BEGA

Application Guide

Introduction

Light is a subtle influence in all areas of our lives. It is the natural agent that stimulates sight and creates a visual space filled with color and texture. Our immune system requires sunlight to function properly, and our body's circadian rhythm is dependent on our exposure to light. Proper lighting can improve our concentration and stamina. It can also help us to regroup and relax. At night, good lighting can make even the darkest areas feel more safe.

But how do we identify "good" lighting?

You could say that good lighting creates a positive emotional response. When you enter a space, you do not have to shield your eyes from the glare, nor are you straining to see. It appears effortless – and yet, much thought and careful calculation goes into creating something that seems so simple. But once you have discovered good lighting in one setting, how do you replicate this effortless effect in another location? There is no single answer – perhaps not even a dozen answers to resolve this question. It becomes more than a question, but rather a conversation. With that in mind, this book is our discussion of how to make good lighting great.

This book is divided into four main parts. The first section includes a brief discussion of basic lighting design concepts, an overview of types of luminaires and their defining characteristics, and an in-depth discussion of fundamental lighting design philosophy including: psychological and subjective effects of varying illumination, proportional versus unproportional uniformity, luminance, illuminance, and brightness.

The next section takes these concepts and applies them to real life scenarios. A wide selection of common spaces are discussed, each with a comprehensive narrative that addresses both analytic and aesthetic lighting objectives.

The third section is an overview of the science and technology related to lighting. We discuss fundamental lighting terminology, the qualitative and quantitative aspects of light, breakthroughs in technology regarding the biological effect of light on personal health, an overview of different types of lamps, and conclude with a step-by-step method for calculating illuminance levels in practice with appropriate formulae.

The final section is a collection of tables with numerical recommended light levels for each of the applications discussed, as well as a comprehensive glossary.

As a luminaire manufacturer, we would like to share our enthusiasm for light with you. This book has been designed and written to provide current and correct information and recommendations for a wide audience of specifiers, with a desire to give you an insight into our exciting world of lighting, and spark you to have the discussion about good light.

Enjoy!

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Chapter 1

Design & Applications

Types of light

Before we start a lighting design, we must first distinguish between three basic types of light.

Unshielded light

Unshielded light is characterized by a light source that is uncontrolled; a light source can spread unhindered in all directions, creating seamless coverage over a broad area. A common obstacle with unshielded sources is glare. Glare is caused by direct view of an unshielded light source, which creates discomfort. To minimize glare, this type of luminaire is often characterized with highly refractive or diffuse coverings made with materials such as opal glass. The stronger the light source, the larger the area of the luminaire glass should be to avoid glare. Unshielded light is an ideal source for ambient light in a space for general illumination. The arrangement of luminaires in the image (left) shows a common application of unshielded luminaires for general area lighting.

Directed light

Directed light is often used when one surface needs to be illuminated, even from a great distance. Through the use of internal reflectors, light from a source is re-directed out of the fixture towards the area that needs to be illuminated. Floodlights are an excellent example of directed light, as the designer can aim the light towards any surface that needs to be illuminated. Directed light is frequently used for task illumination. The row of luminaires in the image (above) shows the light being directed to the floor surface, where it is most needed.

Shielded light

Shielded light is when a source is hidden by an opaque material, so that there is no direct glare from a normal viewing angle. This style is typically found in wall luminaires that are being used in a hallway or entrance for accent lighting. Any direct line of site to the source is blocked, and the light is instead directed to the wall, enhancing the surface texture. The image (above) shows how the use of several shielded wall luminaires can provide pleasant lighting for the space.

Types of illumination

Every design objective can be solved using either one or a combination of these three types of illumination.

Ambient lighting

Task lighting

"Good lighting is a vital part of good living"
- Richard Kelly, (1910-1977)

There are three fundamental techniques used in lighting design today, originally pioneered by architectural lighting designer Richard Kelly in the late 20th century as ambient luminescence, focal glow, and play of brilliants. Throughout the development of the industry, this has been technically refined to: ambient lighting, task lighting, and accent lighting.

Ambient lighting is the most basic form of lighting for functionality, as it is simply used to provide an area with overall illumination to define an environment. The lighting is seen as soft and uniform, and does not create hard shadows or contrasts. In an indoor space, ambient lighting is created using one or two sources to light an entire room, so that the occupant has a clear awareness of the boundaries of the space. Outdoors, this type of lighting can be found in parking lots and streets, where uniformity is one of the most important design considerations.

Sometimes ambient lighting alone does not provide an adequate amount of light to perform tasks such as reading or writing. When this is the case, task lighting is added to the space. This is when light is focused on certain areas where increased attention is required by the occupant. Indoors, this is commonly needed on working surfaces such as tables or countertops. Outdoors, extra light will be added to areas such as stairs, street intersections, and pedestrian crossings for safety reasons. When safety is a consideration, most cities will have formal code requirements for light levels in these areas. With task lighting, there is still significant consideration for uniformity throughout the space.

Contrast is used when the designer wants to bring attention to a certain area or object. The light on an object is perceived as significantly brighter than the general illumination around it through accent lighting. This technique is used in various applications like artwork, sculptures, textured walls, and signs. This method only works when lighting accents are used sparingly in a space.

Accent lighting

The three types of lighting should be used collectively and with equal attention. When well balanced and in proportion, the use of all three techniques will yield appropriate results and good lighting.

But what is really perceived to be good light?

Humans have a biological response to their environments. In a well-lit space, they feel happy and safe. The extent of an area is easily identified. Where the light level changes, there is no complete darkness, light overspill, or excessive brightness (glare). This is particularly important because prolonged exposure to extreme levels of contrast can cause excessive eye adaptation leading to strain and fatigue. When well designed, a space will have a harmonious balance between light and dark allowing for the occupants to successfully distinguish detail and orientation. Particularly with architectural lighting, details are more easily perceived when these lighting principles are applied correctly.

When beginning the lighting design process, indoor and outdoor spaces can be structured using lighting zones. These are determined by identifying applicable tasks and/or the desired emotional response from the viewer. Depending on the importance of these elements, a different degree of illumination will be used for each zone. The important point here is to establish a visual connection between more strongly illuminated zones and their surroundings, essentially guiding the eye where you want it to go. Once the design goals have been established, the next step is to select luminaires that can correctly fulfill those needs.

A luminaire is the way we can control a source of light. It is a complete lighting system with at least a source (LED module, lamp) and a housing; and sometimes reflectors, optics, and, if required, a power source (such as a driver or ballast). With the advancement in lighting manufactures today, exactly calculated light emission and output classes can aid the design process. The development of precise reflectors and optics within a fixture now shape the light and intensity as it exits, creating different outputs for use with different tasks. Some more advanced luminaires will include a way to control the intensity (dimming) or the color of the light.

Assuming that, in an area to be illuminated, there are enough light sources to cover the sum of ambient lighting, task lighting, and accent lighting, and with this sort of control, the perceived mood of the environment can be altered simply by changing the intensity of illuminance of one of the elements of the sum.

This adds yet another point for contemplation- each person perceives light differently and therefore will react to the lighting in a space differently. These subjective feelings will play a role in when determining the interplay between the three types of lighting. Because of this, mock-ups and site tests should be done even if the design is technically sound.

Types of luminaires

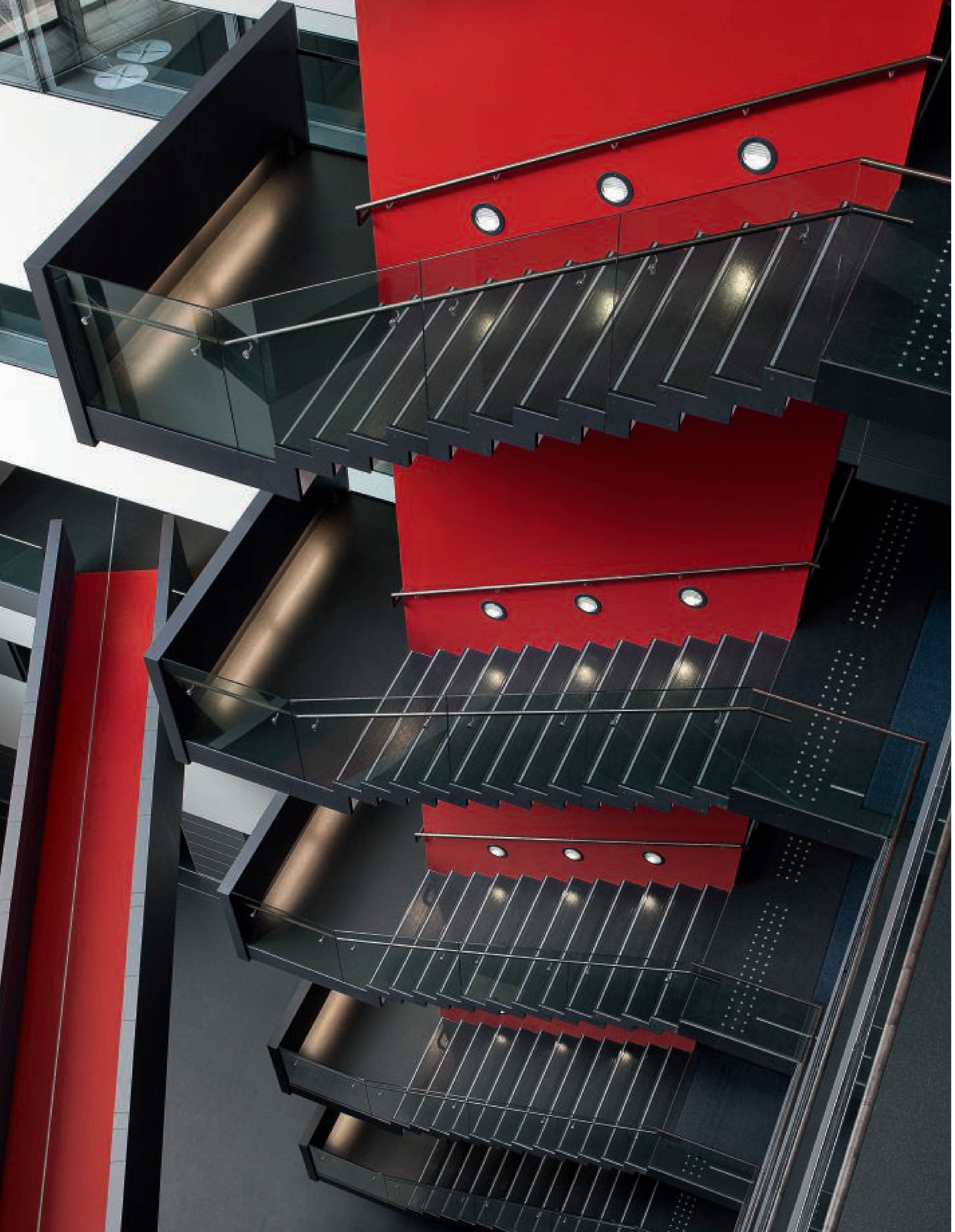
The following section will review the different types of luminaires and their functions. For all types of luminaires, numerous sizes and outputs are available. With this variety, practically all lighting objectives in both indoor and outdoor spaces can be solved.

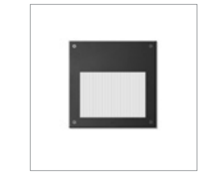
Recessed ceiling luminaires

Choosing whether to use recessed or surface ceiling fixtures can be challenging. When making your decision, it is important to understand the different design effects. Traditionally, ceiling luminaires are used for general space illumination. Their light can be diffuse or directed, with distributions varying from wide, area lighting to very narrow, focused, accent lighting in both indoor and outdoor spaces. In large spaces where a single fixture will not provide sufficient lighting, or there is a low ceiling, it is best to utilize recessed lighting to avoid clutter. These luminaires are either flush with the finished ceiling surface, or include a slightly below-surface glass and/or trim, giving them an exceptionally clean look. With the majority of the fixture residing within the space above the ceiling, these fixtures are usually selected before construction begins, to allow for proper integration into the ceiling system.

Ceiling luminaires

For smaller spaces where a few fixtures will provide adequate lighting, or where the ceilings are high, surface mounted fixtures can be used. Typically, the installation of surface ceiling fixtures does not require as much planning during the construction phase. Often times the photometric characteristics between recessed and surface mounted luminaires are the same. With the advancement of LED technology, maintenance intervals are reduced to a minimum.





Recessed wall luminaires

Just like recessed ceiling luminaires, recessed wall luminaires provide a clean, uncluttered design, but require extra planning before construction begins. For installation in brick or concrete walls, the installation of recessed housings must be planned as early as the design development phase. In addition to choosing a recessed or surface mounted fixture, the performance options can also vary greatly. These fixtures can range in scale from small to large, have diffuse glass or complex optics, and can be oriented upwards or downwards to light surfaces above or below. Recessed fixtures are commonly used in areas where ADA[1] or egress requirements apply. They are great design choices for high-traffic areas such as building entrances, stairways, and corridors.

1 ADA requires that objects projecting from walls between 27" and 80" above the finished floor shall protrude no more than 4" into walkways, halls, corridors, passageways or aisles.

Wall luminaires

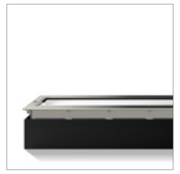
Wall luminaires are commonly found both indoors and outdoors because they are highly versatile. Their light can be unshielded, shielded or directed, and the fixture itself can be decorative as well as functional. They are designed to illuminate areas in front of buildings, pathways in and around buildings, entrance areas, corridors and staircases. Wall luminaires can provide structure and accentuate textures by grazing a surface with light. When arranged in rows or as a group, they can create visual rhythm within a space, and lead the eye to an entry or down a hallway. This type of luminaire is ideal for use as emergency lighting. The work involved in installing surface wall luminaires is significantly less than for recessed luminaires; typically it does not require as much planning during the construction phase.

Pendant luminaires

The most versatile family of ceiling-mounted luminaires, pendants can be used to create ambient lighting, provide task lighting, or decorative lighting. Arranging multiple pendants in groups or rows can provide structure and intimacy in a space with high ceilings. A pendant placed over a table or bar is a classic design decision. Often pendants feature unshielded light and can be used for the general illumination of large spaces. Seen here (right), the pendants featuring a downlight component as well as a secondary ambient light component are used to illuminate a large entry. The functionality of the fixture provides plenty of light for persons entering the building, while shape and beauty of the fixture itself adds an artistic element to the space.

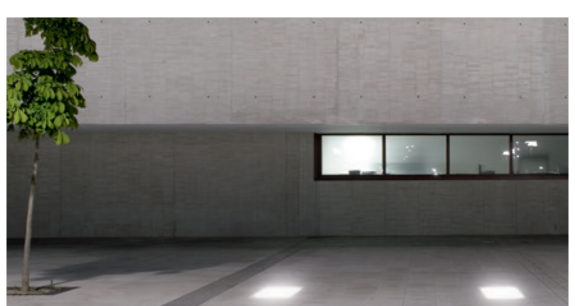
In-ground luminaires

This type of luminaire can be used for many different applications. The most attractive quality is their robust and low profile design, making them perfect for public or high-traffic areas. The luminaires are constructed of stainless steel and cast stainless steel. Some fixtures in the family are rated for pressure loads up to 11,000 lbs and can be used in drive-over applications. These in-ground fixtures are suitable for either new, poured concrete construction, or can be installed in pre-cored holes for use with materials such as stone or tile. The variety of light output ranges from small scale, diffuse, low-voltage indicator lighting, to large scale, field-adjustable floodlights. With modern LED technology, maintenance intervals are reduced to a minimum.


In-ground luminaires

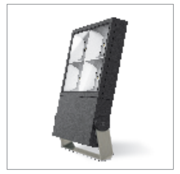
The qualities and applications for rectangular in-grade fixtures are comparable to those of the round fixtures. Depending on the design, fixtures can support loads up to 11,000 lbs. Linear fixtures in this family are ideal for walls or signs and can be arranged in groups or rows to create interesting lighting patterns. The rectangular design allows for the production of narrow, long fixtures, and also exceptionally large fixtures. The largest fixture in the family (pictured below) measures 39" x 39" and is rated for loads up to 2,200 lbs. These walk-over, large area lights are constructed with impressive ruggedness and a shallow mounting depth.



Light from an in-ground fixture can range from diffuse, low-voltage location lights; to high-powered adjustable in-ground floodlights for the illumination of trees, flags, columns, facades, and signage.

We recommend using a low-profile or in-ground fixture where a vertical surface needs to be illuminated.





Floodlights

Floodlights are the ideal fixture for lighting situations where the main focus is to accent or highlight. This luminaire type is available in a wide range of light outputs and beam options, including several in LED. The source sits within a die-cast aluminum housing, and the light is precisely shaped by a pure anodized aluminum reflector, ensuring crisp and accurate beam angles. The light can be adapted to individual needs through the addition of lenses, louvers, glare shields, and colored filters.
A versatile mounting system allows them to be installed on poles, facades, roofs, or on the ground. We recommend using floodlights for highlighting landscaping, facades, flag poles, trees, statues, signage, and more.

Bollards

These robust luminaires are often found along public pathways and in plazas. They can be used to add structure to a large space and for wayfinding. Bollards produce either diffuse, ambient light, or precise, directed pathway lighting. Some create unique light and shadow patterns on the ground that can be used as a design element. Bollards come in a variety of shapes, sizes and finishes to ensure a complementary form to the surrounding architecture.

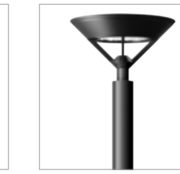
BEGA LED system bollards are an innovative modular bollard solution. Luminaire heads are specified with different bollard tube heights and auxiliary components to create a unified lighting solution to use throughout a project. Options include integral floodlights, GFCI outlets, infrared motion sensors and emergency battery packs.

Home & Garden Collection pathway luminaires

The Home & Garden collection is a family of residential-scale garden and pathway luminaires suitable for various private garden and pathway applications. Each fixture has an option for direct burial or hardscape installation methods. Fixtures are designed to be compatible with low-voltage garden transformers.

Light building elements

These luminaires are large-scale design elements that provide aesthetic form and functional lighting. The family offers many unique shapes that can be integrated into the architecture. Their function is similar to bollards, as they can provide structure and wayfinding with a variety of outputs including diffuse, directed, and ornamental. Many of the shapes are complementary between the light building elements and bollards, allowing for seamless design transitions throughout any project.

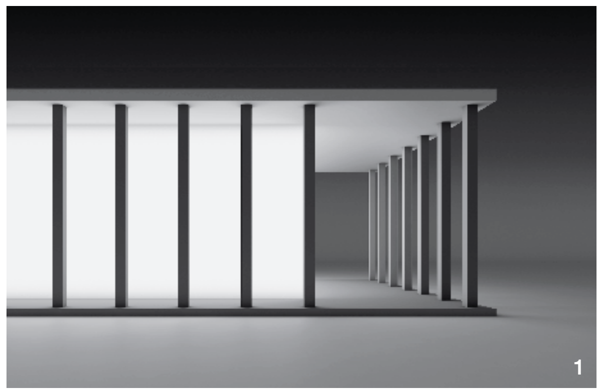


Pole-top luminaires

Pole-top luminaires are designed for use with poles that come in various heights and styles, which allows for a wide range of applications. They are particularly suitable for illuminating large public spaces, streets, and parking lots. There are a wide range of output options. They can be asymmetrical (Type II or Type III) or symmetrical (Type V), and often times they are adjustable. The fixtures can be direct, indirect or diffuse. When used at an appropriate mounting height, these fixtures provide exceptionally uniform lighting and can be installed with wide spacings. They can be used in combination with motion sensors to ensure cost-effective operation. Modern LED technology cuts maintenance to a minimum and ensures that the lighting system can operate for many years.

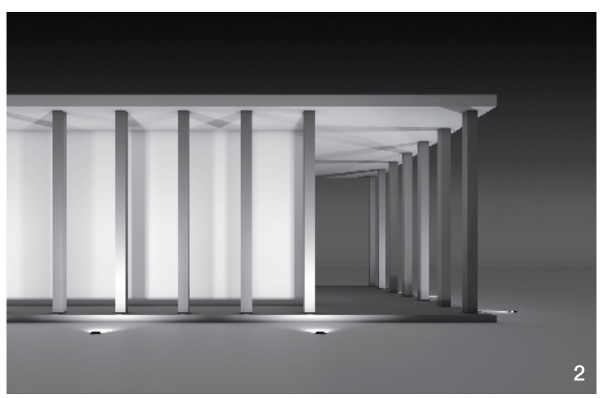
The effect of varying illumination

This section details how to use different combinations of the three types of illumination to achieve different visual effects. The building used is a basic single story structure with a flat roof and exterior pathway and veranda supported by pillars.



In the following example, the building has a glass, transparent façade.

Scenario 1: If the building has a glass shell, it can be illuminated from within. Shown here, the inner cube is illuminated. The surrounding pillars create a strong contrast between the unlit surfaces and the illuminated background. The result is a dramatic image.

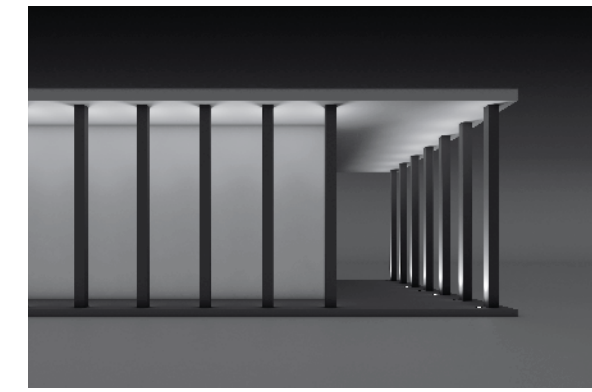


In the following examples, the building has a solid, opaque façade.

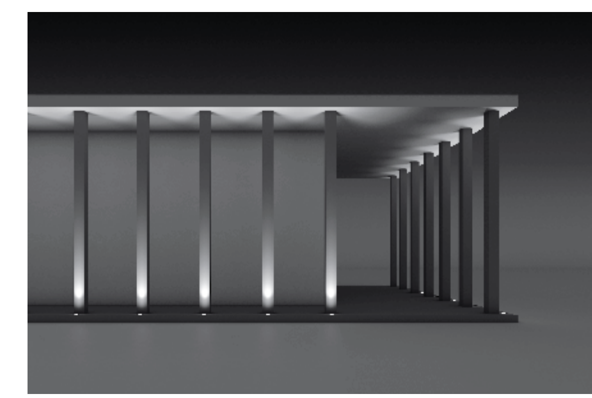
Scenario 2: Using in-ground luminaires, the entire building is uniformly washed with light from the outside. Since the pillars are positioned in front of the building, they cast shadows under the ceiling and onto the building behind. For some applications this could be perceived as too busy.

Scenario 3: The pathway is illuminated from above using recessed ceiling luminaires that are installed in line with the surrounding pillars. The light is directed straight to the walkway, and is very uniform. From a distance, the light appears more controlled than the previous example.

Scenario 4: In-ground floodlights are placed at the inside base of each pillar, accenting each of the their surfaces with light. These fixtures also illuminate the ceiling surface. From a distance, the veranda seems detached from the rest of the building.



Scenario 5: The position of the in-ground floodlights have now been reversed so the outside of the pillars are illuminated. This type of illumination is very suitable for highlighting interesting architecture.



Scenario 6: If the veranda is a public walkway, safety requirements must be taken into consideration. In addition to the lighting in scenario 5, recessed ceiling luminaires are installed to raise the light level on the floor to a safe level. This design shows a balanced combination of functional task lighting and creative accent lighting.

Modified mounting heights in pathway illumination

This section compares the visual effect of different heights of bollards with flat beam light distribution.

Typical pedestrian pathways require a minimum illuminance of 0.1fc for safety. The minimum light level is what dictates how far the fixtures will be spaced: the darkest place between fixtures should never be below the minimum illuminance level.

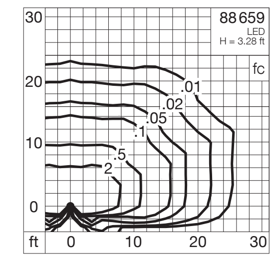
Due to the nature of light, fixtures with a high mounting height will have a lower illuminance level directly in front of the fixture and will be able to push more light out to the sides. This allows for a wider spacing between fixtures.

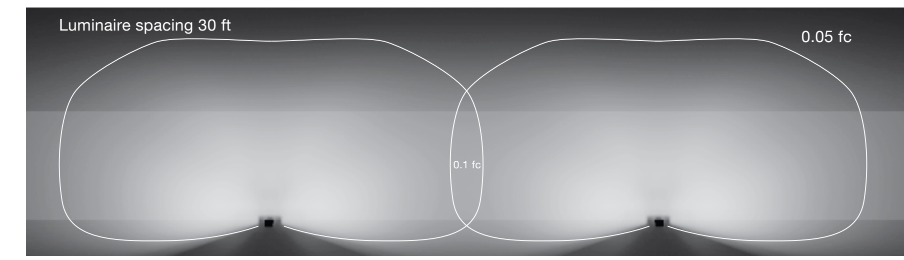
Fixtures with a lower mounting height produce the opposite: they will appear brighter directly in front of the fixture and will quickly darken out to the sides. This causes a need for more fixtures to be spaced closer together to meet the minimum light level.

Example 1
The large bollard has a mounting height of 3 ft. The light between fixtures blends together uniformly. The luminaire spacing is 30 ft.

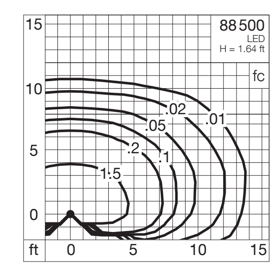
Example 2
The medium-sized bollard has a mounting height of 1.5 ft. The light level variance between fixtures is more noticeable. Here, the luminaire spacing is reduced to 15 ft to maintain the minimum illuminance level.

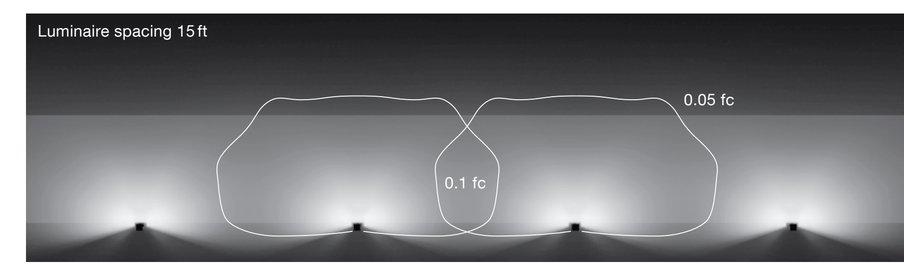
Example 3
The small bollards have a low mounting height of only 8 in. With the source so close to the ground, a distinct bright area is created in the direct vicinity of the luminaire. Luminaire spacing of 8 ft is needed to maintain minimum light levels.



