stated mounting height in m}}$$

Then use the formula given above for maintained illuminance at a point.

Average illuminance using utilisation factors

Utilisation factor determined by W_1/H and W_2/H, where:

W_1 is the road side width between the lantern and the near side of the far footway or boundary line

W_2 is the house side width between the lantern and the near footway or boundary line

H is the mounting height

The formula for calculating the maintained illuminance is:

$$E = \frac{1000\,(U_1 + U_2) \times F \times MF}{(W_1 + W_2) \times S}$$

where:

E is the average maintained illuminance (lux)

U_1 is the road side utilisation factor

U_2 is the house side utilisation factor

F is the initial lamp flux (klm)

MF is the maintenance factor

W_1 is the road side width (m)

W_2 is the house side width (m)

S is the lantern spacing (m)

Floodlighting data and calculations

It is presented by:

Peak intensity

Beam factor to 10% peak

Beam angle to 10%, 50%, and 1% peak

Intensity curves

Isolux diagrams

UF = WLF × BF

where:

WLF is waste light factor

BF is beam factor

The lumen method of design can then be applied, as with interior lighting design:

$$E = \frac{N \times F \times UF \times MF}{A}$$

where:
E is the average maintained illuminance
N is the number of luminaires
F is initial bare lamp lumens per luminaire
UF is the Utilisation Factor
MF is the Maintenance Factor
A is the area to be lit

For preliminary designs use Thorn Floodlighting Calculator or Illuminance templates.

Fibre optics
Graphs show total lumen output from harness so this value is divided by the number of tails before multiplying by data from an intensity curve or cone diagram.

Computer programs
Currently Thorn Lighting programs for outdoor lighting for numerical calculations:
Optilume Street and Amenity
Optilume Flood

Visualisations by:
Lightscape
Adobe Paintbrush

Maintenance and economics

Cleaning and lamp replacement routines should be followed to maintain an installation. Maintenance programmes should include lamp replacement, luminaire cleaning and fault clearance.

In making comparisons of maintenance programmes the following factors are amongst some that should be considered:

- the lamp survival
- the lamp lumen depreciation
- ease of access e.g. extent of signing and coning required
- interference with traffic
- the frequency of luminaire cleaning.

Maintenance factor is the product of these factors.

$$MF = LMF \times LLMF \times LSF$$

where:
MF is the total maintenance factor
LMF is the luminaire maintenance factor
LLMF is the lamp lumen maintenance factor
LSF is the lamp survival factor

The total cost of a lighting installation is the sum of the **capital cost** and the **operating costs**. Some or all, of the following costs apply to most installations and there are occasionally additional charges.

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