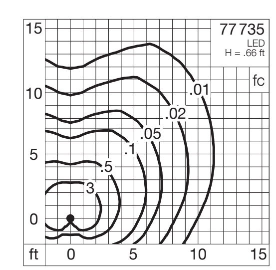


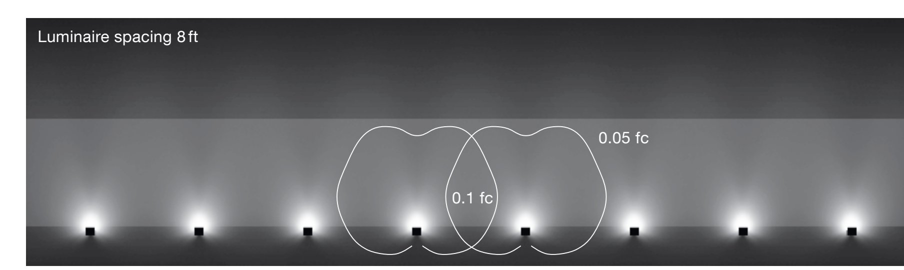
When viewed from above, the light distribution of the three bollard examples can be easily compared. The isoline shown on each graphic illustrates where the illuminance from the fixture reaches 0.05 fc on the ground surface. This value is important for determining the maximum luminaire spacing. A slight overlapping of these isolines is recommended because light is cumulative: in the overlapping area the light from each fixture is added together and results in 0.1 fc. This layout will then meet the minimum illuminance value required on the path.





In public spaces, uniform illumination is an important safety aspect. A typical public pathway will be larger than a residential or private pathway. A larger area will be more balanced and uniformly illuminated when the tall bollards are utilized. Smaller bollards are more commonly used in private environments.





Luminance in proportion

The previous section discussed the concept of illuminance. Next, we will discuss the importance of luminance. Luminance is considered the metric for the human perception of brightness, or how bright we perceive the light that is reflected off of a surface. When light is shined on a highly reflective surface, it will have a higher luminance value and will be perceived as brighter than that same light shined on a less reflective surface.

For the next three examples, luminance values in neighboring zones are compared with each other in specific applications. The ratio between two zones is how we define and measure contrast. For the purpose of this section, the lowest measured zone luminance value is defined as 1, and all other zones are measured by their ratio to that baseline.

Example 1:
Entrance plaza and historical building

Visitors arrive in a large plaza, which is accessible either by a footpath and park or by a small access road designed for drop off and pick up. The park is framed by unshielded bollards that provide ambient light and wayfinding on the footpath. The light also provides safety, as pedestrians in the area are easily recognized by drivers on the access road. The plaza in front of the building is lit with several light building elements which add structure to the otherwise large, unstructured space. Guests are welcomed to the building with a large staircase. Upon reaching the building, the entrance is composed of a large veranda where the columns are illuminated with in-ground floodlights. Surface wall washers are located halfway up the building to add emphasis and draw the eye to the upper building facade.

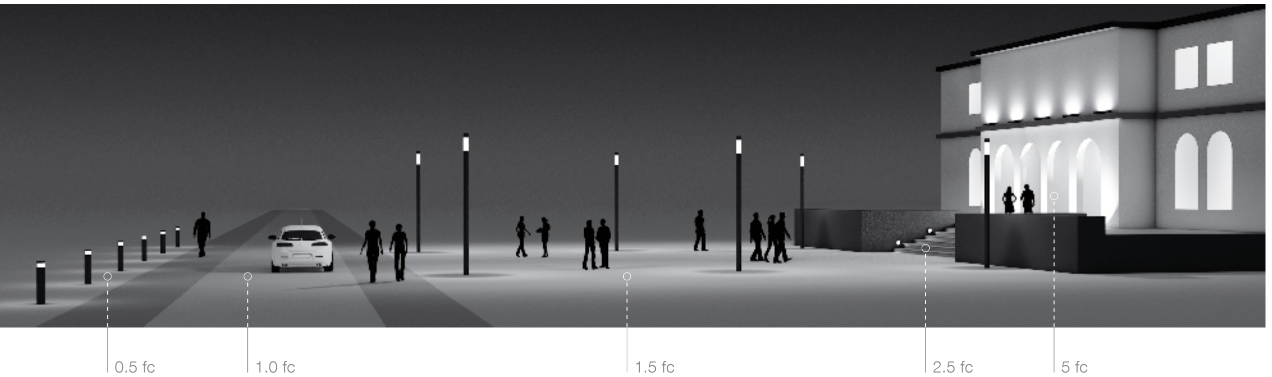
As visitors approach the building, the light level gradually increases. The lowest luminance level is measured in the park, where the only light comes from the adjacent bollards. This level is used as the base level for all other measurements in the space, and is quantified as 1.

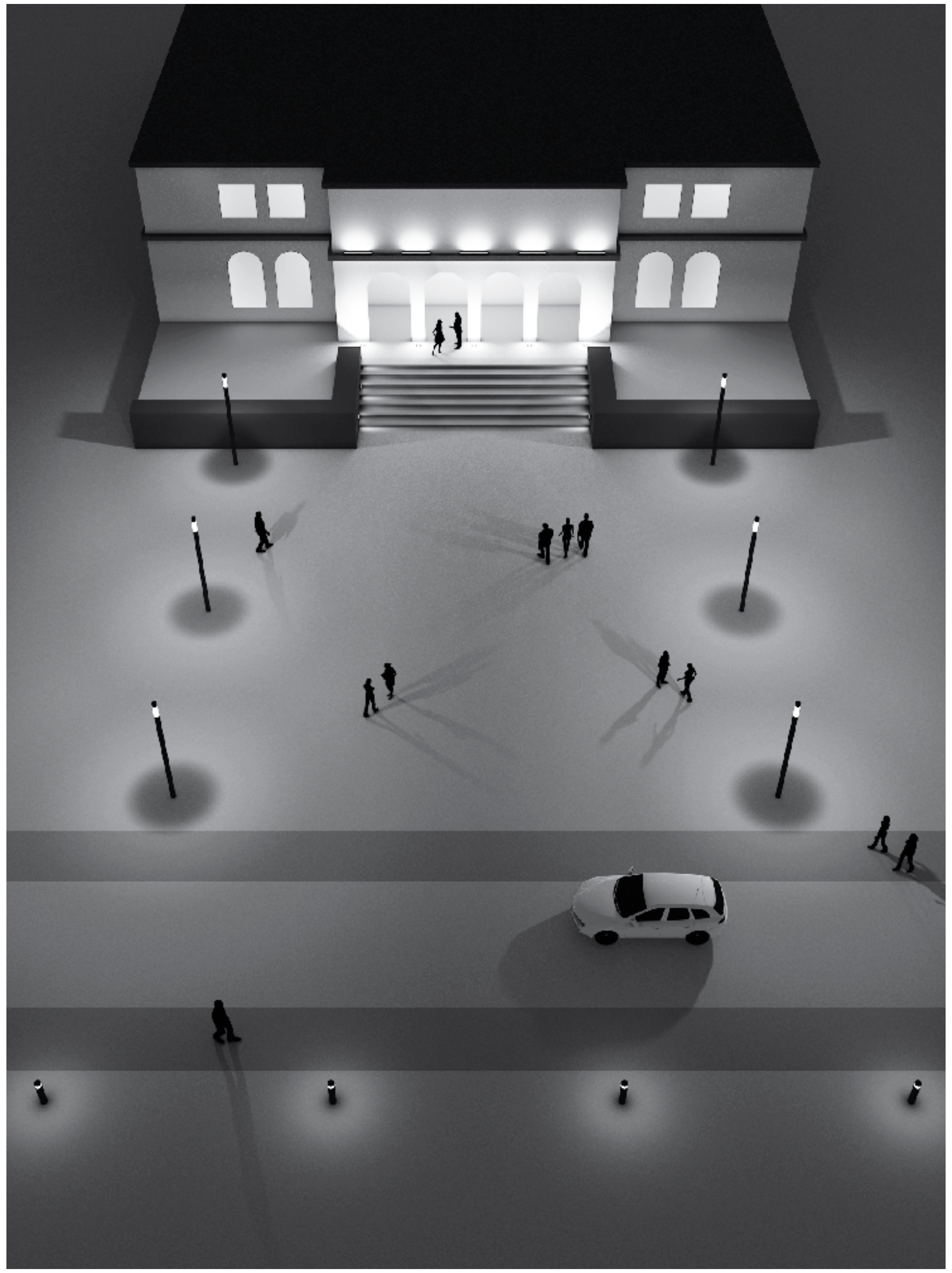
Moving onto the road, the light from the bollards is combined with some overspill light from the row of light building elements, creating a cumulative luminance level equivalent to twice the level in the park, quantified as 2. The luminance ratio between the park and road is therefore 1 : 2.

The center of the plaza is lit only by light building elements, and has a luminance level equivalent to three times the light level in the park, quantified as 3. From the park, the luminance ratio is now 1 : 2 : 3.

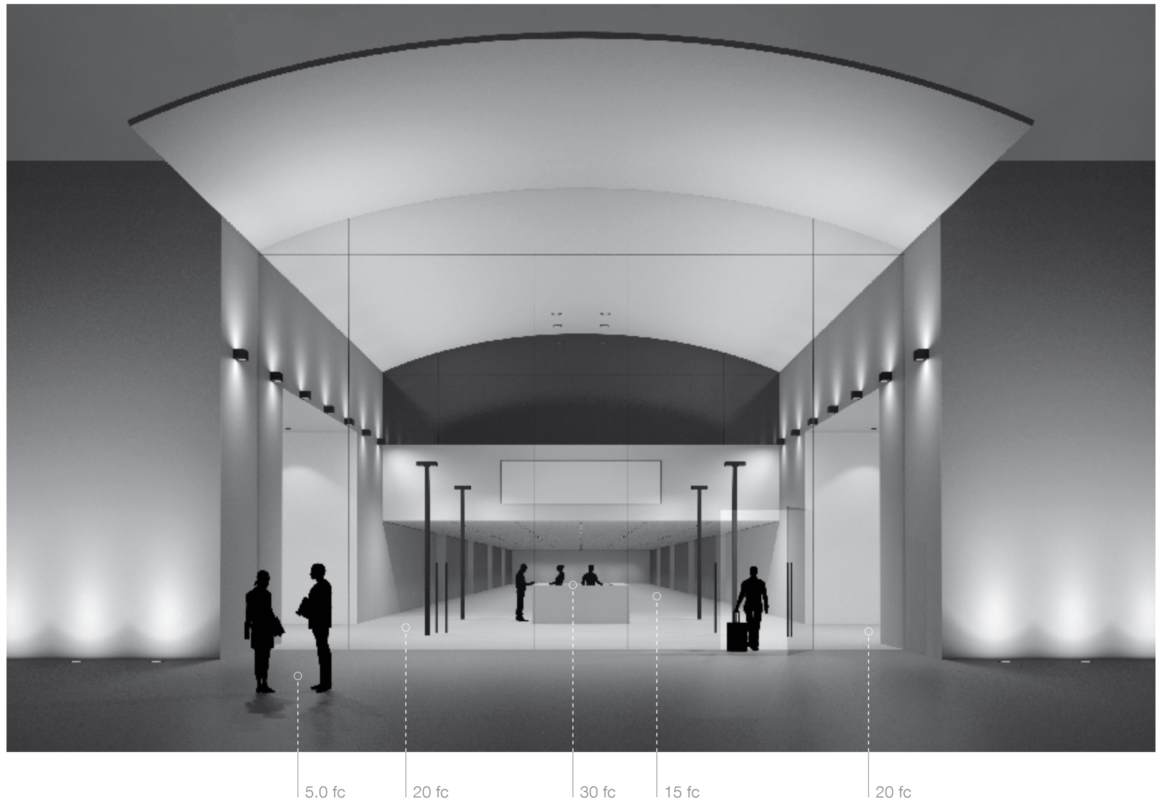
If we continue this logic, we find that the light level from the park to the building entrance can be described as the continuous ratio of 1 : 2 : 3 : 5 : 10. This indicates that the luminance on the stairs is five times, and the luminance in the building entrance is ten times, that of the pathway.

The visitors are guided to the building entrance by means of increasing illumination densities.





The bird's eye view illustrates the relationships of the luminance values. The lowest luminance value (0.5 fc) is defined as 1. Therefore, the relationships between zones from the park to the building entrance can be quantified as 1 : 2 : 3 : 5 : 10.

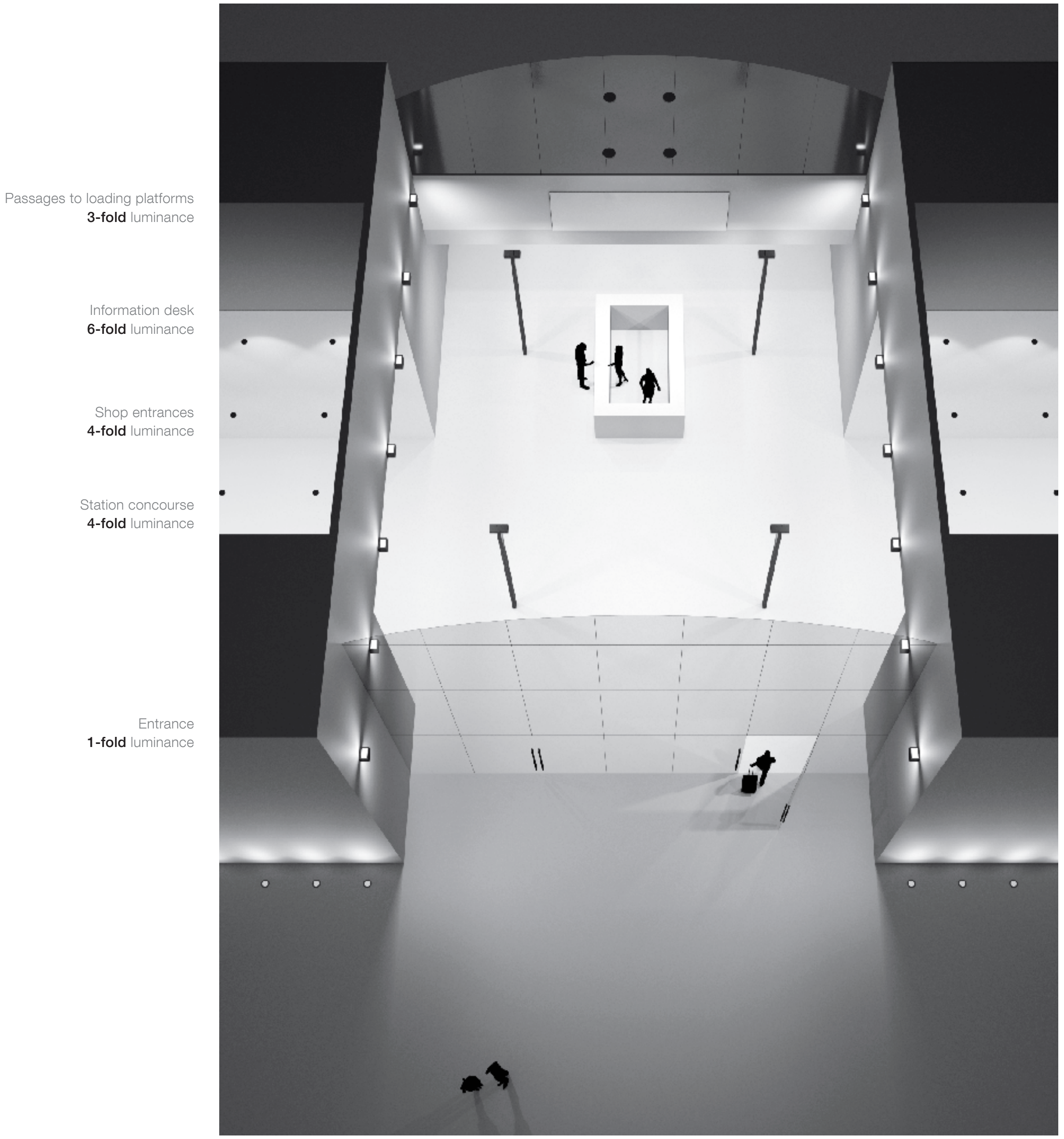


Example 2:
Train station

The train station is constructed as two massive structures connected by an arched roof. The front entrance to the main concourse is a floor to ceiling curtain wall that allows a clear line of site into the building all the way to the loading platforms in the back. On either side of the concourse are small shops. The information desk is in the center of the concourse. Behind the desk is the main hallway and stairs that lead to the train loading platforms. Looking at the whole picture, the lowest luminance level will be found outside the station, on the sidewalk in front of the entrance. This level will be quantified as 1. When you pass through the threshold into the main concourse, the luminance level is three times that of the level outside. The relationship between the outside sidewalk and the concourse is therefore 1 : 3. To draw occupants to the location of the information desk, a luminance six times that of the outdoor sidewalk (and twice that of the surrounding concourse) is utilized. The relationship from the outdoors to the information desk is 1 : 3 : 6.

The lighting in front of the shops is slightly stronger than that of the station concourse. Compared to the outdoor sidewalk, the luminance level is four-fold and therefore the relationship is quantified as 1 : 4. The relationship between the concourse and the adjoining shops is 3 : 4.

As the occupants move past the information desk towards the loading platforms, the luminance level decreases back to three times that of the outdoor sidewalk. From the entrance, through the concourse, past the information desk, and to the loading platforms can be quantified as 1 : 3 : 6 : 3.



This view illustrates the relationships of the luminance values. Here too, the lowest luminance value (5.0 fc) is defined as 1. The resulting relationships are 1 : 3 : 4 : 6 : 3.

Example 3:
Boutique shop in a pedestrian mall

The evaluation of this space begins outside, on the front sidewalk, and continues through the shop to the rear, where several displays hold shop merchandise. As in the previous examples the lowest luminance level, found on the outside sidewalk, is quantified as 1. Stepping into the shop, the ambient light level is four times that of the outside sidewalk, creating a relationship of 1 : 4. The cashier station inside the shop has ten times the luminance of the sidewalk, so that monetary transactions and other sales tasks can be done with ease. The shelving that covers most of the walls in the shop are lit to a level twenty times that of the outdoor sidewalk. This level of contrast is easily noticed, and will draw the eye of the viewer on first glance. Studies have shown that this phenomenon encourages purchases by visual enhancement, and allows for a more enjoyable shopping experience. This is seen again with two special displays towards the rear of the store. These displays are lit with forty times the luminance of the outdoor sidewalk. More importantly, this luminance level on the display is equivalent to ten times the level of the shop floor, which creates a strong visual contrast and luminance ratio of 1 : 10 between the two adjoining zones.

Summary

The three examples show different levels of luminance relationships. From the darkest area to the lightest area, some of the ratios are gradual while some are extreme. Regardless, the lighting in all three examples is still felt to be pleasant. Why?

At the historical building (example 1), the entrance to the building is the brightest point. The luminance gradually increases from the adjacent park and access road as the visitors walk towards and enter the building. The extents of the space and structures can be recognized at a glance. Visitors can easily find their way around and feel a sense of safety. The contrast between neighboring luminance zones never goes above 1 : 2. This means that the transitions are quite uniform and hardly noticeable to the human eye.

At the train station (example 2) the luminance zones also have soft transitions. The contrast of neighboring luminance zones never exceeds 1 : 3. Often times, travelers will be in a hurry and need to find their way quickly and efficiently. Highly contrasting light conditions could be hindering to travelers and interfere with their experience in the space. Certain important areas are emphasized with slightly higher luminance values such as the information desk and shop entrances, but they are not overly bright which could cause excessive eye adaptation, leading to fatigue.
In the boutique shop (example 3), high contrast is used to draw attention to certain parts of the store. When desired, a luminance ratio up to 1 : 10 can be used to highlight or bring attention to a specific area. The shop contains two high contrast ratios- 1 : 5 is found between the floor and the surrounding shelving, and 1 : 10 is found between the floor and sales displays towards the back of the store. Despite the vast difference in light intensity, the overall lighting design is found to be pleasant. The human field of vision can identify these changes in brightness, but it is not hindering to the shopper. When the eye is exposed to these contrasts, the retina effectively normalizes the intensity of luminance which prevents the eye from becoming over-worked too quickly.

The degree of contrast created by luminance ratios can be used to spark different psychological responses from the occupant. If a space is uniformly lit, the transition to a more strongly or less strongly illuminated area should be gradual. This is the only way to give the human eye a chance to adjust to the change in lighting conditions without becoming fatigued. Jumps between greatly differing luminance levels creates perceived glare and will accelerate eye fatigue. Good lighting makes a significant contribution to our well-being. Studies have shown that when used appropriately, good lighting can often lead to business success. Ultimately it is up to the lighting designer to assess a space and determine an appropriate lighting strategy.

Sales display
40-fold luminance

Shelves
20-fold luminance

Cashier station
10-fold luminance

Floor
4-fold luminance

In the shop window, the luminance is subject to daylight-dependent control.

Pedestrian zone
1-fold luminance

In the shop, the relationships between the luminance levels vary greatly. Here too, the lowest luminance value (5 fc) is defined as 1. The resulting relationships are 1 : 4 : 10 : 20 : 40.

Illuminance, luminance, and reflectance

The degree of illuminance E [fc] and the degree of reflectance of the surface ρ are included in the calculation of luminance L [cd/ft²] in accordance with the following formula:

$L = E \cdot \rho / \pi$

The luminance value and the effect of the illuminated surface are influenced significantly by the degree of reflection. A surface's reflective characteristics are defined by its physical properties such as color and texture. The rougher and darker the material, the less reflective it will be. The accumulation of dirt will diminish the reflective properties of a surface and must also be taken into consideration. The degree of illuminance must be adjusted accordingly in order to achieve the desired luminance or perceived brightness of the surface.

The subjective effect of the building is more impressive the more it stands out from the background. The illumination of a tower in the middle of an illuminated city requires a higher degree of illuminance in order to stand out than a building against a dark background; for example a castle standing alone in the landscape.

The table shows the change in level of illuminance required for the desired effect, depending on the surroundings of objects and the surface material.

Illuminated surfaces	**Reflectance**	Building standing alone dark surroundings	Building in a village dark surroundings	Building in a small town medium surroundings	Building in a large city light surroundings
Colored surfaces		Recommended illuminance			
White	90%	0.75 fc	1.5 fc	2.25 fc	3.0 fc
Pastel	60%	1.5 fc	3.0 fc	4.5 fc	6.0 fc
Grey	40%	3.0 fc	6.0 fc	9.0 fc	12 fc
Dark color	10%	9.0 fc	18 fc	27 fc	36 fc
Stone		Recommended illuminance			
Light stone, marble	60%	1.5 fc	3.0 fc	4.5 fc	6.0 fc
Sandstone	30%	4.0 fc	8.0 fc	12 fc	16 fc
Dark granite	10%	9.0 fc	18 fc	27 fc	36 fc
Brick		Recommended illuminance			
Light yellow brick	60%	2.0 fc	4.0 fc	6.0 fc	8.0 fc
Light brown brick	40%	4.0 fc	8.0 fc	12 fc	16 fc
Dark red brick	10%	10 fc	20 fc	32 fc	42 fc
Wood		Recommended illuminance			
Light birch	60%	2.0 fc	4.0 fc	6.0 fc	8.0 fc
Dark oak	20%	8.0 fc	16 fc	24 fc	32 fc
Concrete		Recommended illuminance			
Light grey	60%	3.0 fc	6.0 fc	9.0 fc	12 fc
Dark grey	40%	6.0 fc	12 fc	18 fc	24 fc
Metal		Recommended illuminance			
Natural aluminum	60%	3.0 fc	6.0 fc	8.0 fc	12 fc
Galvanized steel	40%	6.0 fc	12 fc	18 fc	24 fc
Rust-red iron	20%	10 fc	20 fc	30 fc	40 fc

Influence of reflective surfaces

Despite standardized illumination, the perceived light level in a space may be felt to be too low, depending on the reflective nature of the floor, wall and ceiling surfaces.

Public hall · 8,600 ft^2		
Recommended illuminance	20 fc	
	Light room	Dark room
Floor reflection	20%	10%
Wall reflection	50%	30%
Ceiling reflection	70%	50%
Luminance	**1.2 cd/ft^2**	**0.6 cd/ft^2**
Our recommendation	✓	**+ 10 fc**

There are many helpful standards for lighting in public areas. However, these standards do not take into account the influence of spatial conditions.

The following examples discuss some situations where the recommended light level might not be the right light level for the space. The recommended illuminance level for examples 1 and 2 are indicated in footcandles [fc]. The standards for example 3 are indicated in luminance, which is measured as candela per square foot [cd/ft^2].

Example 1:
Public Hall

The recommended illuminance level for a public hall is 20 fc.

This recommendation is based upon a room with clearly defined reflective properties for the ceiling, walls, and floor, usually 70-50-20. Although these surfaces change with every application, the recommended illumination level remains the same at 20 fc. If this public hall is outfitted with darker surface finishes, but the illumination level does not change, the impression of the room will be completely different. The perceived brightness of the space may be felt to be too low. From the table (left), the darker surfaces with lower reflectance levels will cause the luminance levels to fall to 50% of that of light room. In this case, the illuminance level should be raised to 30 fc to compensate for the lower reflectance. The resulting lighting in the room will appear more appropriate and pleasant.

Public square · 27,000 ft^2		
Recommended illuminance	1.0 fc	
	Light ground	Dark ground
Floor reflection	30%	10%
Luminance	**0.1 cd/ft^2**	**0.03 cd/ft^2**
Our recommendation	✓	**+ 1.0 fc**

Example 2:
Public Square

The same principles apply for an outdoor space where only the ground reflectance is taken into consideration. Typically, the recommended illuminance level for an outdoor public space is 1 fc. With a light-colored ground surface, such as concrete, that has a reflectance of 30%, the luminance level reaches 0.1 cd/ft^2. If a darker surface is used, such as asphalt, and the reflectance is reduced to 10%, then with the same source the luminance reached is only 0.03 cd/ft^2. In this case, the illuminance should be raised to 2 fc to compensate for the dark surface and bring up the perceived brightness to a more comfortable level.

Urban road BEGA 99 556 pole-top luminaire (LED 50.6 W)		
Luminance	0.5 cd/ft^2	
	Light road surface **C1**	Dark road surface **C2**
Luminaire spacing	118 ft	85 ft
Luminaires over 1 mi	**45 luminaires**	**62 luminaires**

Example 3:
Urban Road

The design of a road lighting layout is primarily dependent on uniformity, which helps determine the distance between luminaires. The table (left) shows the effects of the road surface on the distance between fixtures. When the road surface is classified as C1 (concrete, 50%) the luminaire spacing can be 118 ft and still maintain the average luminance recommended level of 0.05 cd/ft^2. A road surface classified as C2 (asphalt, 20%), the spacing must be reduced to 85 ft in order to maintain the same average luminance levels. Over a mile-long stretch of road you would need 45 fixtures for the C1 road, compared to 62 for the C2 road. The choice of road surface material therefore has a direct effect on job cost, and should not be neglected during planning.

Light in the private garden

Gardens and green spaces are an essential part of our of our everyday lives, and often times are the heart of our homes. When accented with appropriate and good lighting, private gardens become an extension of the home and living space. When designing the lighting for garden spaces, it is recommended that different entities are illuminated separately, creating islands of light.

For example, ponds, flowerbeds, groups of trees or sculptures should each be lit individually, allowing areas between to remain darker which will create a visual separation of zones. Ideally, the color of light will be 3000K or lower; as warmer light is perceived as more intimate and relaxed. In most situations, a combination of unshielded, shielded, and directed light should be used.

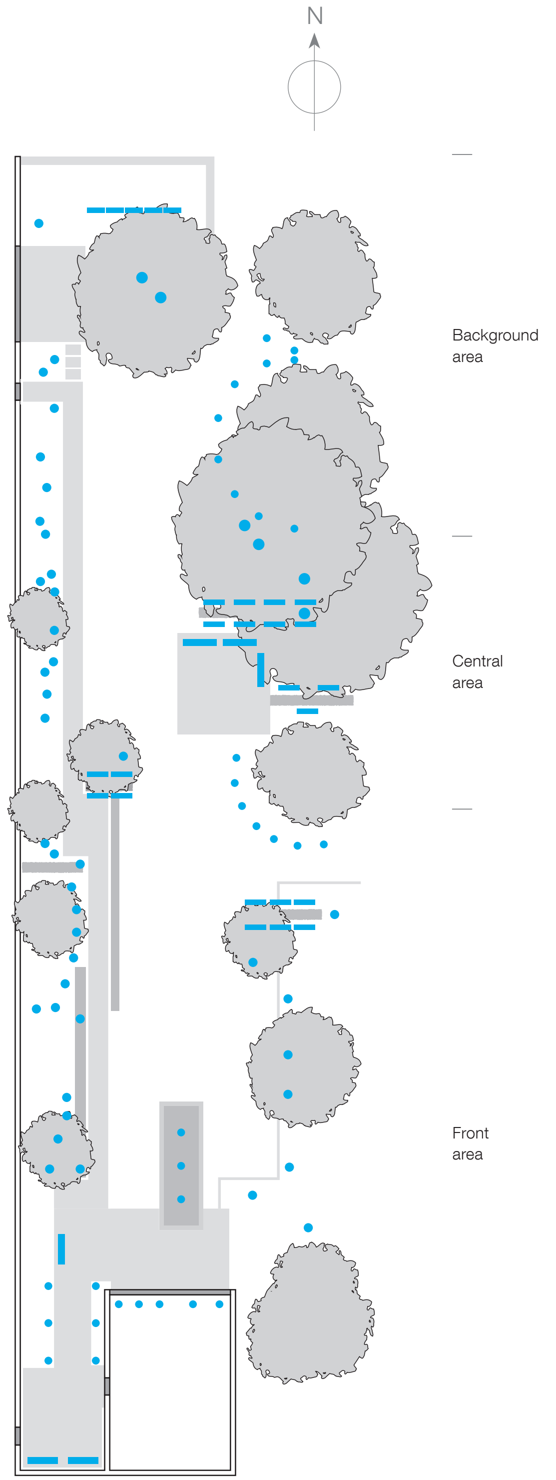
Another important consideration is the dynamic nature of plants. As they grow through time, or change with the seasons, sometimes the lighting will also need to be adapted. Portable fixtures that can easily be moved and integrated into existing environments are an excellent solution.

How to use light to create structure

Seperating the garden into three distinct luminance zones can help define the space and create structure.

Illumination in the background of the garden

In addition center parts of the garden are illuminated



Entire illumination of the garden

When lighting a private garden with an unshielded luminaire, the characteristics of the fixture should be carefully considered. Certain luminaires are extremely effective for lighting courtyard or home entrances, parking lots, or footpaths, but will be inappropriate and glarey when used in a private garden setting. An unshielded luminaire that uses opal glass to diffuse the source should be used instead.

Shielded luminaires, usually in the form of bollards or wall luminaires, are highly versatile and are ideal for illuminating paths, flower bed borders, and property boundaries.

Luminaires with directed light, such as floodlights, in-ground luminaires, surface washers, spotlights, and bollards can provide accent lighting by being used to highlight trees, bushes, or sculptures.This will give the space depth and contrast.

The different zones throughout a space can be isolated through the use of different luminance levels and contrast ratios. A distinctive backdrop effect can be achieved by subdividing the space into foreground, central, and background illumination. The greater the distance from the house, the higher the output of the luminaires should be.

Background: The end of the plot of land is illuminated, forming a clear boundary. A combination of in-ground luminaires and bollards are used to illuminate the boundary hedges and the rear most part of the pathway. Lighting on the property boundaries creates a sense of safety.

Central: the central section of the garden is outfitted with design elements that double as urban furniture, creating a welcoming seating area. Trees are illuminated using in-ground floodlights as well as floodlights mounted within the tree. The light levels here are somewhat lower than in the background.

Foreground: Relatively lower lighting levels are used to accent the trees, bushes and fountains. The entire scene is glare-free. The sketch shows the location of the luminaires.

Background Area	0.6 cd/ft²
Central Area	0.2 cd/ft²
Front Area	0.05 cd/ft²

Luminance ratio 1 : 4 : 12

Tree illumination

These three pictures show examples of how a free-standing tree could be illuminated.

1

2

3

Fig. 1 : Illumination from the front
Illuminating a tree from the front makes it appear flatter. The further away the floodlight is from the tree, the flatter it appears. There is no chance of glare, as the viewer is always behind the source. Floodlights or in-ground luminaires can be used to achieve this effect.

Fig. 2 : Illuminating the crown
If only the crown of the tree is to be illuminated, then backlighting can be utilized. From the viewer's perspective, two in-ground floodlights are installed behind the the tree trunk. With this type of lighting, it is important to ensure that from any accessible viewing angle the observer will not be exposed to direct glare. In-ground floodlights with an asymmetric wide beam spread or adjustable light distribution are most suitable.

Fig. 3 : Illumination from below
A combination of floodlights and in-ground lighting are utilized here. A floodlight has been installed directly in front of the tree trunk. The floodlight specified has a very narrow beam angle and shines directly along the trunk. This beam angle was chosen to prevent excessive light overspill. An additional two in-ground adjustable floodlights are installed on opposite sides of the tree, about 10 ft from the trunk. They have a wide beam distribution and are aimed to illuminate the crown of the tree. This type of lighting is ideal for trees that can be viewed from multiple sides. The overall lighting effect is uniform and harmonious.

Outdoor lighting applications

Outdoor Lighting

The following section is a collection of common applications, where the lighting design requires substantial planning to ensure the light levels are both visually pleasing and meet any safety recommendations. In each example, the technical lighting recommendations are addressed and appropriate fixtures are selected.

For all applications, the light level recommendations are met and often exceeded. Beyond meeting these recommendations, the aesthetic quality of the light and the visual comfort of the viewer are equally important.

If required, special circumstances are addressed so that the form and size of the selected luminaire will fit in with its architectural surroundings.

Outdoor lighting applications are covered in pages 52 to 79. Interior lighting is addressed in the next section: pages 82 to 103.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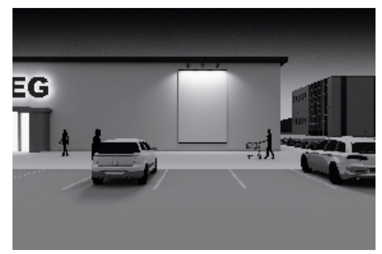
Roundabout Page 54


Bridge Page 60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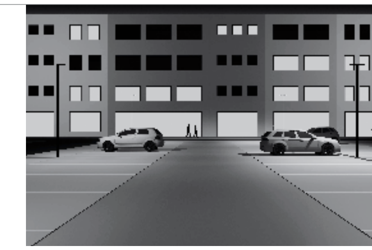
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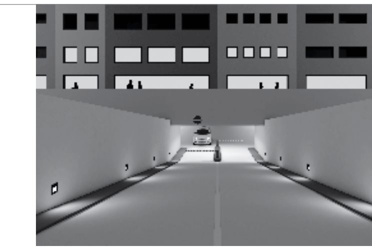
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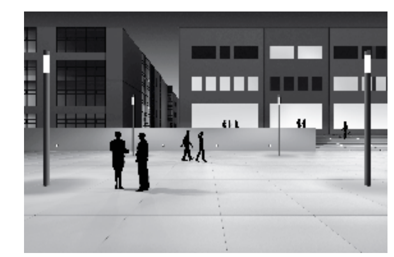
Historical Building Page 64


Historical Façade Page 65


Modern Façade Page 66


Office Building Entrance Page 69


Train Station Plaza Page 70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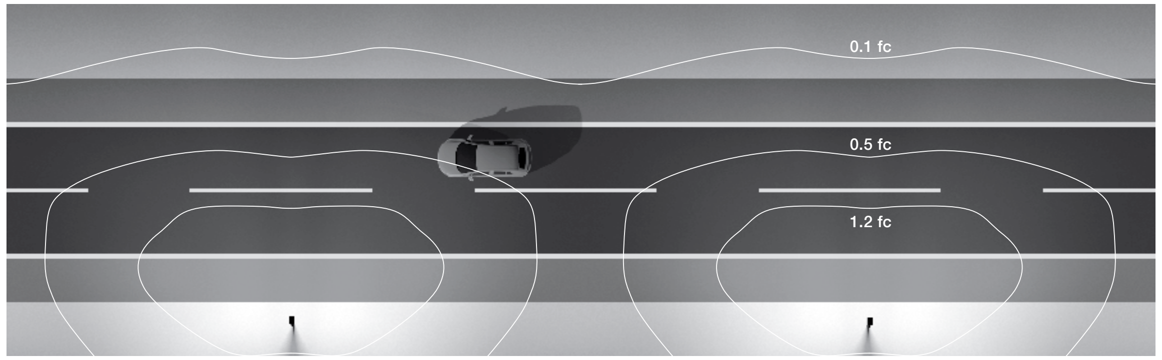
Pedestrian Bridge Page 76


Private House Page 78


Private Garden Page 79

1.0 fc | E_{avg} = 0.5 fc | E_v = 0.2 fc

Luminaire spacing 100 ft



Urban Roadway

In all road applications, safety is the top priority. The road and any hazards must be easily recognizable, and any pedestrians or cyclists must be visible. ANSI/IESNA RP-8-14 addresses the illumination of roads based on the following criteria: type of road material, roadway use, and pedestrian conflict classification.

This example shows a local road in a medium-density residential area where the pedestrian traffic is medium. The road material is concrete. There are two lanes for traffic with a total width of 20 ft and a 6 ft wide, shared use sidewalk on either side.

Using this criteria, we find that the recommended average illuminance level on the roadway is 0.5 fc. On the sidewalk the recommended illuminance level is 1.0 fc, with a vertical illuminance level of 0.1 fc.

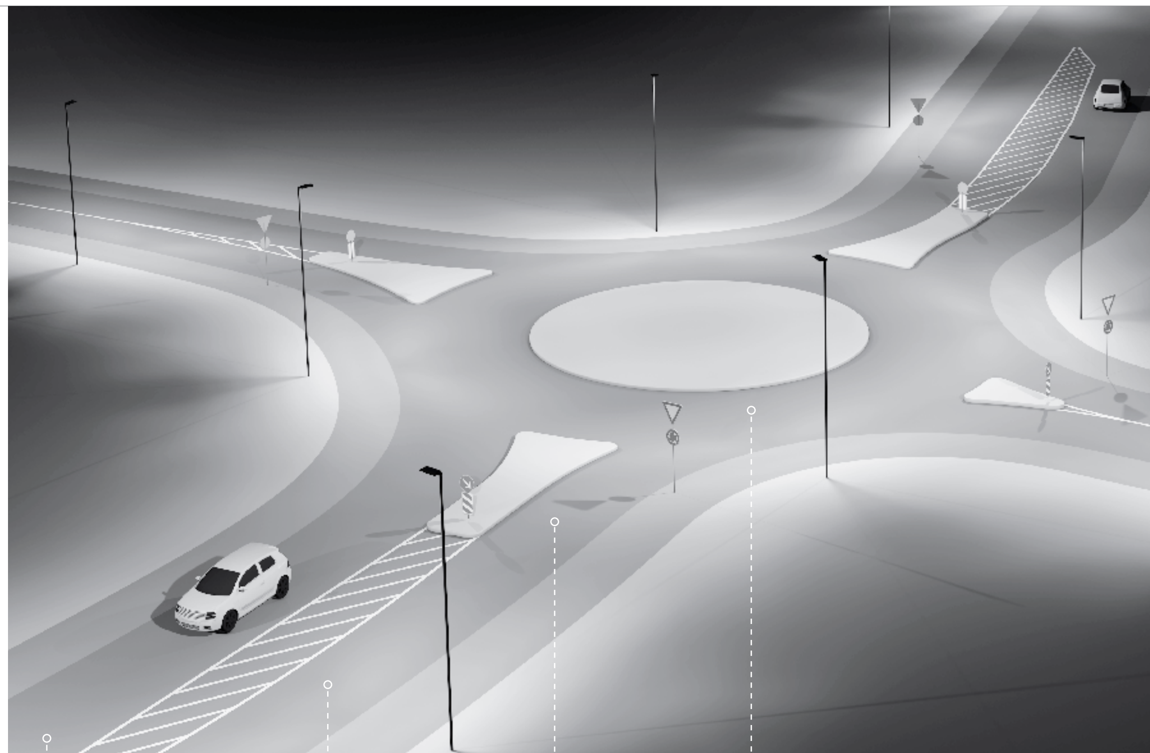
The fixture used is an LED area/roadway pole-top luminaire, used with an 18 ft pole. This fixture features a type II distribution, which covers the entire area width, and allows for wide spacings between fixtures. Precise reflectors create a light spread that is exceptionally uniform. The poles are spaced 100 ft apart, so that the minimum light level between fixtures does not fall below 0.1 fc, and the average illuminance on the roadway is maintained at 0.5 fc.

The bird's eye view clearly shows the light distribution on the road. The darkest place on the road between the luminaires is 0.1 fc. The transition to this level, proceeding from the brightest point directly in front of the luminaire (1.5 fc), is done gradually and uniformly.

The top image shows that the fixture is full cutoff; that is, all light emitted by the fixture is projected below the horizontal plane.

BEGA

99 499



Roundabout

Roundabouts and intersections are considered conflict zones and must be lit accordingly with reference to the recommendations found in ANSI / IESNA RP-8-14. Typically, the intersection must be illuminated if the roads leading to it are also illuminated. Since the risk of collision is highly increased at intersections, the light level is raised to reinforce safety and reduce the risk of accidents.

As on the previous page, the average illuminance level on the feeder streets is 0.5 fc. As vehicles approach the intersection the light level is raised to 1.5 fc. The fixtures are placed closer together than on the feeder roads in order to maintain the higher illuminance level. Within the intersection itself the light level is brought up to 2.0 fc by using a higher wattage fixture, 99 599. The transition is gentle in order to keep the contrast ratios low, which allows the human eye to adapt quickly.

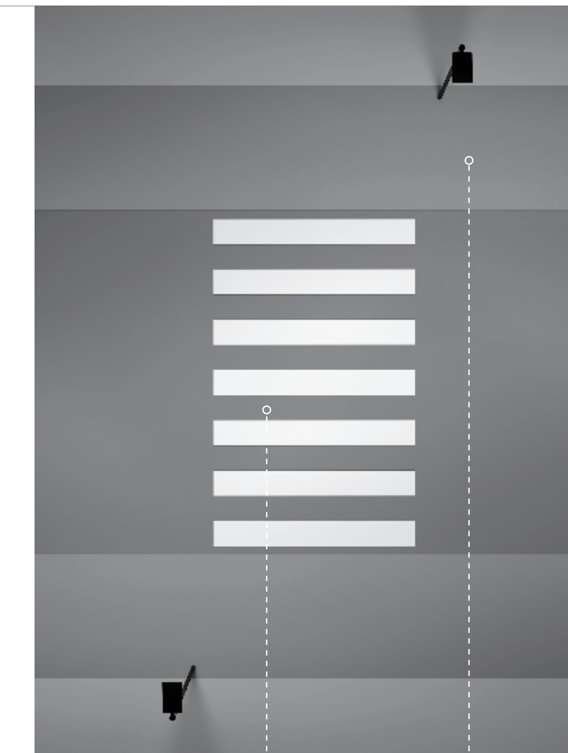
Luminaires used:

BEGA

99 599

A pedestrian crossing for any street or intersection is subject to the recommendations found in ANSI/ IESNA RP-8-14. Here, the visibility and recognition of pedestrians by vehicular traffic is essential. An average vertical illuminance of 3.0 fc, with a minimum value of 0.4 fc is used. Pedestrians who are crossing or waiting to cross must be illuminated from the direction of the approaching vehicles: the image on the right shows the correct pole location to ensure the pedestrians will be lit with the maximum vertical illuminance for oncoming traffic.

In order to meet these recommendations, the street is equipped with 99 595 and 99 596. The 99 595 is a lower wattage luminaire and is used for general, ambient street lighting. The 99 596 features a higher lumen package, and is used to light the crosswalk. This allows for each fixture on the street to use the same pole height, while still meeting the higher illuminance recommendations at intersections and crosswalks.



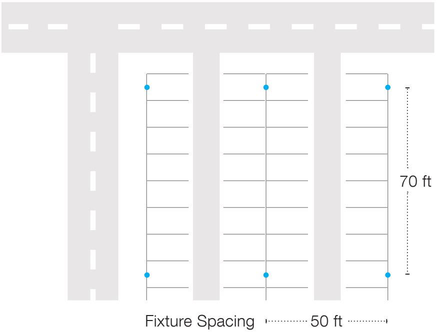
Luminaires used:

BEGA

99 595

BEGA

99 596



0.5 fc

Parking Lot

A typical parking lot (100 ft x 80 ft) that is active to customers, employees or the general public should be illuminated to a minimum of 0.5 fc, per the IES recommendations. A reduction of the illuminance level to 0.2 fc is recommended at night, when activity is minimal.

Using a combination of pole-tops with symmetric and asymmetric distributions is ideal for illuminating the area. With a pole height of 16 ft and luminaire spacing of 70 ft x 50 ft, two asymmetric pole-top luminaires on each of the two long sides of the car park and two symmetric pole-top luminaires of the same type in the center are sufficient to ensure uniform light distribution and the required degree of illuminance. The average to minimum uniformity ratio is 3 : 1.

Luminaires used:

BEGA

77 135

5.0 fc

2.0 fc

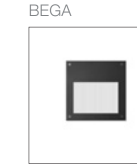
Loading Zone

A well lit loading zone is critical to the safety of workers. In a scenario where there are several adjacent loading bays in a building, it is best to light from above with a glare-free source. Here, luminaires are placed above and between the gates. The fixtures feature an asymmetrical-wide beam distribution and create an illuminance of about 5.0 fc directly below the gates. In addition, recessed wall fixtures are installed about 1.5 ft above the ground, which act as indicator lighting for drivers who may be reversing into a loading bay.

The entire company grounds are illuminated from a height of 25 ft with LED area/roadway pole-top luminaires, ensuring an ambient light level of 2.0 fc.

Luminaires used:

BEGA



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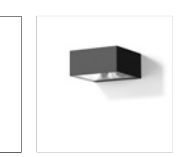

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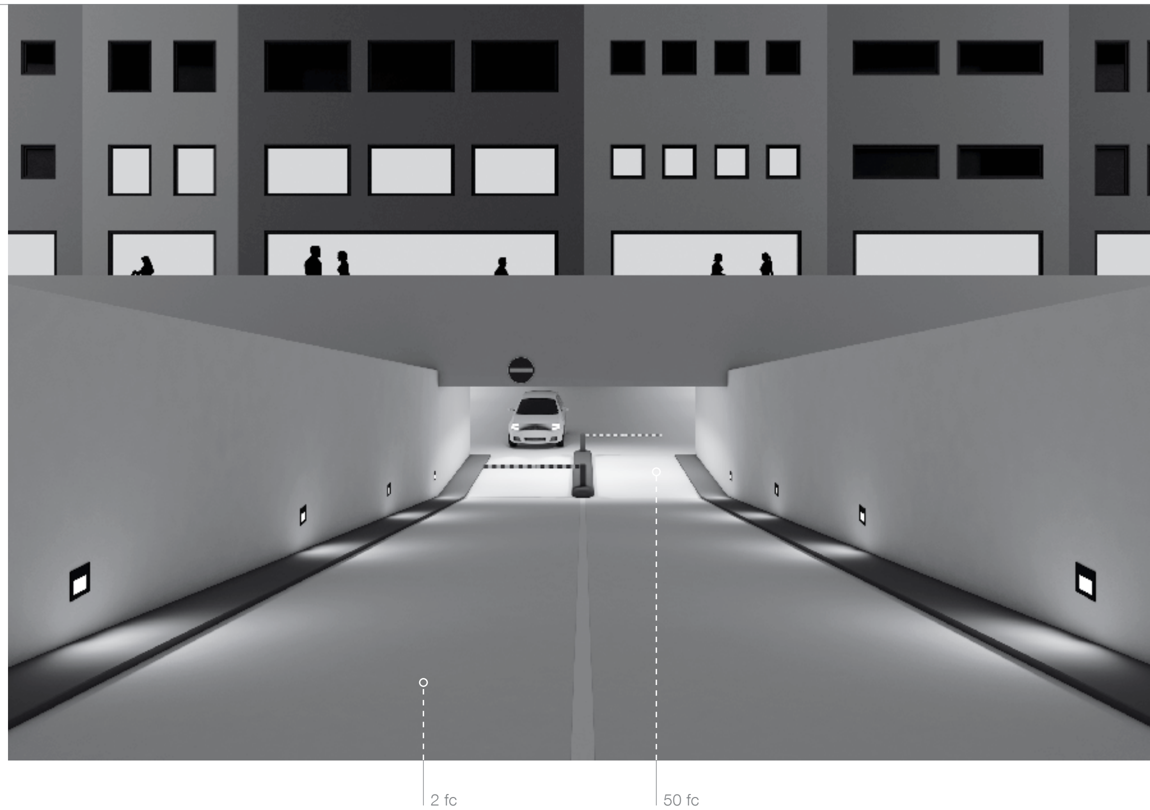
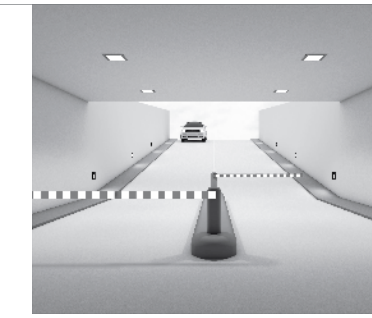
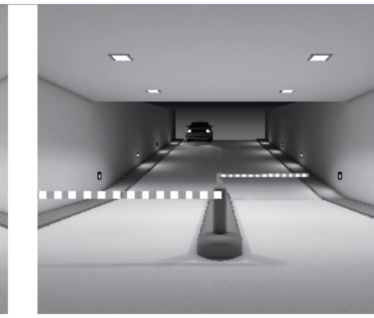






Parking Garage

The main obstacle when designing the lighting for a parking garage is to provide appropriate lighting in accordance with the time of day in order to prevent extreme contrast changes between light and dark. During a sunny day, light levels outside on the ground can reach up to 12,000 fc. This means that the vehicle entrance to the parking garage must be illuminated to at least 50 fc in order to aid in the eye's transition from bright to dark. Beyond the entrance, the illuminance can be stepped down in succession, down to the 2.0 fc recommendation for ramps and intersections, and to 1.0 fc for the rest of the general parking areas. The opposite is true at night: an illuminance level of no more 5.0 fc at the entrance is recommended in order to aid the driver with the transition from dark to light without overwhelming the eye.

The ramp leading into the underground car park is illuminated with recessed wall luminaires. Their asymmetrical flat beam light distribution ensures uniform illumination of the road surface. An illuminance level of 2.0 fc is maintained on the ramp. The light is absolutely glare-free.

Luminaires used:

BEGA

22 378

66 937

During the day, the transition from the parking garage to the uncovered entrance is illuminated to 50 fc. This is designed to help the human eye adapt to the huge difference in light levels. Temporary blindness and poor sight can be caused from a sudden transition into brightness or darkness and should be avoided.

At night, the lighting in the parking garage is higher than it is outdoors. An illuminance level of no more than 5.0 fc is required for the transition between the bright indoor area and the dark outdoor area. Again, this is so the eyes are not overwhelmed during the transitions in and out of the parking garage.

2.0 fc

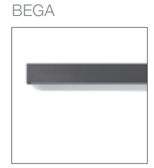
Bridge

Most bridges are built for functional purposes only, but some have become iconic symbols for their cities. The illumination of a bridge can help enhance the striking architectural beauty of the structure. To highlight the form of the bridge, floodlights outfitted with shields and louvers are utilized. These accessories are used to prevent undesired stray light and glare. Often times, colored light is used to create even more visual excitement. Against a dark sky, the illuminated bridge becomes a stunning work of art.

In this example, a pedestrian riverwalk is illuminated using linear wall luminaires, which create a pleasant lighting atmosphere. The recommended illuminance value for a pedestrian underpass is 2.0 fc, for facial recognition as well as security considerations.

Luminaires used:

BEGA



44 419

77 709

The bridge holds a two-lane road with a dedicated bicycle path on either side. As in the previous road example, IES standard RP-8-14 is referenced to find the appropriate light level. LED area/ roadway fixtures are used to light the road and the cycle path. Using a single pole, two types of luminaires are used at separate mounting heights. To illuminate the street, the higher wattage fixtures are mounted at 20 ft. For the cycle path, the lower wattage fixtures are mounted at 13 ft. The poles are spaced at 40 ft. The resulting light level on the roadway is 1.5 fc, and the on the cycle path is 1.0 fc, meeting the IES recommended light levels.

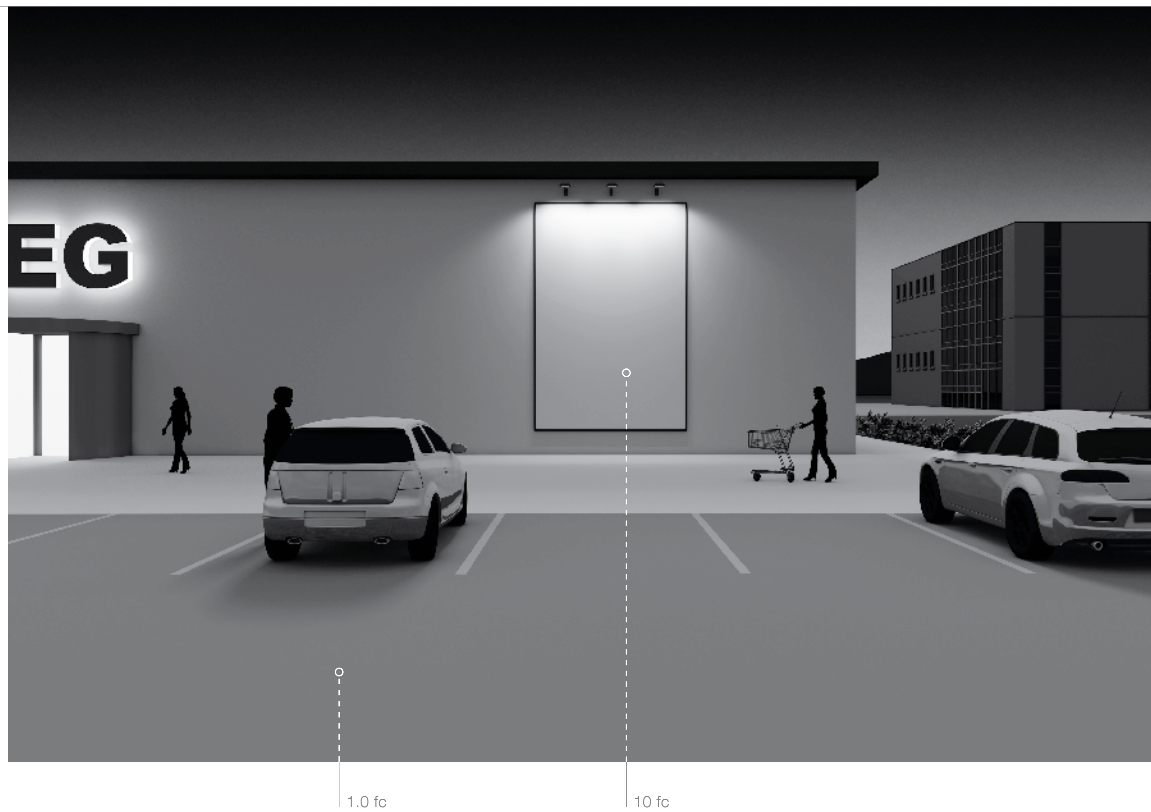
1.0 fc

1.5 fc

BEGA

99 499

99 595



Advertising Space

The illumination of an advertising space will repeatedly present a new challenge due to the dynamic nature of its constantly changing content. In this case, it is strongly recommended to use a dimmable fixture to have the ability to adjust the light level as needed per the content of the advertisement.

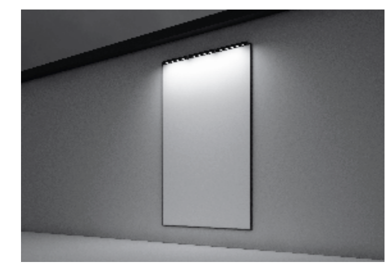
Accent illuminance is measured by the luminance ratio between the focal point and its background. For a dramatic, eye catching effect, a luminance ratio of 10 : 1 is recommended. In this case, the light on the signage is 10 fc and the ambient light level on the background wall is 1.0 fc, thus creating a ratio of 10 : 1.

The following page presents several lighting strategies for a wall-mounted advertising sign that measures 13 x 20 ft. In each example, the average light level on the sign is maintained at 10 fc.

BEGA

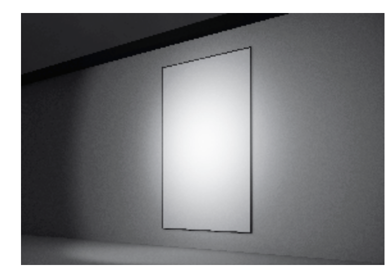
A floodlight with an outrigger arm is ideal for illuminating the advertisement from the top. The light is distributed over a wide area. With this layout, the light level will be higher at the top of the than at the bottom. This effect can be reduced by using a longer outrigger arm.

77 559

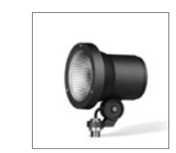


Linear floodlights create uniform illuminance which decreases from top to bottom. The elongated design allows for mounting with a close proximity to the wall surface, and the fixtures can be aligned to create a seamless look.

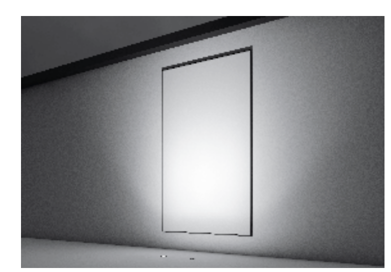
77 363



The most uniform light distribution is achieved using remote mounted floodlights. With this type of fixture, various lighting characteristics are available to ensure optimum illumination of the sign. The example shows the effect of two floodlights mounted on a pole at a height of 15 ft and at a distance of 30 ft from the advertising space.

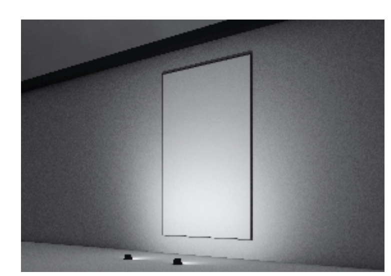


77 652 + 70 065



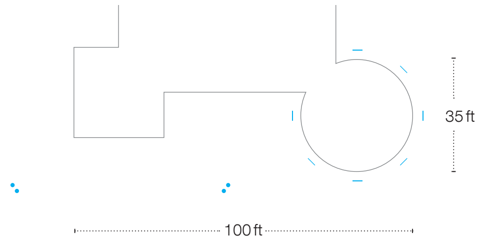
A popular alternative is to use in-ground floodlight to illuminate the sign. A fixture with an asymmetrical or adjustable light distribution can be aimed towards the signage and used to light it with a uniform gradation from bottom to top. The typical setback is dependent on the dimensions of sign. These floodlights are installed at a distance of about one third the poster height (6.5 ft).

77 107



If the area directly in front of the sign is not open to pedestrian or other traffic, then ground surface-mounted fixtures are a suitable solution. The light distribution will be similar to that of the in-ground floodlights. Again, the setback for these fixtures is dependent on the dimensions of the sign, and they are installed at a distance of about one third of the poster height (6.5 ft)

77 630



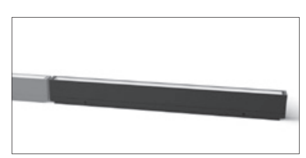
Historical Building

Lighting a large building can be challenging. The objective should be to illuminate all sides of the complex as uniformly as possible, while avoiding any excess light overspill. A common solution is to use floodlights, either ground mounted (if possible) or pole mounted. In most cases, high power floodlights positioned symmetrically at the corners of the building and aimed to wash each surface will be sufficient. The type of floodlight is selected by its beam angle and lumen output. When lighting an exceptionally large surface, a high lumen output, wide beam floodlight is appropriate. It is common practice to have calculations and renderings run or a mock-up built to confirm the specification before the final installation.

Luminaires used:

BEGA


84 501


77 157

Historical Façade

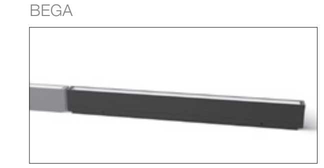
In order to create an interesting lighting design on a historical facade, various types of fixtures should be utilized to accent the architecture. Beginning on the ground floor, the front columns of the arcades are illuminated from below with in-ground floodlights. Since this is a high-traffic area, it is important to select a fixture that is robust and suitable for walk-over applications.

Architectural ledges are found at each floor on the facade. Small scale, adjustable floodlights are selected to up-light the rest of the facade. The less height there is to illuminate, the lower power fixture you can use.

Uplighting works particularly well to emphasise the symmetry of the building and the surface materials. The goal here is to create contrast and enhance the appearance of the architectural details.

Luminaires used:

BEGA


77 157


77 680


77 019


77 852

1.0 fc

10 fc

Modern Façade

This modern building complex is constructed of concrete and glass. On the left-hand side, a solid concrete facade is illuminated using linear in-ground luminaires. They are installed a short distance from and parallel to the wall, creating a soft, uniform wash of light.

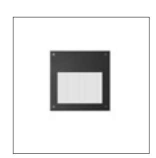
The front entrance is a sheer curtain wall, with a clear view to the interior. It is important to note that you cannot light the glass itself; it is a much better strategy to use the light from the interior as the main focal point for the building.

Typically, human attention is drawn to the brightest point, which is an important concept for building lighting. The entrance to the building holds additional recessed wall luminaires to increase the light level on the floor, and to therefore draw visitors to the area.

Luminaires used:

BEGA

77 915



22 378

2.0 fc

10 fc

5.0 fc

Commercial Building Entrance

A large, covered entry area is illuminated from above with several surface-mounted ceiling fixtures. Using a directed light source ensures that the light will reach the ground surface, even when mounted at a great height. To accent the columns supporting the roof, very-narrow beam in-ground floodlights are installed on the front side. This strategy helps create depth in the space. Additional recessed ceiling lights are installed at the entrance doorway, which increases the light level and creates a visual cue at the location of the entry.

The general lighting of the interior space is created through many large-scale, surface-mounted ceiling luminaires. Since the facade is glass, the illuminated interior can clearly be seen from outside viewers.

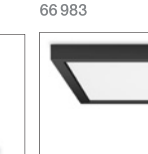
Luminaires used:

BEGA

66 937

66 983

77 852



33 312

Staircase

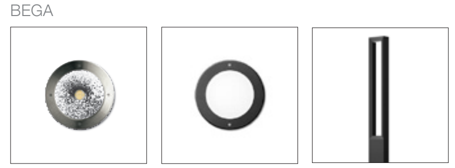
Outdoor staircases often precede an entrance or are main paths of egress. In this example, layers of light are built by adding different types of fixtures as visitors get closer to the entrance and proceed up the stairwell.

The front plaza is illuminated with a row of linear element fixtures, creating a base of ambient light for the space. Recessed wall fixtures are installed alongside the stairs to provide additional lighting. The arrangement of the fixtures is complementary to the pattern of the stairs and the visual rhythm they form is another wayfinding strategy.

Most of the light in the area comes from recessed ceiling fixtures. The placement of these fixtures ensures that the recommended safety light levels are met, and that a visual cue is provided to draw visitors towards the entrance.

Luminaires used:

BEGA



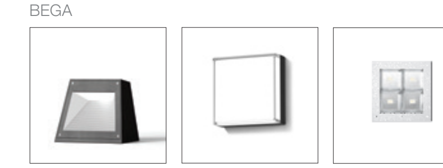
55 824 22 051 99 075

Office Building Entrance

A company can create a significant impression based upon how they light their office entrance. The path to the door should be clearly illuminated using a glare-free source. At the entrance, decorative wall fixtures with pressed crystal glass are used to create a pleasant, welcoming glow. Additional recessed ceiling downlights are installed in the covered entry area and vestibule to add supplementary light and wayfinding into the main building space. The recommended light levels for an office entrance are determined by the surrounding environment and the activity level.

Luminaires used:

BEGA



77 791 33 602 66 834

Train Station Plaza

A sunken plaza, measuring 130 x 65 ft, opens up in front of a train station. This area is bordered by a low retaining wall, which confines the space, and makes it accessible from the street level only by a large staircase.

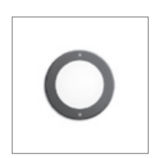
Within the retaining wall, recessed wall fixtures are installed at even intervals so visitors can easily grasp the boundaries of the space. Since the plaza is fairly large, four linear element fixtures are installed in a 35 ft square to help subdivide the space. These fixtures feature a symmetrical Type V distribution, which provide uniform light in every direction. Finally, recessed step lights are installed in the stair risers to indicate the change in grade.

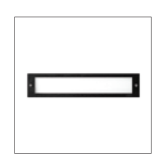
The illuminance level throughout the space is maintained between 1.0 and 2.0 fc.

Luminaires used:

BEGA


88 865


22 052


22 191

Urban Plaza

An urban plaza is often found at the heart of a city, and acts as a public meeting space. Flanked by shops, cafes, and restaurants, the plaza is a popular destination during all hours of the day and night. Often times, plazas will have fountains or sculptures as the central focal point. In this example, a small water feature is prominent in the center of the space. After the sun sets, LED pole-top luminaires are illuminated, creating a soft, ambient glow throughout the plaza. These decorative fixtures provide a safe amount of ambient light and vertical illumination which allows for shoppers to easily recognize others. The fixtures are spaced at 75 ft in order to maintain a 1.5 fc average light level.

Luminaires used:

BEGA


77 122

Pedestrian Walkway/Cycle Path

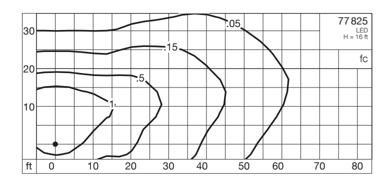
Proper lighting of a pedestrian pathway is essential to the safety and comfort of walkers, joggers, and those on bikes. IES RP-33-14 recommendations for lighting are primarily dependant on the community goals for safety, security, and nighttime ambience and beauty. For walkways that are not adjoining roadways, continuous lighting is not necessary. Lighting is suggested to alert users of hazards such as stairs, or abrupt changes in elevation or direction. For this example, an average illuminance of 0.5 fc is recommended due to the path's curvy shape and shared use. Pole-top luminaires with an asymmetrical wide beam light distribution are spaced every 100 ft along the pathway. The mounting height is 16 ft.

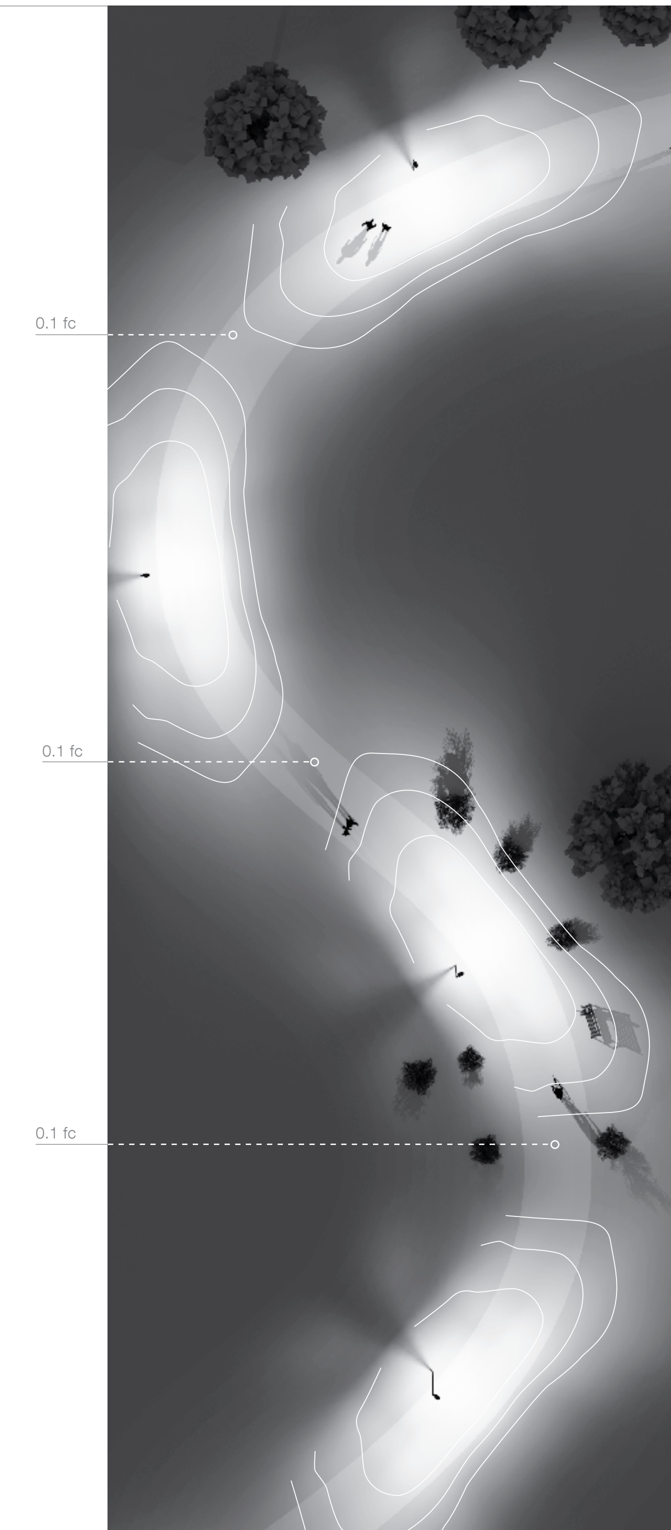
Luminaires used:

BEGA

77 825

In the picture on the right, the light distribution curve has been overlaid on this bird's eye view image of the pedestrian walkway/cycle path. The darkest place on the path between the luminaires has an illuminance of 0.1 fc. The transition from the lightest point directly in front of the luminaire (1.5 fc) to the darkest place is gradual and is felt to be pleasant.





0.5 fc 0.05 fc

Park

A pedestrian-only pathway in the middle of a park is illuminated by LED bollards. These fixtures are unshielded and light the pathway and surrounding areas uniformly. The bollards are spaced 20 ft apart, so that the minimum light level on the pathway does not fall below 0.05 fc. The recommendations are similar to those of a standard pedestrian and bicycle pathway, as discussed in the previous example. The recommended light levels are lower here, since the pathway is designated for pedestrian use only and the path is straighter.

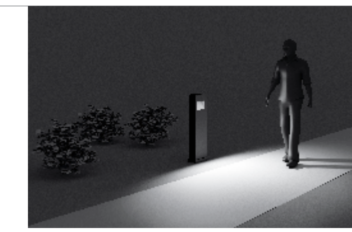
Some of the trees and bushes throughout the park are illuminated with in-ground floodlights. For the larger trees, two in-ground fixtures are used to ensure adequate lighting. The color temperature of the fixtures is 3000K.

Luminaires used:

BEGA

77 145 + 77 146

99 727 + 99 622



Shielded light

The light is directed downwards and is contained in the immediate vicinity of the bollard. The bollard is full-cutoff, so there is no light output above the horizontal. The light appears the brightest directly in front of the fixture, and quickly darkens out to either side. The resulting effect is a high level of visual comfort, uniform illumination, and maximum glare control.

BEGA

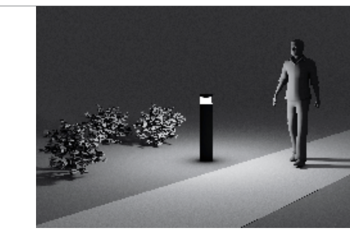
88 868

Wide beam light

This type of fixture features a wide distribution: the light is directed out to the sides instead of in front. Compared to the shielded source, this fixture does not appear as bright directly in front of the fixture, but clearly illuminates a much wider area. This bollard is also full-cutoff. This type of fixture is best for maintaining minimum illuminance levels with the widest spacing.

BEGA

99 058



Unshielded light

These luminaires distribute unshielded light, which is uniform and best for ambient lighting. These luminaires also offer a high degree of vertical illumination, which is important for the recognition of people as well as architectural and landscape elements.

BEGA

99 727 + 99 622

0.5-0.1 fc

Pedestrian Bridge

When lighting a pedestrian bridge, there are two major considerations: the accenting of the architectural structure, and the lighting for the safety of the bridge pedestrians.

For the structure of the bridge, four compact floodlights are used to accent its architectural features. This creates a striking contrast between the bridge and the dark surroundings.

For the pedestrian section of the bridge, the recommendations IES RP-33-14 for the lighting of pedestrian walkways and bicycle paths is applicable. Pedestrians and cyclists should feel secure and safe on the bridge. With this in mind, the recommended average illuminance value for the bridge is 0.5 fc, with a minimum value of 0.1 fc. Two approaches are discussed on the next page.

Luminaires used:

BEGA

77 700

For general area illumination, two 77 825 pole-top luminaires at a 13 ft mounting height would meet the recommendations. This pole top fixture has a wide beam light distribution, which is directed down onto the path below.

While this layout meets the lighting recommendation on its own, additional wall fixtures have been added for accent lighting. The fixtures are mounted on the struts of the railing every 8 ft. From a height of 4 ft, their light is directed onto the ground to accompany the walkers. The light also falls onto the struts of the railing, creating an interesting and decorative lighting effect.

Example 2, is designed for functionality only. Two unshielded pole-top luminaires direct soft, ambient light onto the path and surrounding area.

In both cases, an average illuminance of 0.5 fc, and a minimum of 0.1 fc is achieved. Ultimately it depends on the application and the lighting designer on whether the layout will be more utilitarian or lean towards the decorative side.

BEGA

33 514

77 825

BEGA

77 122

Private House

A well kept house and yard is often a point of pride for a homeowner. When done correctly, lighting can transform the evening environment and put the home architecture and surrounding landscaping on display.

The driveway and entry paths are illuminated using small LED bollards that have an asymmetrical wide beam light distribution. When specifying residential lighting, it is important to choose something that is appropriately sized. In this case, larger scale bollards would be distracting to the overall effect of the lighting design.

The trees in the front are illuminated using several in-ground floodlights. On the house itself, unshielded wall luminaires are installed beside the front door and the garage, adding a layer of ambient light to the space. Up-lit trees and decorative sconces on the facade create an inviting and pleasant atmosphere.

Luminaires used:

BEGA


77 735


77 010


22 453

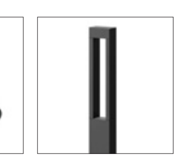
Private Garden

Separating the garden into zones can help define the space and create structure. In this example, the boundary of the garden is defined with the ambient light from small spherical elements. The large trees and bushes are illuminated from below using portable floodlights. The walkway is bordered with small bollards that lead to a central seating area. Each feature is illuminated separately, creating islands of light. Some of the luminaires chosen are portable so they can easily be moved into new landscaping or adapted to change with the growth of plants throughout each season. The resulting lighting design is practical and beatifully enhances the outdoor space.

Luminaires used:

BEGA


77 010 or 77 008


77 266


77 903


55 030

Indoor lighting applications

Indoor Lighting

The following section is a collection of common indoor applications, where lighting design requires substantial planning to ensure the light levels are both visually pleasing and meet safety recommendations. In each example, the technical lighting recommendations are addressed and appropriate fixtures are selected.

Indoors, the design and material finish of the luminaires have a considerable effect on the overall design concept. When specified appropriately, they can compliment and enhance the interior design.

For all applications, the light level recommendations are met and often exceeded. The aesthetic quality of the light and the visual comfort of the viewer are equally as important as meeting these recommendations.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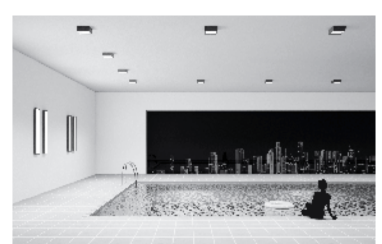
Shopping Mall Page 95


Living Area Page 99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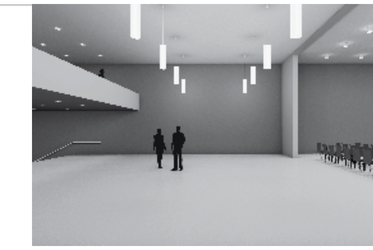
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Restaurant Page 96


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Spa/Health Facility Page 101


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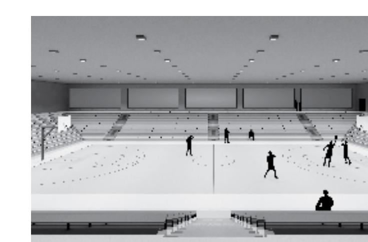

Multipurpose Gym Page 103

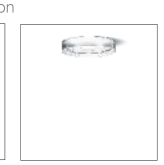
Lobby

Often times a lobby is quite large, but needs to still feel welcoming and pleasant. In this example, all three types of light can be found in different layers throughout the room. First, a hybrid ambient and directed light layer is created using a series of semi-recessed ceiling fixtures. These fixtures have an impressive downlight capability, while also producing soft ambient light through a diffuser made of white opal glass. Second, pendants with a polished aluminum finish and thick crystal glass add task lighting over the reception area. The general light level on the reception desk is higher than that of the surrounding area in order for the receptionist and guests checking in to be able to complete related tasks. The elevated light level also provides a subconscious indicator for arriving guests. Finally, accent lighting is placed on either side of the entry doors. The sconces have matching finishes to the other luminaires, which helps tie the space together.

Luminaires used:

LIMBURG Collection


12 069.3


23 225


50 091.3


56 444.3

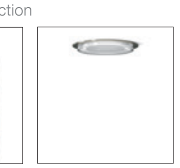
Foyer

Spaces with exceptionally high ceilings can be difficult to illuminate effectively without using an excessive number of fixtures. The best practice in this situation is to use pendants to create a false ceiling at a height that creates a more intimate feeling in the space. With a diameter of nearly 30”, the scale of the pendants is appropriate and complementary to the generously dimensioned foyer. The mounting height of the pendants is largely dependent on the recommended light level on the floor. In this case, they are at a height so that a light level of 20 fc is maintained evenly throughout the space. In sections where the ceiling is significantly lower, recessed ceiling luminaires are installed to maintain the light level recommendations. The remaining light in the space comes from two large wall mounted fixtures, whose design matches that of the pendants.

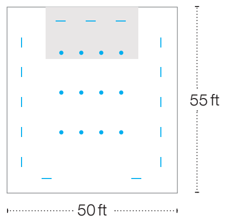
Luminaires used:

LIMBURG Collection


23 369.3


12 085.3


56 552.3



15 fc

Religious Space

Spiritual spaces are often intimate and personal, and the lighting design can vary greatly. There is often a focal point, or narthex, that should be lit to a higher level than the rest of the space. Artwork, sculptures, and other focal areas should be accented appropriately. Surrounding walls are illuminated using in-ground linear floodlights. The flush mounted fixtures do not distract from the architecture and frame the space with light.

Our example space is a simple 50 ft x 55 ft room with a high ceiling and a single, central pulpit. To increase intimacy, pendant lights are used to create a false ceiling and to evenly illuminate the room to 15 fc. It is good practice to install dimmable fixtures, so the mood of the space can easily be changed. For example, the lighting can reflect a sense of quiet meditation by simply dimming the overhead fixtures in the space. Just as easily, the lighting set at full brightness can enhance a celebratory ceremony, such as a wedding.

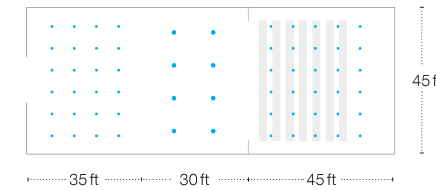
Luminaires used:

BEGA

77 916

LIMBURG Collection

56 531.3



20 fc 10 fc 20 fc

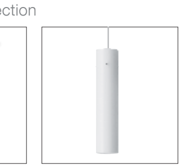
Public Hall

Public meeting halls can be used for many different purposes. Often times, conferences or large meetings will take place here. This public hall has three distinct sections. On the far left, a viewing balcony and the floor space below are illuminated using recessed ceiling fixtures. The low ceiling height dictates the choice of recessed instead of surface mounted fixtures. In order to maintain the 20 fc recommendation, the quantity of required surface mounted fixtures would have made the space look too cluttered and confined. The central section is mainly for socializing, so the light level is maintained at 10 fc using several pendants. The section on the far right is a general seating area. Since this area has a high ceiling, densely spaced surface mounted fixtures are used to ensure there is enough light, an illuminance level of 20 fc, for the assembled public to read, write, and communicate.

Luminaires used:

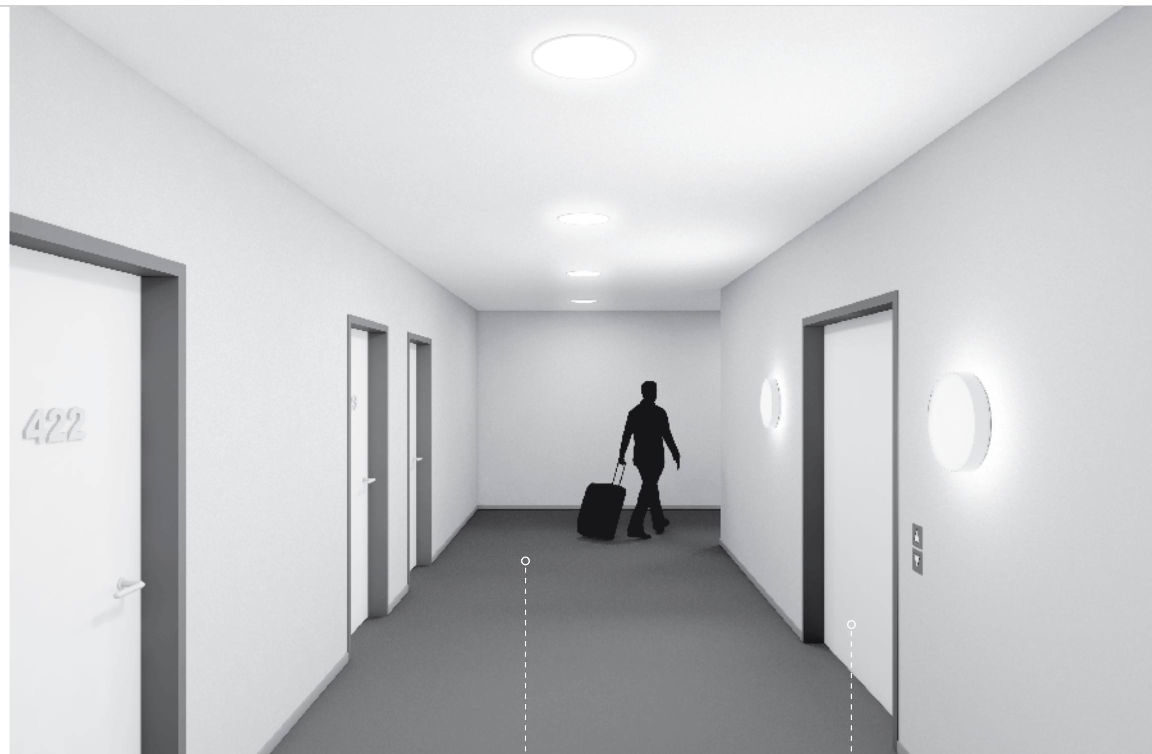
LIMBURG Collection

12 085.1



56 490

34 021.1



Hotel Corridor

This hotel corridor is uniformly illuminated with a combination of recessed ceiling and surface wall fixtures. The ceiling fixtures are flush with the finished ceiling surface, creating a simple and orderly appearance. The wall luminaires are strategically placed near elevators and stairwells to indicate their location in each hallway. The wall fixtures feature hand-blown opaque crystal glass. All of the light in the hallway is soft and glare-free.

Luminaires used:

LIMBURG Collection


12 056.1


23 315

Pedestrian Tunnel

This underground pedestrian walkway is connecting two building complexes. There are two important concepts to consider.
First, is the safety of all persons using the walkway. The IES recommends a light level of 10 fc for the general illumination of the pedestrian walkway. Surface wall mounted fixtures with two sided light output are installed along either side of the tunnel. This fixture produces both direct and indirect light on the pathway.

The second concept to consider is the transition in brightness between the buildings and the walkway. Since it is safe to assume the walkway light level will be lower, additional lighting should be installed in the transition between the building and the walkway. In this case, recessed wall fixtures are installed in the stairwell to provide additional wayfinding lighting as well as act as a transition zone between the bright building and the darker tunnel.

Luminaires used:

BEGA


22 372


44 438

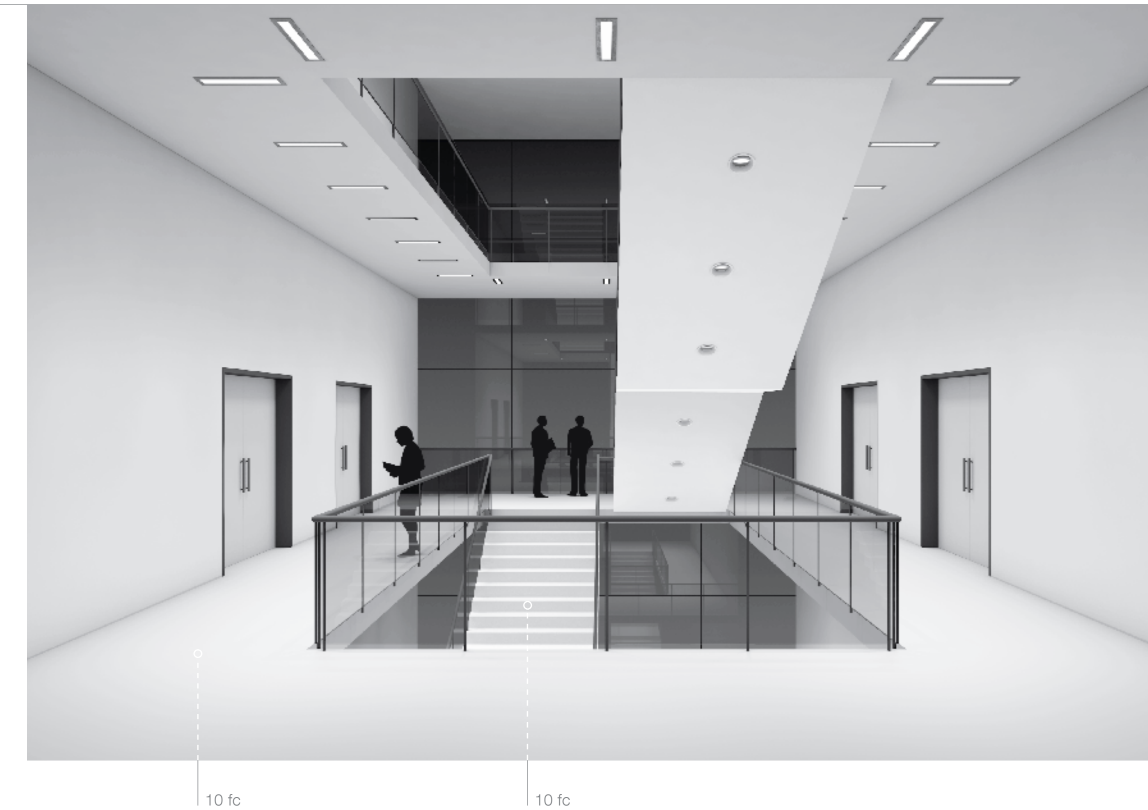
Staircase

Uniform illumination is critical in staircases for the wellbeing and safety of the people who use them. Often times, the stairs will be a main path of egress, and must be illuminated accordingly. The IES recommends maintaining at least 10 fc on each of the steps, with a uniformity ratio of 2 : 1. This uniformity will ensure there are no harsh shadows, which could be disorienting and create a hazard. In this example, the same fixture is used to light the steps and the landings. The white opal glass diffuses the light and creates a uniform light distribution on every surface. At the landings, the fixture is mounted to the ceiling surface, and over the steps the fixture is mounted to the wall surface. Fixtures must be ADA compliant.

Luminaires used:

LIMBURG Collection

12103.1

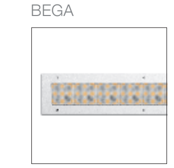


Staircase with Gallery

Some staircases have a central open well that spans the entire height of the building. In this case, the stairs themselves cannot be lit from an adjacent wall. The main landings are illuminated using linear recessed ceiling fixtures. The underside of the stairs also have recessed ceiling fixtures installed. Since the surface (and therefore the luminaire housing) is sloped, the fixtures with an adjustable light output direction were chosen so that the light can be directed straight down. The light level recommendations are met as in the previous example.

Luminaires used:

BEGA



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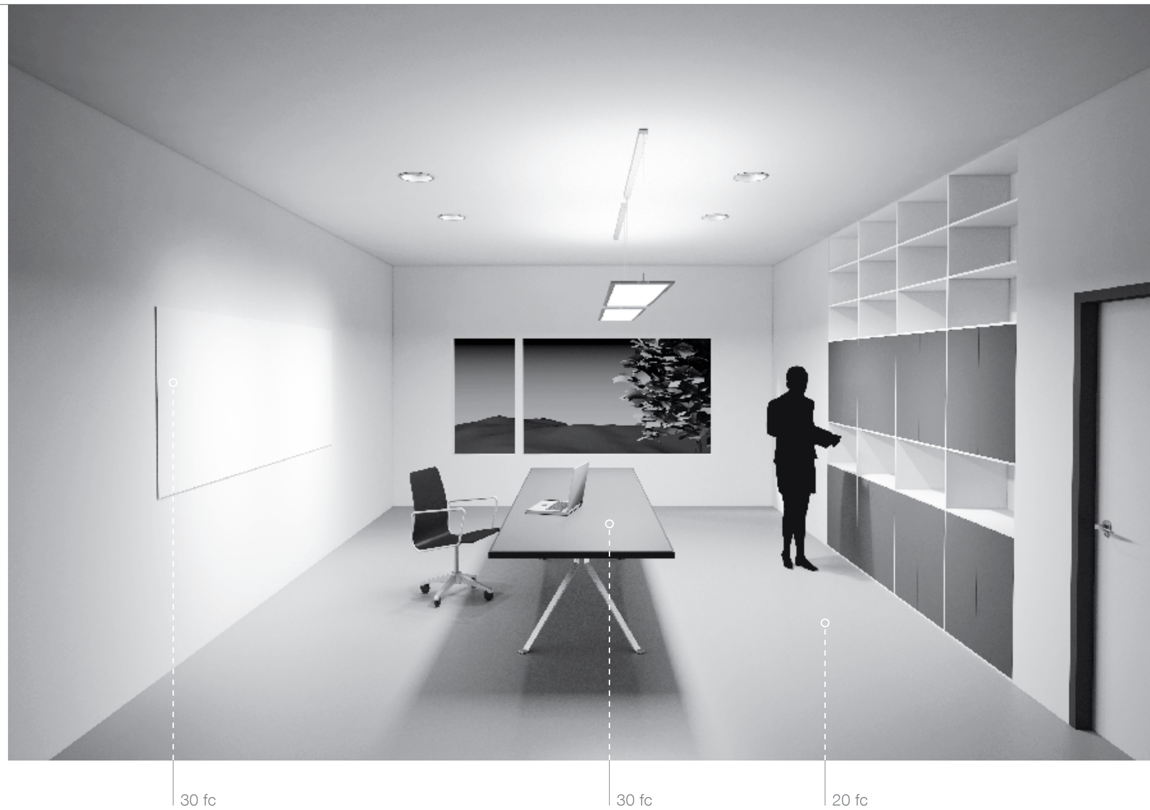
LIMBURG Collection

12121.1



Study

The lighting for a study or office must be designed by first determining the tasks that an occupant will need to complete while in the space. In most offices, reading and writing will be the primary tasks. The IES recommends a light level of 30 fc on the working surface for reading and writing. To meet this level, a wide-area pendant is installed directly above the desk. Secondary tasks in the space include reading and writing on the whiteboard behind the desk, and reading at the book shelves. These tasks are addressed with adjustable recessed ceiling fixtures that are aimed to illuminate each area.

Luminaires used:

LIMBURG Collection


56 624.2

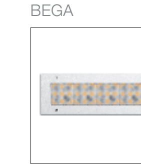

12 120.1

Conference Room

As in the previous example, the spacial tasks must be identified. Reading and writing are the primary tasks found in a conference room. Downlights in the ceiling illuminate the room uniformly and create an illuminance level of 30 fc on the table top. Additional linear recessed wall fixtures are installed along the front wall, where there is a presentation board. The general lighting in the room is maintained at 20 fc. There is a large window on one side of the room. A shading device should be used to mitigate glare during meetings and presentations.

Luminaires used:

BEGA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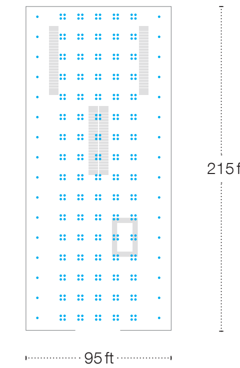
LIMBURG Collection


34 864



Boutique

The illumination of a boutique must convey high quality and style, and simultaneously illuminate the shop's wares. Strong visual contrast should be created between the lighting on the products and the general illumination of the space, in order to draw buyers towards products throughout the shop. Since most boutiques are constantly changing to keep up with the latest trends, adjustable and aimable lighting is the most sensible choice.

Luminaires used:

LIMBURG Collection

50 187.1

Shopping Mall

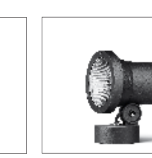
A shopping mall is typically a large, open, high-ceiling space. For this example, the main concourse of the mall is 215 ft by 95 ft, with 40 ft ceilings. Here, the main source of light is from surface ceiling fixtures that have been grouped into sets of four and spaced in a grid. These fixtures use a precise reflector to direct all of the light from the lamp downward onto the floor surface. The resulting light level is 30 fc. The brightly illuminated space will induce a sense of energy and excitement to the shoppers passing through. The surrounding walkways and storefronts are illuminated with recessed ceiling luminaires, spaced to create a uniform light level on the floor. Finally, aimable floodlights are installed for special events, or for the accenting of seasonal decor and kiosks.

Luminaires used:

BEGA

66 057

66 935



77 639

15 fc   10 fc

Restaurant

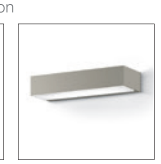
The lighting design for a restaurant should aim to create a sense of relaxation and intimacy. This is typically achieved by bringing the ambient light level down, and only bringing up the light level where it is absolutely necessary for the comfort of the diners. For this example, each table in the bistro has its own pendant fixture. These pendants effectively light the table surface, so the diners can see their menus and food, but leave the rest of the area around the table darker, reinforcing a sense of privacy. The only other light around the diners is created by a series of slim-profile wall fixtures that graze the wall above and below with light. This helps maintain the low ambient light level, while also creating an interesting accent.

The safety of the restaurant workers must also be considered in this design. Main walkways and the kitchen are illuminated using surface ceiling fixtures that feature an impressive, controlled downlight. Because of the precise light output, the fixtures can be placed in a way that the light is not obtrusive to the dining area, but still maintains a safe level of light in the necessary locations.

Luminaires used:

LIMBURG Collection

56 614.2



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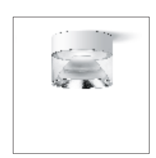


23 571.1

5.0 fc   10 fc

Bar

Similar to a restaurant, the lighting design should aim to create a sense of relaxation with low ambient light levels and limited task lighting. In this bar example, a similar approach has been taken: above the bar area pendant luminaires form small pools of light, creating a sense of privacy for customers seated there. The low ambient light in the space is created by a series of large-area wall luminaires that feature large pieces of hand-formed crystal glass. The glass is finished with a white coating on the inside, so when the light passes through it the resulting distribution is highly uniform and diffuse.

Again, there is a main walkway that requires a higher illuminance value than the ambient light in the space provides. Additional semi-recessed, wide-beam ceiling luminaires are installed over this walkway. The placement of these fixtures ensure that a safe level of light is provided in the most active areas of the bar.

Luminaires used:

LIMBURG Collection

23 369.1

12 089.1

56 564.5

15 fc

Waiting Area

Waiting areas in airports and other travel hubs are typically full of people passing the time by reading, catching up with work, or even snoozing before they travel. The tasks in this area can vary greatly, so the lighting should be kept simple and uniform. This waiting area is illuminated from surface ceiling fixtures to an illuminance level of 15 fc. These fixtures have a thick piece of partially-frosted glass. Most of the light is emitted downwards, but the remaining light is refracted by the edge of the glass, creating a nice level of vertical illumination. Additional soft, ambient light is created by square large-area luminaires installed on one wall.

Luminaires used:

BEGA

33 311

LIMBURG Collection

34 350.1

20 fc

5.0 fc

Living Area

Homeowners spend a lot of time choosing the furniture or the paint color for their living room, but often forget about the importance of proper lighting. More often than not, this space is meant to function as an area for relaxing and entertaining. A good living room lighting scheme will use ambient, task, and accent lighting together to create a space that is warm and inviting.

Our example is an open concept living room with 18 ft ceilings and a large glass front that extends to an outdoor terrace. A layer of basic ambient light is created using a grid of semi-recessed ceiling luminaires. With the entire luminaire housing residing above the finished ceiling, the fixtures appear to be a glowing pieces of glass affixed to the ceiling. Task lighting is added in areas where supplemental light may be needed for various tasks. The most notable addition of task lighting is a central arrangement of pendants above the table. This creates an obvious focal point for the room. Accent lighting is found at the boundaries of the room: slim profile wall grazing luminaires are installed on the back wall and second floor overlook, and small square indicator lights guide residents along a hall to rooms behind the living area.

Through the windows, a glimpse of the garden lighting is visable. Low profile fixtures are illuminating the boundaries of the terrace.

Luminaires used:

LIMBURG Collection

78 047.1

23 225

12 278.1

56 575.1

BEGA

77 069

10 fc

Indoor Swimming Pool

Pool lighting can be divided into two sections: lighting in the pool, and lighting around the pool. For our example, we will presume the pool is internally illuminated with luminaries provided by the pool manufacture, and we will focus mainly on the necessary lighting around the pool on the deck.

For the safety of those using the pool area, lighting on the deck should be addressed from the pool edge to a point extending 10 ft beyond. The IES recommends that this hazard zone be illuminated to 10 fc. An important point to consider when choosing the type of fixture and location is the possibility for glare off of the water. A direct fixture installed directly over the pool surface could create reflective glare and cause temporary blindness in people walking on the deck or for lifeguards on duty. This would create an unsafe situation. To reduce the risk of this reflective glare, the surface ceiling fixtures are installed over the deck in a location where the light distribution is diminished before it hits the water surface.

Additional diffuse surface wall fixtures are installed for ambient light and decoration.

Luminaires used:

BEGA

66 925

33 312

1.0 - 2.0 fc

10 fc

Spa / Health Facility

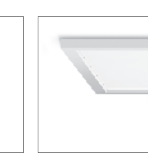
The lighting design for a spa should enhance a feeling of rest and relaxation. To create the appropriate psychological response, the design here uses primarily non-uniform distributions, peripheral lighting, and lower light levels alternating with accented areas. To achieve this effect, many different fixtures are utilized.

In the foreground, recessed ceiling luminaires are used to gently illuminate the room with light. Two main structural columns are accented with the installation of two in-ground floodlights that create a wall-wash effect and highlight the architecture. The main walkway between the hot tubs is illuminated to a higher level using surface ceiling fixtures. This is done for ambience and the safety of people walking through the space. For additional wayfinding and safety, recessed wall step lights are installed along the outer walls. The hot tub areas are illuminated indirectly by using a wall mounted fixture aimed upwards. The light reflected from ceiling is soft, and creates a pleasant light level within the area. Finally, a far wall is accented using more in-ground floodlights.

Luminaires used:

BEGA

66 935



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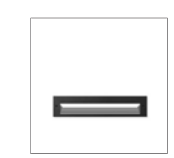

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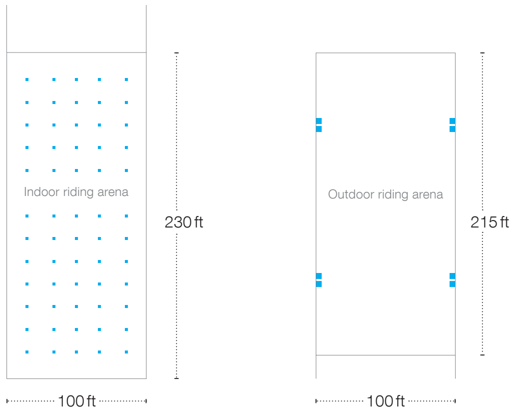
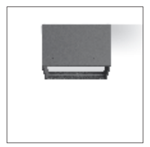


Riding Arena

A riding arena must be illuminated uniformly to ensure the safety of the horses and their riders. The indoor riding area measures 230 ft x 100 ft and is illuminated with powerful directed downlights mounted to the structural ceiling beams. A level of 20 fc is reached on at floor level. There is a secondary outdoor arena measuring 215 ft x 100 ft that is illuminated using powerful pole-mounted LED floodlights. Only eight fixtures are needed to evenly light the space to 15 fc.

Luminaires used:

BEGA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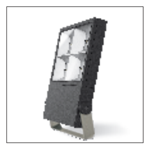
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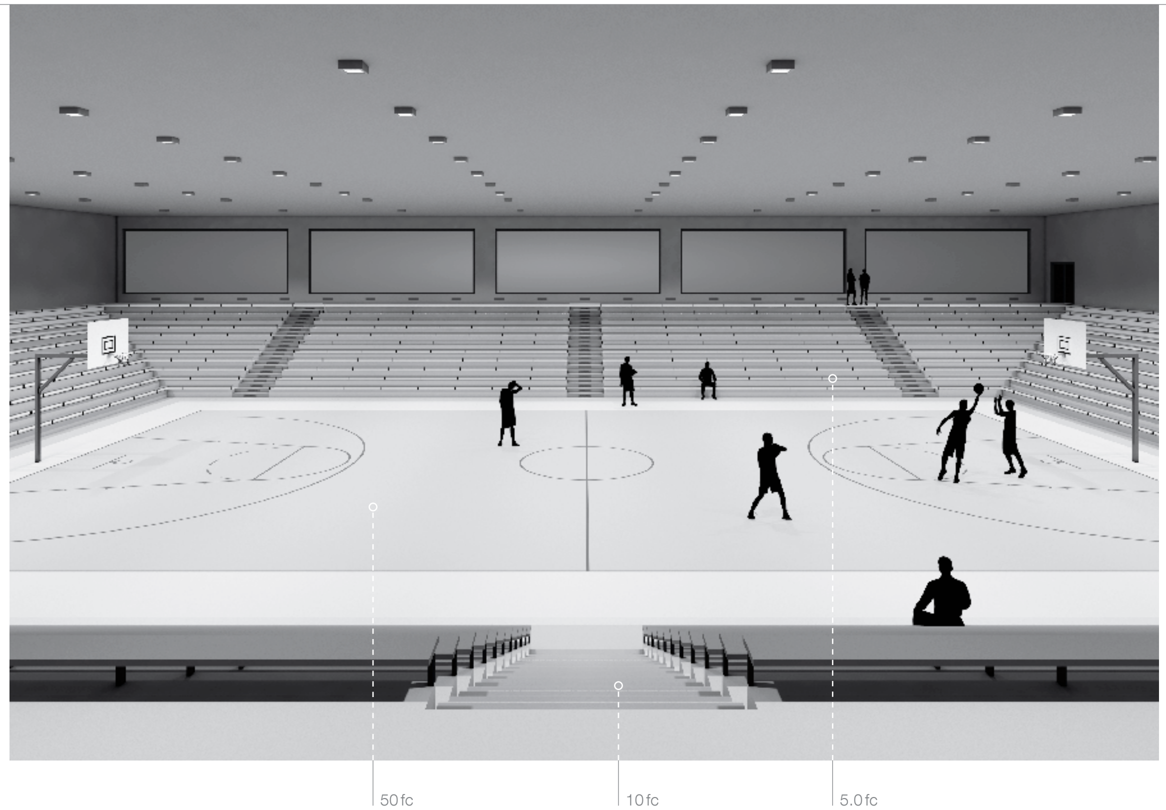


Multi-purpose Gym

Multi-purpose gymnasiums are often found in public recreation centers or in schools. They are used for general training and local competitions. Here, a level of illuminance on the playing field should be at least 50 fc. The general viewing area can be illuminated to a much lower level, around 5 fc. Main aisles and stairs may be lit to 10 fc for wayfinding. The entire space is illuminated using robust surface ceiling mounted fixtures. Extra light on the stairs is achieved through the installation of louvered step lights.

Luminaires used:

BEGA


66 925


22 196

Chapter 2

Technical Information

Quality Characteristics of Illumination

In exterior and interior lighting, the quality characteristics of lighting are determined by the perception of its performance, visual comfort and how it affects the spatial mood and atmosphere. This can further be quantified with the level of illumination as measured by luminance and illuminance, a fixture's light distribution type, the limitation of glare, the luminaire optical performance as defined by a fixture's BUG rating, and by the color rendering index and color temperature of the source.

Visual Performance

The perceived visual performance of a fixture is determined by the level of perceived brightness. This is how bright or dark we perceive a surface to be and is highly influenced by the surface's degree of reflectance. A good rule of thumb is to remember that a highly reflective surface can be illuminated with a lower illuminance value than a surface with a lower reflectance. For example, a white wall is 85% reflective, while a red brick facade is only 25% reflective. In order for the red brick wall to appear as bright as the white wall, a much higher level of illuminance must be directed onto the brick wall surface.

Maintained Illuminance

Often times this concept is overlooked- the maintained illuminance defines the average level of illuminance on a reference surface over time. As the fixture gets older, its light output will diminish due to several light loss factors. To compensate for this, lighting in new construction should be specified with slightly higher starting illumination values.

Maintained Illuminance =
light loss factor x output of brand new fixture

Light Loss Factor

The light loss factor (LLF) is dependent on the type of lamp, the design of the luminaire, the cleanliness of the environment, and the site's maintenance intervals. These factors are further divided into two types: recoverable and nonrecoverable. Recoverable factors can be changed with regular fixture maintenance and cleaning, while nonrecoverable factors are attributed to the equipment itself and cannot be changed with normal maintenance.

Contrast

Light defines the spatial environment, while the addition of light and shade (contrast) gives the room structure. Contrast is quantified by the luminance ratio of adjoining zones. This interplay between light and shadow enables viewers to determine distances and grasp dimensions.

There are two extremes that must be addressed: Diffused light will hardly develop any shadows, while directed light will create strong shadows. When a room is filled solely with diffused light, the room appears monotonous, objects and dimensions are difficult to fully grasp. In a situation with only directed light, individual room elements are strongly emphasized and cast high-contrast or strong shadows. The rest of the room out of the single beam angle remains dark.

Both types of lighting when used individually can feel incomplete, and create discomfort. A balanced combination of both creates a defined and well lit space. For this reason, many luminaires are developed to combine direct and indirect or diffuse output.

Luminance, Illuminance, and Brightness

In the lighting world, many technical terms sound the same but have vastly different meanings. Often, the terms luminance, illuminance, and brightness are used interchangably, when they should not be.

Luminance describes the measurement of light that has reflected off a surface and is absorbed by the human eye. Luminance is dependent on the reflectance value of a surface. Luminance is objectively measured by the amount of candelas over an area. [Cd/ft^2], [Cd/m^2]

Illuminance describes the amount of light that is projected onto a surface. Illuminance is also measured in candelas over an area, but is designated with a different unit, the footcandle [fc]. Illuminance is the most commonly used measurement in lighting application software.

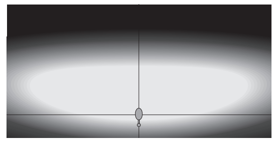
Brightness is not a term used for quantitative purposes at all, but instead is used to describe the visual perception and physiological sensations of light.

Light Distribution Types

A luminaire's light distibution type will depend on the projected beam pattern it produces. Typically, only outdoor light fixtures use these type designations.

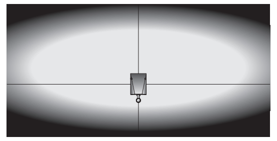
Type II

When the half maximum luminous intensity isoline falls within 1.75 times the mounting height, or has a lateral width of 25 degrees. Typically intended for walkways, roadways, bike paths, and other long, narrow lighting applications.



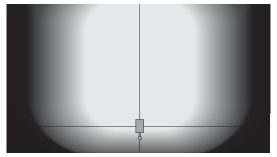
Type III

When the half maximum luminous intensity isoline falls within 2.75 times the mounting height, or has a lateral width of 40 degrees. Ideal for roadways and parking lots.



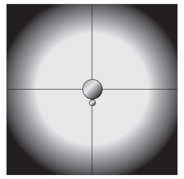
Type IV

When the half maximum luminous intensity isoline falls beyond 2.75 times the mounting height. Typically known as forward throw or asymmetric throw.



Type V

Fixture distributes symmetrically in all directions, usually a circular or square pattern.



Glare

Glare is caused by a direct or reflected view of an unshielded light source. It is perceived as excessive brightness that is physically or psychologically uncomfortable.

Glare Assessment: GR Rating

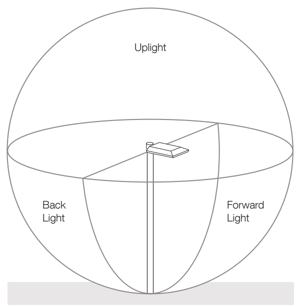
To avoid discomfort, fatigue and temporary blindness, it is important to avoid and mitigate glare. The calculation of glare rating is based upon illuminance on the eye when observing a single point in a field of points from a single observer position. The resulting values range from 10 to 90:

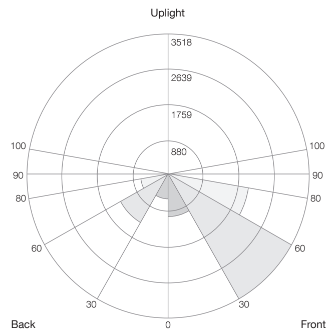
Intolerable	80 - 90
Irritating	60 - 70
Just acceptable	40 - 50
Perceptible	20 - 30
Imperceptible	10

Glare Limitation - Reflected Glare

Reflected glare is used to describe irritations that are triggered by light reflecting off of an exceptionally shiny surface, for example, wet asphalt roads, glossy paper, or computer displays. The occurrence of these disruptions can be avoided with the correct choice of luminaires, lamps and their arrangement both indoors and outdoors.

Reducing the effects of glare involves the measure of light spillage and the fixture's position. Light spillage is a property of the luminaire design and is related to how well the luminaire controls the light and projects it on to the intended area. This concept is up to the luminaire manufacturer to address, and is typically accomplished with the incorporation of shades, reflectors, or lenses which reduce light projection in unintended area and therefore reduces fixture glare. The other property which influences glare is the fixture position. In general, a fixture that is positioned directly overhead will result in less glare than the same fixture positioned off-center.





BUG Rating

A fixture's BUG rating may be used to evaluate its optical performance. There are three primary solid angles that relate to the evaluation of light trespass, light pollution (sky glow), and glare. They are backlight, uplight, and forward light.

Backlight is the primary cause of light trespass, or unwanted light in adjacent lots. For example, a street light in a residential neighborhood that produces a lot of backlight will be shining unwanted light into the windows of the houses behind it. Backlight is evaluated between 0 and 90 degrees vertical, and falls in the horizontal 180 degrees behind or opposite from the area intended to be lit. This B rating takes into account the amount of light in the BL (back low, 0-30deg vertical), BM (back medium, 30-60deg vertical), BH (back high, 60-80deg vertical), and BVH (back very high, 80-90deg vertical).

Uplight is any and all light that is directed above 90 degrees, and is the main cause for light pollution or artificial sky glow. The U rating takes into account the amount of light in the UL (Upper low, 90-100deg vertical) and UH (upper high, 100-180deg). Any lumens that fall into the UH category are considered to be wasted energy.

Forward light describes the light that is directed in front of the fixture. This zone is defined between 0 and 90 degrees vertical and 180 degrees horizontal directly in front of the luminaire. The G rating takes into account the FH (forward high, 60-80deg) and the FVH (forward very high, 80-90deg), as well as the BH and BVH, which can cause glare to someone looking directly at the fixture.

The BUG rating is quickly replacing the old designation for shielding, full cutoff, semi cutoff and non cutoff because it has proven to be a more accurate and useful measure of how the fixture performs.

Correlated Color Temperature (CCT)

The correlated color temperature (CCT) is a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from the absolute temperature of a blackbody when heated, measured in degrees Kelvin (K). The CCT ratings for a lamp is the general 'warmth' or 'coolness' measure of its appearance.

This color can directly influence the mood of a space. Warm light colors (up to approx. 3000K), have a higher orange content and tend to have a calming effect. In western culture, warm light is associated with feeling comfortable and cozy, and is the primary choice for residential lighting. Cool light colors (4000K and up), have a higher blue content and tend to have the opposite effect: cooler lighting promotes productivity and is seen as modern and clean. Cool light is more common in retail shopping centers, offices, and health facilities.

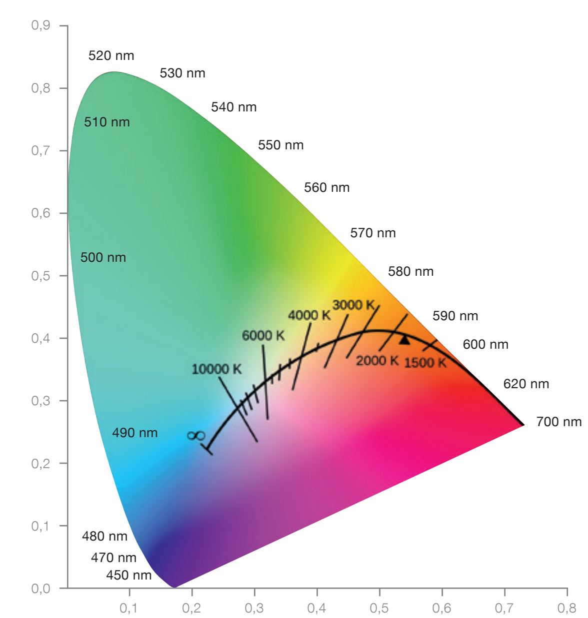
Color temperatures in Kelvin:

warm white	3000 K
neutral white	4000 K
cool white	5000 K

The color of white can be quantified by a set of three numbers, the CIE coordinates X, Y and Z which specify the color and brightness of a particular source. The chromaticity is the color projected into a two-dimensional space that excludes brightness, and is often graphed as seen on the next page: the colors of the visible spectrum appear around the upper edge (in nm). The Planckian locus shows the path of color a blackbody takes with temperature change, and is overlaid on the chromaticity diagram.

The mathematical procedure for determining CCT involves finding the closest point to the light source's white point on the Planckian locus. However, two sources that appear very different can technically have the same color temperature. This is especially true with LED sources. BEGA has addressed this concern- our strict quality standards ensure that our LED modules have a maximum deviation of three MacAdams ellipses from a specified color coordinate.

A MacAdams ellipse is an elliptical region on the CIE chromaticity diagram that contains all colors that are indistinguishable to the average human eye. Adjacent ellipses are 'just distinguishable' in terms of color.



Color Rendering Index (CRI)

Color rendering describes how well a light source is able to reveal colors of various objects in comparison with an ideal source. The CRI of a light source is determined by the source's spectral power distribution, the radiant power emitted by a light source at each visible wavelength in the electromagnetic spectrum. These values can be graphed into an easily understandable pictorial representation and is discussed in the next section. The spectral output of a light source affects its ability to render colors.

The quantification of color rendering is calculated by a comparison of a source's ability to render colors to that of a ideal source, usually sunlight or an incandescent lamp. The actual procedure involves comparing the appearance of eight color samples under a source to those same colors under the ideal source. The average of the differences in appearance is subtracted from 100 to get the CRI rating. The lower the CRI rating, the less accurately the source will render colors. Halogen and incandescent bulbs typically have a high CRI rating between 95-100,

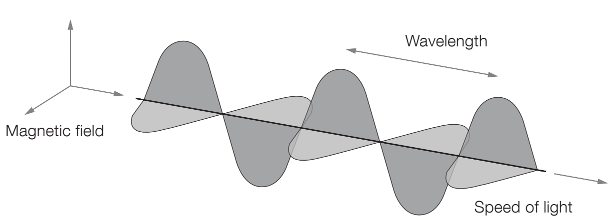
The traditional CRI rating method is widely used, but does not take into account lamps that fall to an extreme color temperature. Two sources could have the same CRI, but one could be excessively blue and the other excessively red. Surely one of those sources would render warm colors very well, but the other could render them quite poorly. Because of this, an additional metric should be considered when choosing a source. R9 is a saturated color test that measures how accurately a source will render reds. Lamps with high R9 values will show the most vivid reds. The color of many items including fruit and vegetables, skin tones, and some art galleries will appear washed out and pale if a lamp does not contain enough red wavelengths.

Physical nature of light

What is light?

Light in the strictest sense of the word refers to electromagnetic radiation that can be perceived by the human eye. Usually, the word light is referring to the visible spectrum, that is, electromagnetic radiation with a wavelength between 400-750 nanometers, between infrared and ultraviolet.

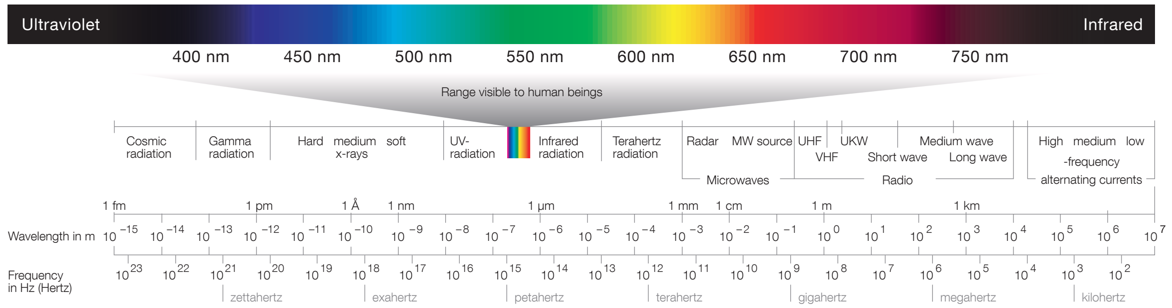
Back in the late 1600s, an important question was raised: Is light made up of particles? Or is it made up of waves? At the time, some experiments conducted on light supported both wave theory and particle theory, leading to difficulty in explaining which was correct.



In 1905, Albert Einstein proposed that light was, in fact, both. From the work of his predecessors, Einstein suggested that light is composed of tiny particles called photons- each photon is a very small packet of energy. One effect of this wave-particle duality is that photons, though treated as particles, can be calculated to have frequency, wavelength, and amplitude.

Light wave theory shows that monochromatic light can be described as continuous electromagnetic radiation of a certain frequency and intensity. Specific frequencies, or wavelengths, can be assigned to various individual colors. If we arrange the wavelengths in order, the result is the well-known spectrum of visible light.

The wavelength of the individual color corresponds to the relative energy content of the light. In relative terms, red light (~700nm) has less energy than blue light (~400nm). In 1900, German physicist Max Planck recognized the proportional constant between the energy of a photon and the frequency of its associated electromagnetic wave. This discovery is widely recognized today as Planck's constant. The significance of Planck's constant is that light is emitted, transmitted, and absorbed in discrete energy packets, or photons, determined by the frequency of the radiation and the value of Planck's constant. It essentially describes the behavior of particles and waves at an atomic level, as well as the particle nature of light.

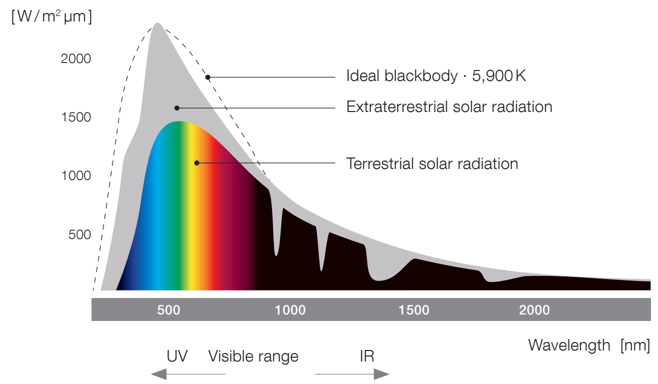


Today, light's particle behavior is primarily studied through quantum mechanics, or the study of the motion and interaction of subatomic particles. If we leave the macroscopic field, light (and other forms of radiation) is shown to have a discontinuous nature, which is contradictory to wave theory. The radiant energy is characterized by certain granularity. Light, it seems, is the transmission of tiny units (photons) that travel in waves.

Looking at the bigger picture, particle behavior of light can be simplified into a basic ray model. Rays of light are emitted from a source in all directions until they either hit a surface and are reflected, refracted, or scatter, or until the ray is absorbed by the human and eye and interpreted.

In physics, the superposition principle states that for all linear systems the net response caused by two or more stimuli is the sum of the responses which would have been caused by each stimulus individually. When two or more waves traverse the same space, the net amplitude of each point is the sum of the amplitudes of the individual waves. So, in accordance to this principle, light waves can be freely mixed.

Radiation intensity of the sun



Adding individual monochromatic components creates mixed light. If a spectrum of light source contains all visible wavelengths, and their intensities are somewhat evenly distributed, the light appears to be white in color. The most pure, ideal spectrum of white light is represented by sunlight. The spectral composition of white or mixed light can be identified, separated and quantified. We call this a source's spectral power distribution.

The quality of an artificial light source must always be comparable with sunlight. As a result of millions of years of evolution, our eyes have adapted to the quality and spectral characteristics of sunlight.

Biological response to light

The energy of sunlight supports almost all life on earth by photosynthesis. Water and light react and release oxygen, while the biproducts mixed with carbon dioxide to produce surgar through the Calvin Cycle. This sugar (or glucose) is the energy supply for cell respiration, which is the driving force for life. These producers (plants, algae, etc.) are consumed by consumers (all animals, fungi and mankind). Besides supplying energy, sunlight also has profound relationships with various biological systems including day-night plant cycles in nature, circadian rhythm in all living things, the earth's ecosystem and its effect on the weather and seasons.

In the course of human evolution, mankind has developed a direct internal link to the natural 24-hour cycle of light and dark. This internal clock is the reason humans tend to be tired and unmotivated at night; it is simply because the body is preparing for sleep and recovery. In the morning, when they wake up, their efficiency increases significantly and peaks around mid-day. The early afternoon brings a slight energy slump, but is then followed by a second energy increase in the late afternoon. As the evening wears on and the sun goes down, the body once again relaxes and prepares for rest. The study of these cycles is called chronobiology.

The human biological response begins when light enters the eye through the pupil and the lens to the back of the eye. The inside lining of the eye, the retina, is comprised of special photosensitive cells. The retina converts the light into electrical impulses, which are carried through the optic nerve to the brain. There are three types of photoreceptor cells found within the retina: rods, cones, and photosensitive retinal ganglion cells. The rods and cones translate the incoming light to form a representation of the visual world in our brains, sight. The photosensitive ganglion cells do not contribute to sight, but instead are the main cues for circadian rhythms and pupillary reflex. Light exposure is the primary stimulant or suppressant for the hormone melatonin, which normally makes people tired and initiates the sleep cycle.

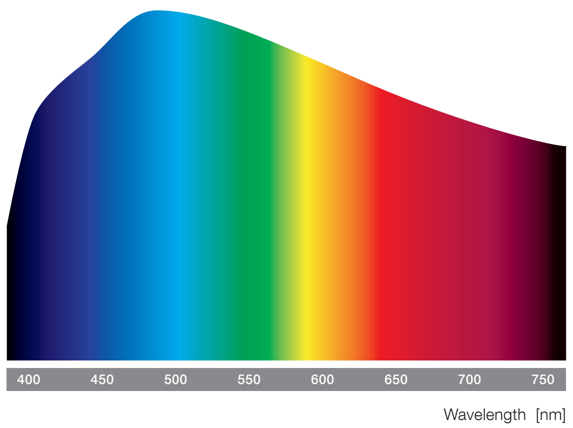
The receptiveness of the photosensitive ganglion cells has been directly related to the amount of blue content of light, which indicates a direct relationship with sunlight exposure. Insufficient exposure to suitable light during the day disrupts the hormonal synchronization of the biological clock and can lead to insomnia, reduced motivation and moodiness.

In some parts of the earth, where the length of day is dramatically reduced during the autumn and winter months, the lack of exposure to sunlight has been linked with depressive symptoms or seasonal affective disorder. A notable shift in the circadian process occurs with the lack of light stimulation. These symptoms can be reversed with high exposure to good quality lighting, a strategy sometimes known as light therapy.

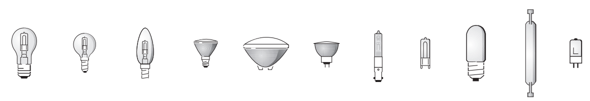
The effects of lighting on our biological systems can be felt in ways other than from traditional or natural lighting sources. The light from our phones, computers, e-readers, and television is short wave enriched meaning it has a higher concentration of short-wavelength light than natural light. Exposure to this blue light at night suppresses melatonin production significantly, and has been linked with insomnia, and circadian delay (inability to wake up in the mornings). The opposite is true during the day: exposure to higher energy, blue light has been shown to improve concentration and productivity in office spaces, schools, and health facilities.

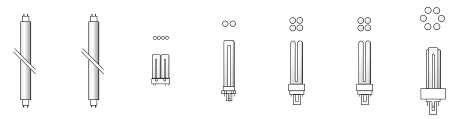
One of the core tasks of illumination with artificial lights should be to create and support optimum lighting conditions. Visual tasks must be identified and solved, and aspects such as comfort and well-being should be considered.

Daylight spectrum



Types and properties of lamps





Temperature Radiators

In ancient history when humans moved from using stone tools to metal tools, man became aware that heating metal caused it to glow and create visible light. For example, as iron is heated to a high temperature, it first glows red, then orange, yellow, and finally white. The color of the metal became the primary indicator for when the metal had reached forging heat, that is, when the metal has become hot enough to hammer and shape into various tools.

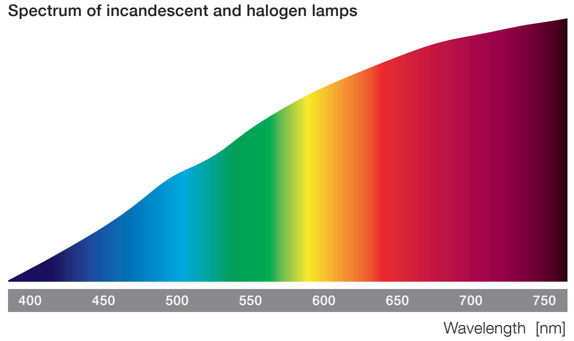
The blackbody theory describes this phenomenon in physical terms: the metal represents the black body and as it is slowly heated it will emit thermal radiation. As the temperature rises, the metal begins to emit long-wave light (infrared). Soon, the radiation gradually shifts into the visible spectrum, a dark reddish tone. As the metal becomes hotter, the more high energy waves are emitted. The color eventually becomes more and more orange, yellow and then finally white. The light emission caused by thermal excitation creates a continuous spectrum.

The very first incandescent and halogen bulbs were created using this principle. Electricity when passed through a conducting wire (filament) will create heat, and therefore, light.

Incandescent and Halogen Lamps

Modern day incandescent lamps use a tungsten filament that is enclosed in a vacuum or gas-filled bulb. Tungsten is used due to its high melting point, high temperature stability, and its inactive properties which protect it from premature oxidation from its interaction with filler gasses. These bulbs are cheap to manufacture, have good color rendition and excellent optical control.

Spectrum of incandescent and halogen lamps



Since the lamp's light emission is created from heat, and therefore has a continuous spectrum, the incandescent lamp can nearly perfectly render colors and has a CRI of 100. Dimming this type of lamp is simple, you can lower the filament temperature by lowering the voltage. The disadvantages of an incandescent lamp are its short service life (approx 1500 hours) and its low efficacy.

The filament of an incandescent lamp must burn at a very high temperature, nearly 5500 F (3200K). This high temperature causes a continuous vaporization of the tungsten wire. The tungsten atoms are released into the filler gas of the bulb. As they move away from the filament, the temperature reduces significantly, and the tungsten atoms end up deposited on the inside of the glass bulb, causing it to blacken over time. The lamp will fail when the tungsten fillament wire has become so weakened that it breaks.

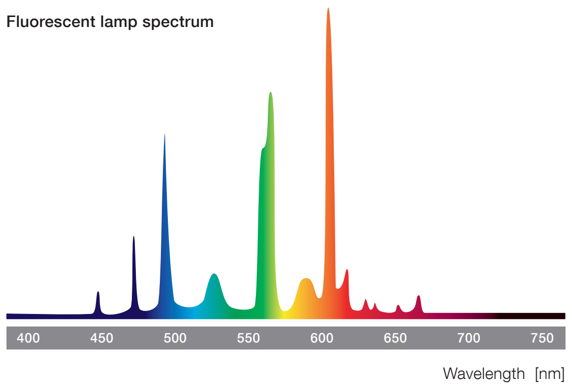
In halogen lamps, small quantities of inert halogen gasses such as chlorine, bromine, or iodine are added to the bulb's filler gas. The name halogen means 'salt-producing'. In these bulbs, tungsten atoms are vaporized and transmitted into the filler gas, but instead of just floating around until being deposited on the glass, they react with the halogen gas. For example, tungsten iodide is formed when tungsten reacts with iodine. The compound does not become deposited on the glass of the lamp, and is instead deposited onto a colder area of the filament, where it decomposes back into tungsten and iodine. This is called the halogen cycle, and greatly improves the service life and luminous efficacy of the lamp.

Fluorescent Lamps

Fluorescence is the emission of visible light by a substance that has absorbed light and ultraviolet radiation, and is not created by heat. This cold-body radiation is called luminescence, and can be created by a chemical reaction or from electrical energy on a subatomic level.

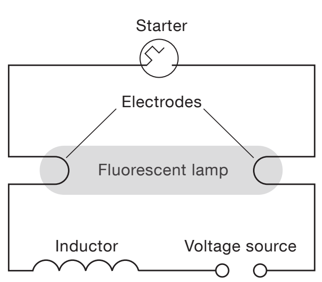
The conversion from electrical energy into radiant energy inside a fluorescent lamp is built upon the properties of luminescence. At an atomic level, a fluorescent lamp produces light by introducing an electric field to vaporized mercury. When the free electrons have enough kinetic energy, they transfer to a mercury atom's outermost layer of electrons, elevating that atom to an excited state. This higher energy state is unstable, and the atom emits photons before returning to its ground state. The construction of a fluorescent lamp starts with a glass tube filled with low pressure mercury vapor. At each end of the tube there is an electrode where voltage is applied to induce an electric field. After ignition, a current flows between the two electrodes, creating a mercury plasma and the emission of photons. Most of the photons emitted from the mercury atoms have wavelengths in the ultraviolet spectrum.

Fluorescent lamp spectrum



The inside of the glass tube is coated with phosphors. Thus luminescence is created when the ultraviolet wavelengths are absorbed by the phosphors and transmitted into the visible spectrum.

Fluorescent lamps create negative resistance. As more current flows through them, the electrical resistance drops, allowing for even more current to flow. Without some form of limitation, the current flow in the lamp would increase rapidly and lead to the destruction of the lamp. In order to regulate the current flow, fluorescent lamps must be operated with a ballast.



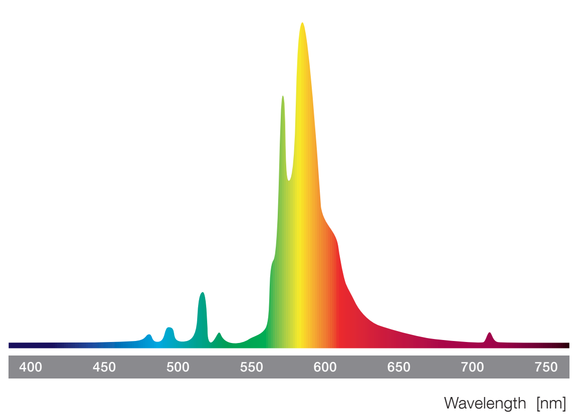
The diagram on the previous page shows the typical spectrum of a normal fluorescent lamp. Compared to the spectral distribution of sunlight, it is highly discontinuous; light from the lamp consists of several peaks in the blue, green, and red wavelengths. While our eyes perceive the light as white, such lamps are frequently associated with moderate color rendering properties due to their uneven distribution of wavelengths. Fluorescent lamps are characterized by an acceptable luminous efficacy and a relatively long service life (up to 45,000 hours).

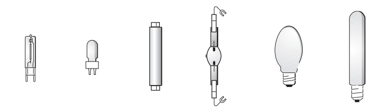
Sodium Vapour Lamps

Sodium vapor lamps use the photon emission of sodium plasma to generate light. These lamps have a discharge tube containing solid sodium and at least one assist gas, typically neon and argon. At each end of the discharge tube there is an electrode where voltage is applied to induce an electric field. After ignition the assist gas will quickly begin to conduct current through the lamp and take on a plasma state. This causes the lamp to heat up, and the sodium will begin to vaporize. As the sodium plasma content increases, the light will change color from red to a distinct yellow. This process happens over a few minutes.

Unlike fluorescent lamps, the sodium discharge emits light within the visible spectrum. Low-pressure sodium lamps are characterized by their dominating yellow monochromatic light, while high-pressure sodium lamps generate mostly the dominating yellow but also several other wavelengths. Since these lamps only have one dominating spectral line, they actually have the lowest interference with astronomical observation and the lowest impact on surrounding ecosystems, especially around areas that are known sea turtle nesting beaches. This makes them somewhat desirable sources near observatories and beaches. Both types of lamps have poor color rendering, but have high efficacy and a moderate service life (approx 18,000 hours).

Sodium lamp spectrum



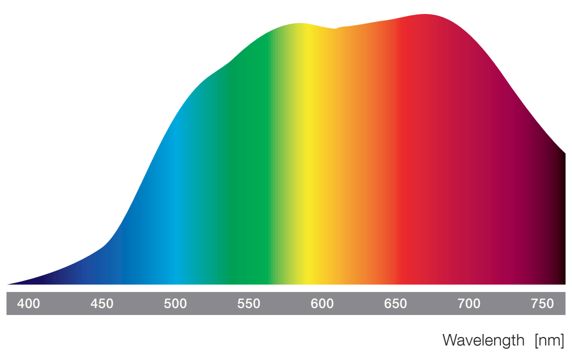


Metal Halide Lamps

This lamp uses an arc tube with high pressure mercury vapor and a mix of other halide salts, that is, a chemical compound of a halogen combined with an electropositive metal. As with the sodium vapor lamp, some of the substances are initially solid, and are vaporized during the startup phase by the sharp rise in temperature within the arc tube.

The lamp is ignited by a high voltage impulse, which starts the current through the assist gas. Via negative resistance, the current flow will continue to increase and heat up the other components, eventually leading to the vaporization and ionization of all filler materials. This startup phase takes up to 60 seconds, and only after this phase will the lamp reach its full brightness. The composition of the halide salts will determine the color temperature of the lamp. These lamps are characterized by a high efficacy, a life up to 15,000 hours, and they have excellent color rendering properties.

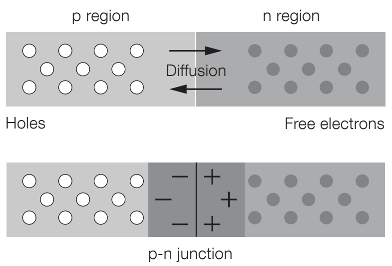
Metal halide lamp spectrum

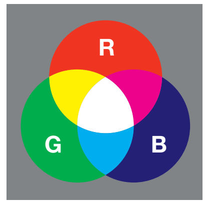


Solid-state emitter

Light-Emitting Diodes (LED)

An LED chip produces photons through a one-way current flow semiconductor, and harnesses the use of free electrons and so called ‘holes’. When current is applied to the system, the electrons reach an excited state and emit photons.





Looking a little closer, the diode of the LED is actually created from two wafer-thin semiconductor layers. These layers are created, or grown, from a crystalline silicon and serve as a housing for microelectronic and microfabrication processes. The semiconductor’s conduction properties can be altered by the introduction of trace elements. Elements such as boron or phosphorus can be added to the semiconductor material in precise amounts, ‘doping’ the crystal substance and changing it to either a net positive (anode) or net negative charge (cathode).

These two layers are called an ‘n’ region and a ‘p’ region. The n-type (the cathode) semiconductor contains a surplus of free electrons, giving the region a negative charge. In the p-type region (the anode), there is a surplus of ‘free holes’, which is the opposite of a free electron, giving the region a positive charge. The contact area between the two layers is called the p-n junction.

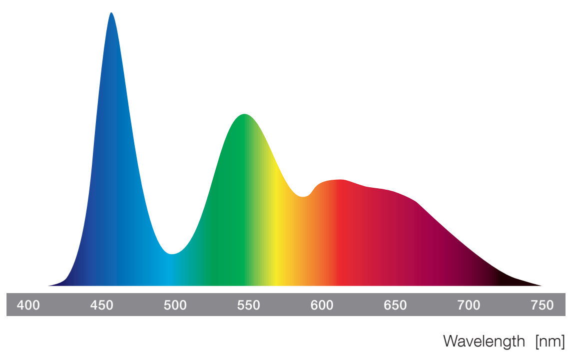
When a voltage source is applied to the diode it becomes conductive, and the electrons and the holes are driven into the p-n junction, where they combine and release energy. This energy is released as heat (infrared) and light (photons). The modern understanding of the properties of a semiconductor relies on quantum physics to explain the movement of charge carriers in a crystal lattice.

The wavelength of light emitted from an LED source is constant, and the range is fairly narrow. White light can be generated two different ways. As previously discussed, light is additive. The emissions of red, green, and blue LEDs can be mixed with each other in precise quantities to produce a spectral power distribution that appears white. Light from an RGB white source is not of optimum quality, its spectrum is very discontinuous due to the individual wavelength peaks of each of the LEDs.

Significantly better white LED light can be achieved with the help of phosphors. This method uses a short-wave LED such as blue or ultraviolet, and a phosphor coating. Usually the phosphors yttrium, aluminum, and gallium (YAG phosphors) are used; they emit a light in the yellow-green range. The combination of the short wave and the phosphor emissions result in high quality white light. Current developments in the research of phosphors and LEDs are constantly aiming to improve the spectral composition and raise the quality of these sources.

LEDs are characterized by an excellent service life, which is usually in excess of 50,000 hours. Unlike other lamps, which completely fail at end of life, the LEDs will not stop working at this point, but the light output will slowly continue to degrade. The service life is defined as the point at which the luminous flux (F) drops below 70% of its original output.

LED spectrum

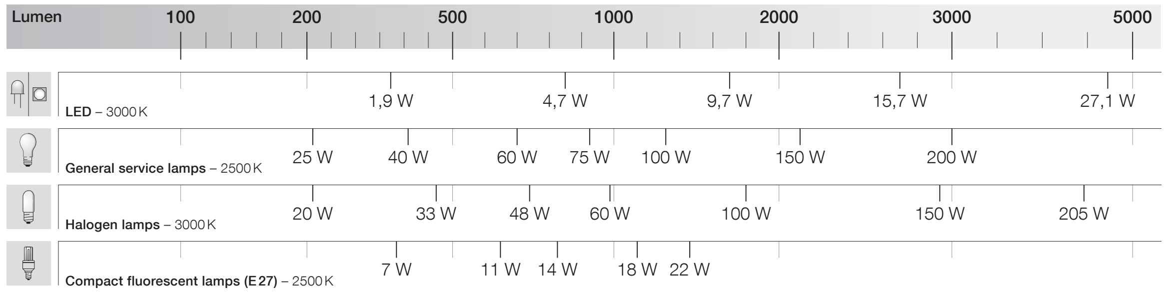


Organic Light-Emitting Diodes (OLED)

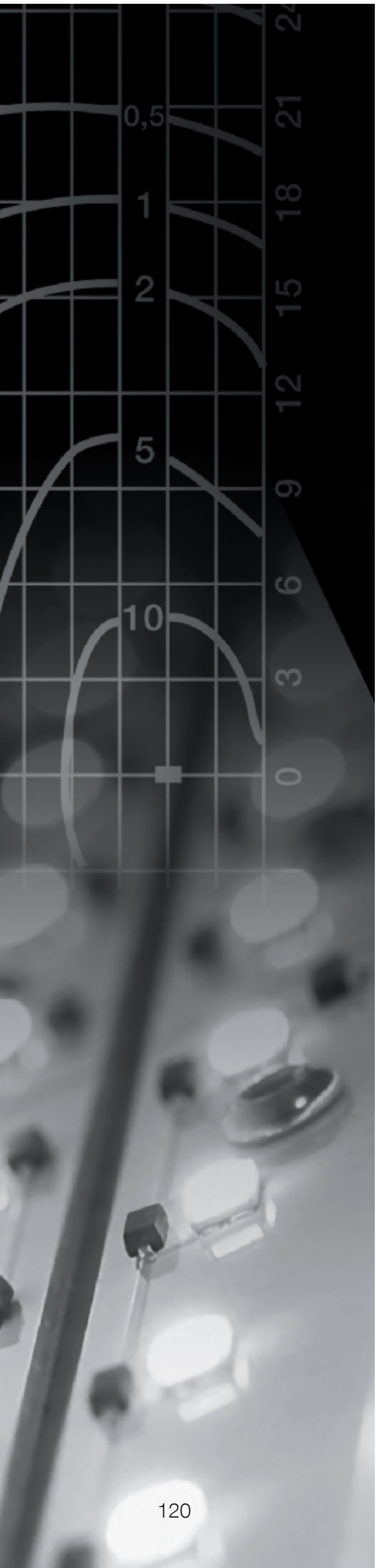
OLEDs operate in almost exactly the same way normal LEDs do. The biggest difference is the addition of carbon to the semiconductors. This allows for the semiconductor to be made of polymers (very thin layers of organic material), or amorphous small molecule layers. In OLED manufacturing, several successive organic layers are applied to a conductive substrate between two electrodes. The color of the light depends on the molecular structure of the organic semiconductors.

This new technology is leading to light sources that are lighter and smaller than anything on the market, are more energy efficient, and can be used in a range of new applications where lighting technology has never been used before. Although OLED products are commercially available, they are still considered to be in the development stage.

Light output
The following diagram enables the luminous efficiency of LED to be compared with that of conventional lamps (last revised: January 2016).



Technical parameters of LED luminaires



Often times the selection of LED fixtures can be tricky, as there is no real standard for the assessment and comparability of technical parameters for LED luminaires. It does not take long before you will run into huge variances in price, wattage, and quality.

The most important parameters are described below. These parameters should be listed on any manufacturer's specification sheet, or the information should be readily available if requested. Comparing these parameters is immensely helpful in the selection between LED luminaires.

Module luminous flux (nominal value)
The luminous flux (ϕ) of an LED module, measured in lumens (lm). This value defines the luminous flux which is created by an LED module at an ambient temperature of 25 °C.

Luminaire luminous flux (rated luminous flux)
The luminous flux (ϕ) of a luminaire, measured in lumens (lm). This value defines the total luminous flux which is emitted by the luminaire.

Module connected wattage (nominal value)
The connected power of an LED module measured in watts (W). This value defines the power which is consumed by an LED module.

Luminaire connected load (rated input power)
The connected power of a luminaire measured in watts (W). This value defines the total power which the luminaire consumes. This value covers all the installed components, e. g. LED module(s) and driver(s).

Luminaire luminous efficacy
The luminaire luminous efficacy is the ratio of the emitted luminous flux and the electric power consumed by the luminaire. The value is expressed in lumens per watt (lm/W).

Color temperature
The term "color temperature" is used for the light color of white light. It is expressed in Kelvin [K]. The term warm white is used up to 3000 K, neutral white from 3000 K to 4500 K, and daylight white over 5000 K.

Color rendering index
The color rendering index (CRI) stands for the degree of conformity between the perceived color of an object and its appearance under a specific light source.

Service life criteria
The aging process in electronic components, in particular in light-emitting diodes, is a function of the temperatures they are exposed to in operation. The higher the temperature of the component, the shorter the expected service life. LEDs have a service life in excess of 50,000 hours. Service life is defined as the point at which the luminous flux (F) drops below 70 % of its original output. The LEDs will not stop working at this point, but the light output will slowly continue to degrade.

Voltage
The maximum electric rated voltage, measured in volts (V), at which a luminaire is allowed to be operated.

Module designation
All BEGA LED luminaires are fitted with modules adapted specifically to them, produced on our own premises. Unlike conventional lamps, which have clearly defined connection standards, LEDs are integral components of luminaires. Accordingly, it is difficult to obtain suitable LED replacement modules without specialized knowledge. As a responsible manufacturer, we have solved this problem for our customers. A lamp designation in each LED luminaire gives exact information about the modules installed. We guarantee our customers that even 20 years after buying an LED luminaire, they will still be able to obtain replacement modules from us. Perhaps the technology and design of the components will have changed by then – nonetheless, the light color and output of these spare parts will match those of the LED modules originally supplied.

Photometric information

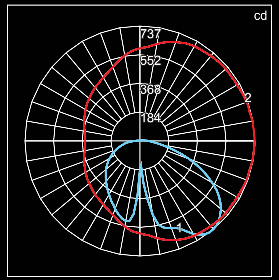


Fig. 2: Polar Curve
77 151

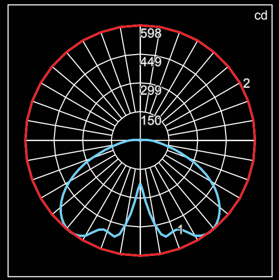


Fig. 3: Polar Curve
77 135

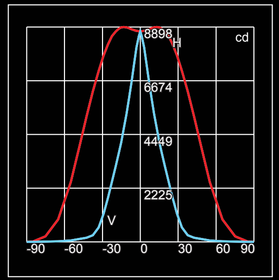


Fig. 4: Polar Curve
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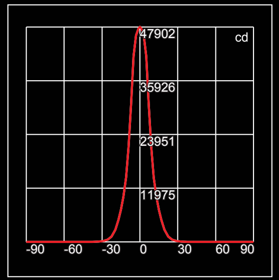


Fig. 5: Polar Curve
77 584

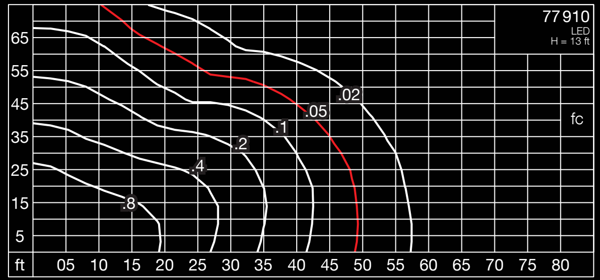
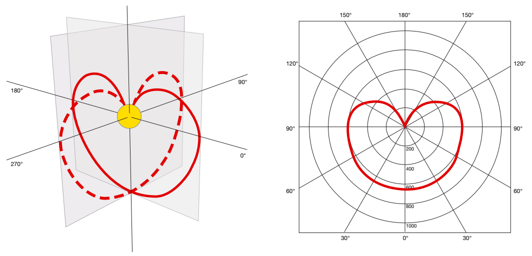


Fig. 6: Isofootcandle Diagram

A fixture's photometric information can be extremely valuable and useful when planning a lighting design. Each fixture will have a unique light distribution curve or axial candela display, and is accompanied by an isofootcandle diagram. The following section is an explanation of how to interpret this information and how to apply it in practice.

Fig. 1



Light distribution curves

A luminaire's light distribution curve is a graphical representation of the intensity and direction of it's light emission, measured in candelas [cd].

Light distribution curves are usually plotted in a polar coordinate system (Figure 1), and is respectively called the fixture's polar curve. This diagram shows cross sections for both a vertical plane through a horizontal angle, and a horizontal cone through a vertical angle. The cross section is taken through the maximum candela value. In Figure 2, the blue line represents the vertical plane, and the red line is the horizontal plane.

A polar curve is an easy way to quickly understand what the fixture's light distribution will look like, whether it is symmetrical or asymmetrical, and its relative intensity.

Figure 2 and Figure 3 show two fixtures that look the same but have different light distributions. Figure 2 shows a fixture with a Type III distribution. At a glance, it is clear that this fixture has an asymmetrical distribution: one side of the fixture will have relatively more light output (a higher intensity) than the other side. Figure 3 shows a fixture with a Type V distribution, which is clearly symmetrical.

Axial candela display

The light distribution curve for a floodlight is plotted on cartesian coordinate system (Figure 4) and is called an axial candela display. In Figure 4, the luminous intensity [cd] values are given on the vertical axis, and the beam angle is given on the horizontal axis. It is graphed so that the most important floodlight characteristics are shown: the horizontal and vertical beam angles (at 50% maximum candela), and the horizontal and vertical field angles (at 10% maximum candela).

Two floodlights are shown in Figure 4 and Figure 5. Figure 4 shows a round floodlight that has a symmetrical beam. The horizontal and vertical beam angles will be the same, so the lines are plotted together. From this graph we can determine the beam angle by looking at the 50% candela line. We can also find the field angle by looking at the 10% candela line.

Figure 4: Beam Angle [β] = 17° Field Angle = 34°
Figure 5 shows a square floodlight that produces a flat beam. The horizontal and vertical beam angles are different.
Figure 5: Horizontal Beam Angle [β] = 92°
Vertical Beam Angle [β] = 28°
Horizontal Field Angle = 131°
Vertical Field Angle = 63°

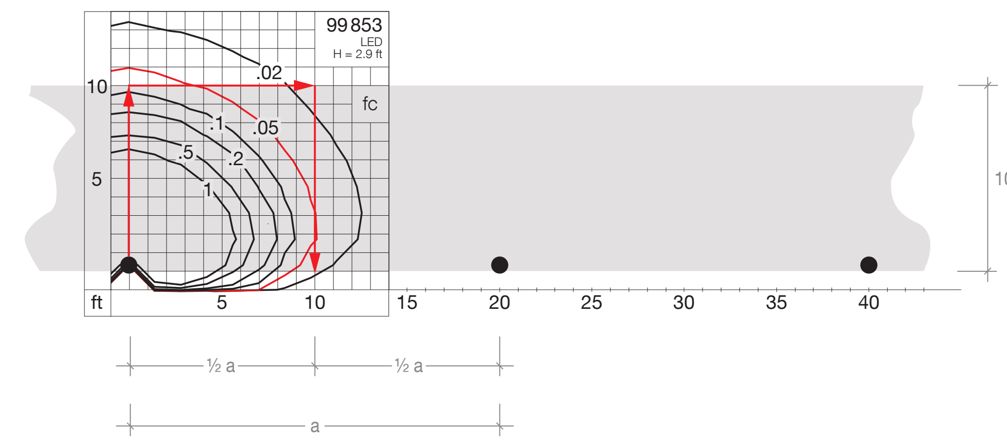
Isofootcandle diagrams

An isofootcandle diagram is used to specify the distribution of the light on a visible surface.

Points with the same illuminance value are connected to each other with isolines. Depending on the luminaire type, the mounting height or the appropriate pole height is specified [h]. The configuration of these isolines allows us to infer the relative gradient and gives us the ability to estimate the light level at specific intervals.

In the isofootcandle diagram shown in Figure 6, the 0.05 fc line runs laterally at a distance of 50 ft from the fixture origin. If a path is to be illuminated with a minimum illuminance value of 0.1 fc, then the spacing for the fixture will be around 100 ft. This procedure allows the lighting designer to make a quick estimate on the number of fixtures they will need for a design. If the luminaire has a symmetrical light distribution (Type V) the resulting isofootcandle lines are concentric circles.

Determination of the luminaire spacing “a” for illumination of a pathway with BEGA 99 853 using the luminaire‘s isofootcandle diagram

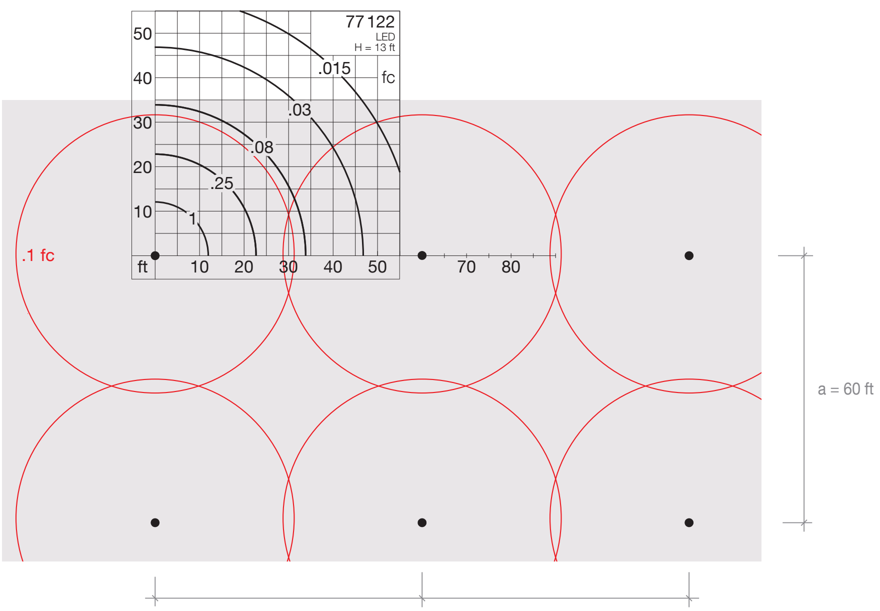


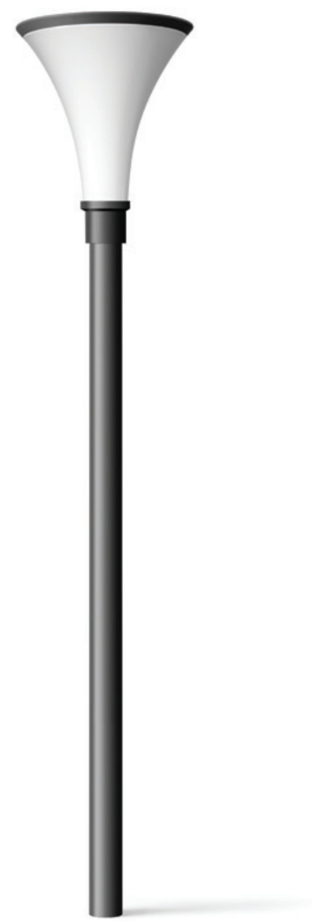
99 853 + 99620

A lighting designer wants to use an asymmetric bollard to light a footpath. During planning they decide on a minimum illuminance level of 0.1 fc, and therefore reference the 0.05 fc line on the isofootcandle diagram. Based on this diagram, 10 ft from the bollard the illuminance on the pathway will be 0.05 fc. So, if another bollard is placed 20 ft from the first, the illuminance level between the two will add up to 0.1 fc.

In practice

Determination of the luminaire spacing “a” for illumination with BEGA 77 122 using the luminaire’s isofootcandle diagram

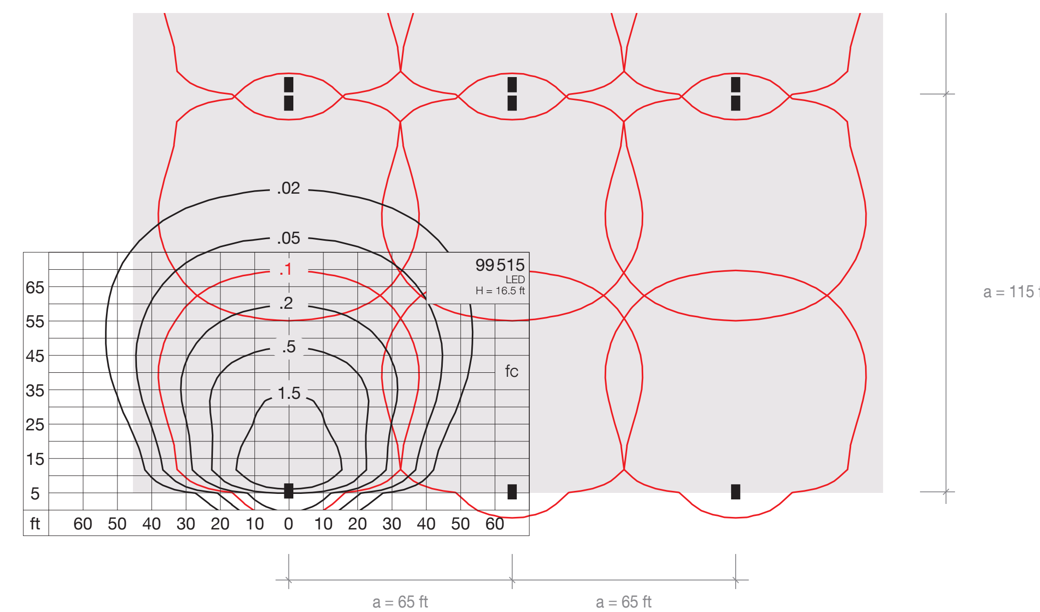




77 122

For luminaires with a symmetrical light distribution (Type V), the isofootcandle diagram will be a series of concentric rings. The average degree of illuminance for a plaza should be 0.2 fc. About 1 fc is reached directly at the luminaire. In order to obtain an average of 0.2 fc, the minimum illuminance between two luminaires should be about 0.1 fc. In the diagram, the red circles indicate these values. The luminaire spacing will be around 60 ft.

Determination of the luminaire spacing “a” for illumination with BEGA 99 515 using the luminaire's isofootcandle diagram



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The same principle applies for luminaires with an asymmetrical light distribution. Since this fixture pushes more light forward, the spacing to the front will be farther than the spacing to either side. The luminaires are arranged along the edge of the plaza, with the twin version illuminating the center.

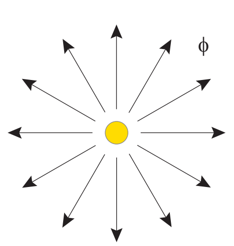
Lighting variables and formulae

Luminous flux

Luminous flux defines all of the light that is emitted by a lamp in all directions.

ϕ Manufacturer's specification

Symbol: ϕ
Unit: Lumen
Abbreviation: lm



Spatial angle

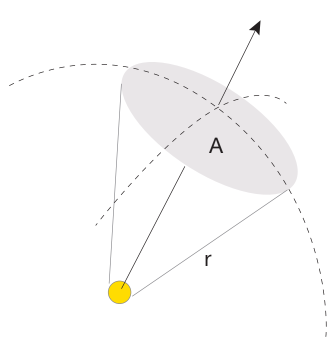
The solid angle describes the relationship between the size of an illuminated surface and the square of the distance between the light source and the surface. It is a two-dimensional angle in a three-dimensional space.

When the solid angle [Ω] is constant, the farther the distance [r] the larger the area [A] becomes.

$$\Omega = \frac{A}{r^2}$$

Symbol: Ω
Unit: Steradian
Abbreviation: sr

A: illuminated surface (spherical cap) in ft^2
r: Distance from illuminated surface in ft



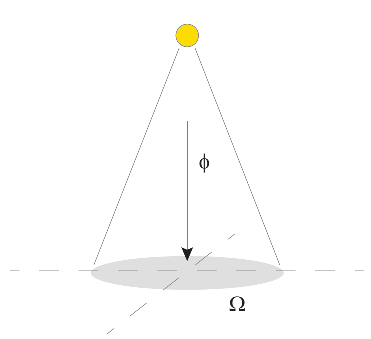
Luminous intensity

The luminous intensity is the relationship between the luminous flux that is emitted at a small spatial angle and the size of this spatial angle.

Luminous intensity is a measure for the light emission from a light source in a certain direction.

$$I = \frac{\phi}{\Omega}$$

Symbol: I
Unit: Candela
Abbreviation: cd



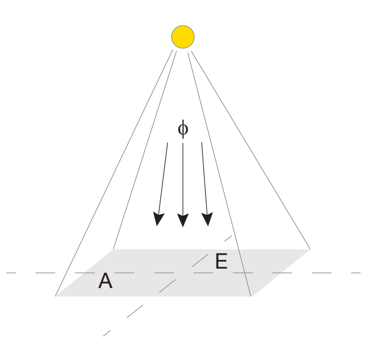
Illuminance

Illuminance determines the relationship between the luminous flux that falls on an illuminated surface and the size of the illuminated surface. The degree of illuminance is a measure of the light striking a surface.

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

$$E = \frac{I}{r^2}$$

Symbol: E
Unit: Footcandle
Abbreviation: fc



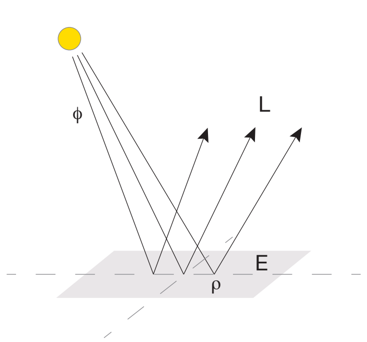
Luminance

Luminance describes a measure for the brightness impression that is created in the human eye of a luminous or illuminated surface. The numerical value of luminance is obtained by multiplying the illuminance by a surface's reflectance value.

$$L = \frac{E \cdot \rho}{\pi}$$

Symbol: L
Unit: Candela per ft^2
Abbreviation: cd/ft^2

ρ: Reflectance of surface material



Luminous efficacy

Luminous efficacy specifies how efficiently the consumed electrical power [P] is converted into light, that is, how much luminous flux is produced per watt of consumed electrical power.

$$\eta = \frac{\phi}{\rho}$$

Symbol: η
Unit: Lumen per watt
Abbreviation: lm/W

Quick Calculation

Here you have a means of making a rough estimate of the number of luminaires required indoors and outdoors using the Lumen Method.

The number of luminaires required indoors and outdoors can be determined with an easy calculation.
A distinction is made between three different types of luminaire:

Each type of luminaire is assigned a **coefficient of utilization** which approximately describes the characteristics of the luminaire in question.

Factor CU for	Indoors	Outdoors
1. Luminaires with specifically directed light	**0.7**	**0.8**
such as floodlights or downlights, whose light is directed specifically onto the surface to be illuminated.		
2. Luminaires with directed light	**0.5**	**0.6**
such as bollards or pole-top luminaires, whose light is directed onto the surface to be illuminated via a reflector system; or for ceiling luminaires with partially frosted glass.		
3. Luminaires with soft light	**0.3**	**0.4**
such as ceiling luminaires with opal glass or decorative light building elements with a diffuse light distribution.		

The formula:

$$n = \frac{E \cdot A}{\phi \cdot LLF \cdot CU}$$

Legend:

n	Number of luminaires
E	Average illuminance
A	Surface area
ϕ	Luminous flux of the luminaire
LLF	Light Loss Factor – (standard practice 0.85-0.90)
CU	Coefficient of Utilization for indoors / outdoors

A standard value of **between 10 and 20 ft is assumed for the room height indoors**. If the room is higher, the required number of luminaires rises in order to reach the required average degree of illuminance.

Outdoors, we assume **mounting heights of 12 to 20 ft**. As a rule, the degrees of illuminance that must be reached here are so low (about 1.0 fc) that differences in mounting heights within the defined range are between 0.1 and 0.2 fc. This cannot be detected with the naked eye.

The size of the surface and the required level of illuminance are integral components when planning the lighting design.

First, we must determine the total luminous flux [ϕ_{tot}] using the tables (right). We find the total area to be lit on the x-axis, and determine the required light level. The intersection of these two variables will have a corresponding lumen value on the y-axis.

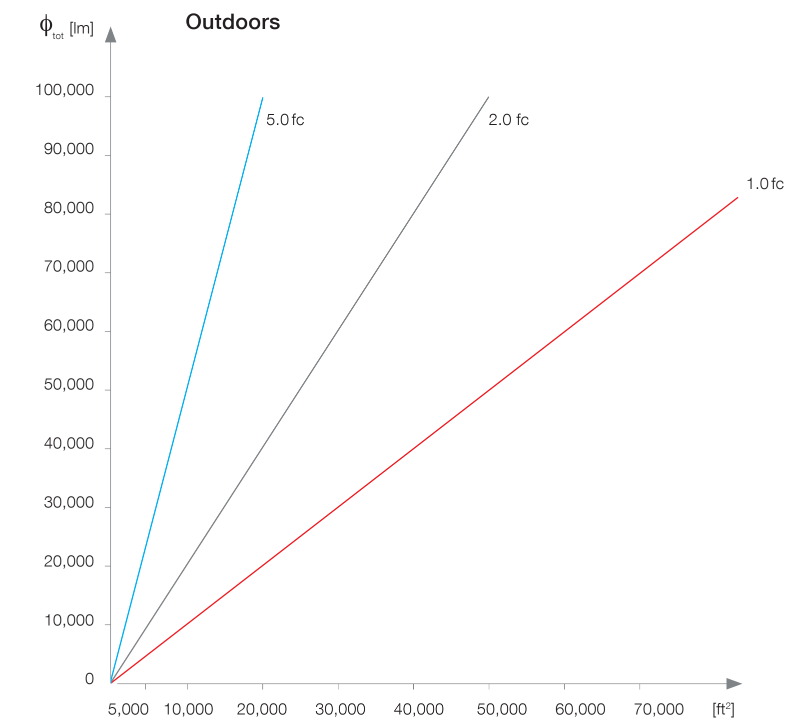
From this, the required luminaires and the quantity can be defined. The total luminous flux [ϕ_{tot}] is divided by the luminous flux [ϕ] of a selected luminaire, and the result equals the theoretical number of luminaires.

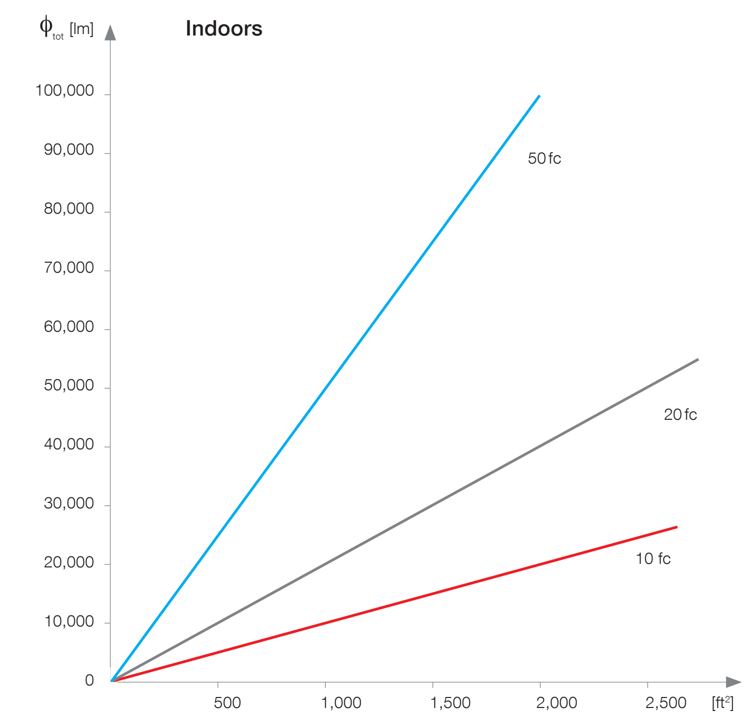
In order to account for the properties of the luminaire, this theoretical number of luminaires should be divided by the coefficient of utilization [CU] (table on the left) and the light loss factor [LLF] (standard practice 0.85-0.90).

The result is a fairly accurate approximation of the number of luminaires that will be necessary to light the space.

The formula:

$$n = \frac{\phi_{tot}}{\phi \cdot LLF \cdot CU}$$





UL and CSA & protection classes

UL and CSA

All BEGA products offered in our catalogs are UL or CSA listed, suitable for wet or damp locations. BEGA products are not suitable for installation inside of a spa, sauna, or in the wall of a shower/bath stall. BEGA does not recommend luminaires with non isolated metal parts to be used in these applications.

Protection classes

The information we provide on a luminaire's ability to withstand the penetration of dust, solid bodies and water is according to DIN EN 60598 (YDE 0711). Please see the table on this page for allocations of the degree of protection according to DIN EN 60598.

	1st digit: foreign body protection
IP1x	Protection against penetration of solid objects ≥50mm
IP2x	Protection against penetration of solid objects ≥12mm
IP3x	Protection against penetration of solid objects ≥2.5mm
IP 4x	Protection against penetration of solid objects ≥1mm
IP5x	Dust protected
IP6x	Dust tight

	2nd digit: water protection
IP1x	Protected against dops of water falling vertically
IP2x	Protected against drops of water from angles up to 15°
IP3x	Protected against showers up to 60°
IP 4x	Protected against splash water
IP5x	Protected against water jets
IP6x	Protected against powerful water jets
IP7x	Protected against temporary submersion
IP8x	Protected against permenent submersion as far as the specified depth in meters

Reference values for illumination

The following reference values are published by the Illuminating Engineering Society of North America, New York.

IES Sources:

DiLaura, D. L., Houser, K. W., Mistrick, R. G., & Steffy, G. R. (2011).
The lighting handbook: Reference and application (10th ed.).
New York, NY: Illuminating Engineering Society of North America.

IES RP-33-14
Lighting for exterior environments: An IESNA recommended practice. (2014).
New York: Illuminating Engineering Society of North America.

IES RP-20-14
Lighting for parking facilities. (2014).
New York, NY: Illuminating Engineering Society of North America.

IES RP-8-14
Roadway lighting. (2014).
New York, NY: Illuminating Engineering Society of North America.

Outdoor

This final section is a collection of reference tables for the applications discussed previously. The tables were created to show recommended illuminance levels relevant to each application. Some supplemental text is included to clarify and expand upon the data included.

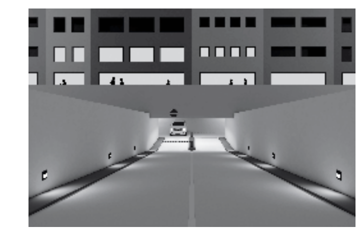
Roadway/Intersection Roadway reflectances have two major components: specularity and road building material. Average reflectance values are recorded here, with descriptions of the type of material, and their relative reflectance characteristics.	ρ	Type of Reflectance
Concrete Portland cement concrete road surface with steel rebar reinforcement. Typical construction material for bridges, overpasses, and other similar structures	30%	Mostly diffuse
Asphalt Asphalt surface laid on a gravel base. Generally constructed for high-traffic roads (typical highways)	22%	Slightly specular
Composite Pavement Composite pavements composed of a cement concrete sublayer with asphalt overlay	22%	Mixed (diffuse and specular)

Intersection	Average Illuminance by Pedestrian Conflict Risk			Avg:Min
	High	Medium	Low	
Major/Major	3.4 fc	2.6 fc	1.8 fc	3:1
Major/Collector	2.9 fc	2.2 fc	1.5 fc	3:1
Major/Local	2.6 fc	2.0 fc	1.3 fc	3:1
Collector/Collector	2.4 fc	1.8 fc	1.2 fc	4:1
Collector/Local	2.1 fc	1.6 fc	1.0 fc	4:1
Local/Local	1.8 fc	1.4 fc	0.8 fc	6:1

'Major = 3500+ ADT, Collector = 1500-3500 ADT, Local = 100-1500 ADT
(ADT = Average Daily Traffic)

Parking Lot	E_h	Avg:Min
Asphalt All parking areas (Pre/Post curfew)	0.5 fc / 0.2 fc	4:1
Concrete All parking areas (Pre/Post curfew)	1.0 fc / 0.2 fc	4:1

Parking Garage	E_h	$E_{v\,min}$	Avg:Min
Active (motion) Inactive (no motion)	1.0 fc / 0.2 fc	0.5 fc / 0.1 fc	
Drop off / Pick up areas (active/inactive)	1.0 fc / 0.2 fc	0.5 fc / 0.1 fc	4:1
Vehicle Entries/Exits (daytime/night)	50 fc / 1.0 fc	25 fc / 5.0 fc	



Loading Zone	E_h	$E_{v\,min}$	Avg:Min
Dock	10 fc	3 fc	2:1
Receiving/Staging	30 fc	10 fc	2:1
Loading/Unloading Platforms - Outdoor	10 fc	5 fc	5:1

Key	
ρ	Reflectance value
E_h	Illuminance measured on a horizontal plane, can be either average or minimum. [fc]
E_v	Illuminance measured on a vertical plane, can be either average or minimum. [fc]
Avg : Min	Uniformity ratio between the average illuminance of a plane and the minimum measured illuminance on the same plane.

Pedestrian Crossings

Pedestrian crossing types are identified by conflict risk: either low, medium, or high. This risk should be determined by the use of the surrounding area. For example, a local road next to a neighborhood elementary school would be considered a high risk pedestrian conflict zone.

Road and pedestrian conflict area		Pavement Type		Avg:Min
Road	Pedestrian conflict	Concrete	Asphalt or Composite	
Freeway (Interstate) Road only accessible via on/off ramps, little/no cross traffic		0.4 fc	0.6 fc	3:1
Expressway (Highway) Roads with higher speeds and higher traffic, but still contain occasional cross traffic and intersections with stops	High	1.0 fc	1.4 fc	3:1
	Medium	0.8 fc	1.2 fc	3:1
	Low	0.6 fc	0.9 fc	3:1
Major (Arterials) Roads expected to carry large volumes of traffic, many intersections with stoplights/stop signs	High	1.2 fc	1.7 fc	3:1
	Medium	0.9 fc	1.3 fc	3:1
	Low	0.6 fc	0.9 fc	3:1
Collector Connect local roads to major roads	High	0.8 fc	1.2 fc	4:1
	Medium	0.6 fc	0.9 fc	4:1
	Low	0.4 fc	0.6 fc	4.1
Local Low speed limit Low traffic volume Typical residential roadway	High	0.6 fc	0.9 fc	6:1
	Medium	0.5 fc	0.7 fc	6:1
	Low	0.3 fc	0.4 fc	6:1

*Major = 3500+ ADT, Collector = 1500-3500 ADT, Local = 100-1500 ADT
(ADT = Average Daily Traffic)

Pedestrian Underpass	E_h	$E_{v\,min}$*	Avg:Min
Day	10.0 fc	5.0 fc	3:1
Night	4.0 fc	2.0 fc	3:1

Walkway/Bikeway	E_h	$E_{v\,min}$*	Avg:Min
Rural/Semi-Rural	0.2 fc	0.06 fc	10:1
Low Density Residential	0.3 fc	0.08 fc	6:1
Medium Density Residential	0.4 fc	0.1 fc	4:1

*Evmin = minimum vertical illuminance at 5' above walkway/bikeway (eye-level)

Facade Lighting	$E_{v\ min}$	Avg:Min
Histsorical Building		
Darker toned facade, Low activity, LZ1*	1.5 fc	3:1
Detail lighting, applied strategically to 10% of building facade	4.0 fc	
Histsorical Facade		
Lighter toned facade, Medium Activity, LZ3	5.0 fc	3:1
Detail lighting, applied strategically to 20% of building facade	7.5 fc	
Modern Facade Urban		
Lighter toned facade (Glass), High Activity, LZ3	7.5 fc	3:1
Detail Lighting, applied strategically to 25% of building facade	20 fc	

*See lighting zones table, pg 141

Building Entrances	E_h	$E_{v\ min}$	Avg:Min
Commerical Building Entry	1 fc	2 fc	2:1
Office Building Entrance **Lobby Floor at Building Entry**			
Day	10 fc	5 fc	3:1
Night	5 fc	2 fc	3:1
Exterior Sidewalk at Building Entry			
Night	2.5 fc	1.0 fc	2:1

Exterior Stairwell	E_h	$E_{v\ min}$	Avg:Min
Stairs - High Activity (Egress Stairway)	5 fc	2.5 fc	2:1
Stairs - Typical	1 fc	0.6 fc	5:1

Plaza	E_h	$E_{v\,min}$	Avg:Min
City Plaza	0.6 fc	0.2 fc	5:1
Night - Late Curfew	3.0 fc	1.0 fc	2:1

Park	$E_{v\,min}$	Avg:Min
Landscape Highlights*	1.0 fc - 2.0 fc	3:1

*Apply strategically to 25% of zone, focusing on main points of interest (e.g. statues, extraordinary trees etc.)

Private House	E_h	Avg:Min
Front Entry - Front Door	0.6 fc	4:1
Secondary Entry - Garage Entrance	0.2 fc	4:1
Entry Walkway - Driveway	0.1 fc	4:1

Lighting Zones

Determining the applicable lighting zone is dependent on the amount of surrounding ambient light and activity level. A project's lighting zone is crucial to specifying the correct type of luminaire and amount of light needed for a project. Lighting zones are summarized below:

Zone	
LZ4	LZ4 is only applicable to areas with very high, 24-hour ambient lighting levels. LZ4 is not appropriate for most cities. (e.g. Las Vegas, Tokyo)
LZ3	LZ3 is applicable to most areas that have popular night-life activities or heavy night-time business activities such as a shipping yard or sports arena. This is appropriate for a major city's downtown area.
LZ2	LZ2 is applicable to most business districts in smaller cities or residential areas. Typical for multi-family housing (apartment complexes), and public buildings with moderate night-time activity including schools, hospitals, or hotels.
LZ1	LZ1 is applicable to residential neighborhoods and rural areas. Night-time activity is not common. Can also be applicable to city parks.
LZ0	LZ0 is applicable for open land, national parks and forests, or near observatories. Typically there is no street lighting, and permanent lighting is discouraged.

Indoor & outdoor

Accent Illuminance Ratios

Role	Luminance Ratio	When to use	Examples
Powerful	20:1	Use to create powerful visual contrast or to invoke an emotional response. Not for common applications.	-In a museum to highlight something extraordinary
Impressive	10:1	Use on one or two focal areas	-Textured wall or exotic material -An exclusive display in a gallery
Highlight	5:1	Use to bring attention to important features or areas and act as a visual guide	-Entrances -Reception desks -Store front to highlight
Focal Point	2:1	Use to draw the eye to certain features or as a visual guide.	-Commercial artwork -Residential artwork -Points of interest within a space

Activity Levels

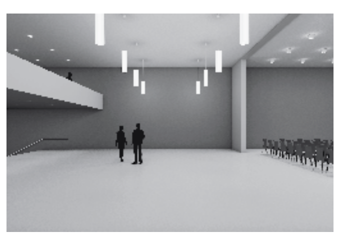
A project's projected activity level is crucial to specifying the correct type of luminaire and amount of light that will be needed. Different activity levels are summarized below:

Activity Level	Definition	Examples
Indoor - High	High indoor activity levels are characterized by either consistently high volumes of people or by high volumes of people pertaining to certain times of day.	-Stairs and hallways during class changes at a school -Indoor public market during typical lunch or dinner hours -A major-league sports venue
Indoor - Med	Medium indoor activity levels with a consistent stream of people throughout the day, only minor swells of activity.	-General shopping centers -Museums -Typical office spaces
Indoor - Low	Low activity levels indicate few to no people for most of the day with small swells of little groups from time to time.	-Hotel pools or fitness centers -Civic building entries
Outdoor - High	High outdoor activity levels are characterized by either consistently high volumes of people or by high volumes of people pertaining to certain times of day.	-University campus -Amusement or water parks -Major city downtown area
Outdoor - Med	Medium outdoor activity levels with a consistent stream of people throughout the day, only minor swells of activity	-Urban parks -Major train or bus station -Office parks
Outdoor - Low	Low activity levels indicate few to no pedestrians or vehicles for most of the day with small swells from time to time.	-Residential neighborhoods

Indoor

Lobby	E_h	Avg:Min
Reception Lobby - Work Surface	15 fc	4:1

Religious Room	E_h	$E_{v\,min}$	Avg:Min
General Congregation	10 fc	5 fc	3:1
Narthex (front of church)	15 fc	7.5 fc	3:1



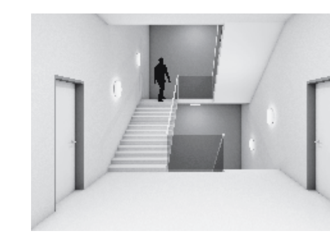
General Hallway	E_h	$E_{v\,min}$	Avg:Min
Public Seating	10 fc	5 fc	2:1
Lectern or Podium, Visual Aids	50 fc	20 fc	2:1

Multipurpose Room	E_h	$E_{v\,min}$	Avg:Min
General Circulation	5 fc	1.5 fc	3:1
Exhibition	50 fc	20 fc	3:1
Meeting	40 fc	15 fc	3:1

Hotel	E_h	$E_{v\,min}$	Avg:Min
Hotel Corridor	5 fc	3 fc	2:1

Pedestrian Subway	E_h	$E_{v\,min}$	Avg:Min
Concourse - General	5 fc	2 fc	3:1
Concourse - Seating	15 fc	5 fc	3:1
Boarding Station	10 fc	5 fc	3:1

Interior Stairwell	E_h	$E_{v\,min}$	Avg:Min
Stairs - High Activity (Egress Stairway)	10 fc	5 fc	2:1
Stairs - Typical	5 fc	3 fc	2:1



Study	E_h	$E_{v\,min}$
Handwritten Work	30 fc	7.5 fc
Print Media	30 fc	5 fc
Computer*	15 fc	5 fc

*Avoid reflected glare by using indirect lighting

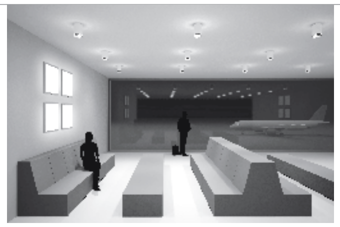
Conference Room	E_h	$E_{v\ min}$	Avg:Min
Meeting (periodic notetaking, reading, facial detail)	30 fc	7.5 fc	
Whiteboard (reading, reference)		15 fc	3:1
Reading (presentation)		10 fc	3:1
Walls			
40% matte reflectance		40 fc	1.5:1
50% matte reflectance		30 fc	1.5:1
60% matte reflectance		20 fc	1.5:1

Boutique	E_h	$E_{v\ min}$	Avg:Min
Features Displays	x5-x10*	-	-
Circulation	15 fc	2.0 fc	1.2:1
General Retail Displays	40 fc	15 fc	1.5:1
Sales Counter	30 fc	10 fc	1.5:1

*Use multiplier based on surrounding or neighboring light level - see accent illuminance ratios table, pg. 142

Shopping Mall	E_h	$E_{v\ min}$	Avg:Min
Main Shopping Concourse	10 fc	3.0 fc	2:1
Retail Kiosks	10 fc / 30 fc	3.0 fc	1.5:1

Bistro/Bar	E_h	$E_{v\ min}$	Avg:Min
Barback	5 fc	15 fc	3:1/5:1
Bar Top	7.5 fc	2 fc	5:1
General Seating	5 fc	3 fc	3:1
Lounge	10 fc	5 fc	3:1
Dining Areas - Restaurants			
Casual Dining	10 fc	5 fc	3:1
Coffee Shops	10 fc	3 fc	3:1



Waiting Area	E_h	$E_{v\ min}$	Avg:Min
Waiting Area - General	4 fc	1.5 fc	4:1

Living Area	E_h	$E_{v\ min}$	Avg:Min
Family Room - General	15 fc	4.0 fc	3:1

Swimming Pools and Hot Tub Deck - Outdoor	E_h	Avg:Min
High Activity	1 fc	4:1
Medium Activity	0.5 fc	4:1
Low Activity	0.2 fc	3:1

Outdoor In-pool/In-hot tub lighting: Pool and hot tub presumed to be internally lighted.
Lighting should address the pool and a deck area extending 10' beyond the pool edge.

Spa/Health Zone	E_h	$E_{v\,min}$	Avg:Min
Changing Rooms	5.0 fc	10 fc	5:1
Hot Tub Area	2.0 fc	-	10:1

Swimming Pool/Hot Tub Deck - Indoor	E_h	$E_{v\,min}$	Avg:Min
High Activity	10 fc	3.0 fc	3:1
Medium Activity	5.0 fc	2.0 fc	3:1
Low Activity	1.0 fc	0.4 fc	3:1

Riding Arena	E_h	$E_{v\,min}$*	Avg:Min
Arena Lighting	50 fc	15 fc	3:1
Rodeo	50 fc	15 fc	3:1

*Evmin measured 5' AFF

Glossary

A

Absorption
The term absorption generally refers to the absorption of light or any other electromagnetic radiation. When light strikes a surface, it is absorbed to differing extents depending on the material, color and reflectance. Light is absorbed when it passes through any medium, including the earth's atmosphere. It can only propagate without hinderance in a pure vacuum (outer space). Light that is not absorbed is either reflected or transmitted.

Accent lighting
Accent lighting is used to create contrast between an object or area and its surroundings. The light on the object is perceived as significantly brighter that the general illumination around it. This technique is used in various applications like artwork, sculptures, textured walls, and signs. This type of lighting should be used sparingly in a space.

ADA
The ADA (Americans with Disabilities Act) requires that objects projecting from walls between 27“ and 80“ above the finished floor shall protrude no more than 4“ into walkways, halls, corridors, passageways or aisles

Adaptation (Eye Adaptation)
The ability of the human eye to adjust to various levels of light and darkness. The change in luminance levels (brightness) affects the process and adaptation time. Adaption from dark to light only takes a few seconds, while adaptation from light to dark takes several minutes.

Adaptive Lighting
When the lighting conditions adjust per the time of day or night, or when the lighting conditions aid in the eye adaptation process (e.g.: entering a tunnel or underground parking garage, where there is an large difference in luminance between two adjoining areas) values recorded by sensors. The fields of application include, for example, the approach to an illuminated roundabout or tunnel lighting.

Ambient Lighting
The most basic form of lighting for functionality. Used to provide an area with general illumination in order to define an environment.

Average Illuminance
The sum of each point of illuminance on a plane, divided by the number of points on the plane. Can be calculated using various lighting software.

Axial Candela Display
A luminaires light distribution curve plotted on a cartesian coordinate system. See “Light Distribution”

B

Basic illumination
See “Ambient Lighting”

Beam angle
A source's beam angle refers to the angle between two planes of light where the intensity is 50% of the maximum intensity. The beam angle is important when specifying a floodlight and is determined by the design of the internal reflectors.

B < 7deg	Very Narrow Spot
B = 5-15deg	Narrow Spot
B = 16-22deg	Spot
B = 23-32deg	Narrow Flood
B = 32-45deg	Flood
B = 45-60deg	Wide Flood
B > 60deg	Very Wide Flood

BEGA
An international lighting company based in Menden, Germany. Our approach to product design is to innovate, not follow. Each product family is conceived to satisfy a general or specific lighting task as defined by its architectural or exterior surroundings. BEGA designs are intended to be classic, to blend with and complement all types of architecture, whether old or new. To accomplish this goal, we use only the highest quality materials. Our approach to engineering emphasizes practicality. At BEGA, our attention to detail, fit, tolerances, and installation methods is paramount.

BEGA-US
A joint venture partnership with the managing partners of BEGA in order to bring the entire BEGA product offering to the U.S. This partnership was the inception of BEGA-US, a U.S. corporation.

Binning
Binning is a process during the industrial production of LED chips. Different product batches tend to produce slightly different lighting properties, like color and luminosity. To ensure a consistent light quality between several LED chips, they are sorted (binned) with other LED chips of the same brightness and color qualities.

Blackbody
A blackbody is a perfectly opaque object with 0% reflectance that absorbs all incoming light and emits thermal radiation.

Brightness
Brightness is used to describe the physiological sensation of light, often used in conjunction with luminance

BUG Rating
A fixtures BUG rating describes its optical performance. There are three primary solid angles that are evaluated: backlight, uplight and forward light. These are then related to how much light trespass, sky glow or high angle brightness a fixture will produce.

C

Candela
Candela [cd] is the unit for luminous intensity. It is calculated as luminous flux per solid angle.

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

CCT
Correlated Color Temperature. See “Color Temperature”

Chromaticity Diagram
A chromaticity diagram is color projected onto a two-dimensional space that excludes brightness. The diagram shows all colors in the visible spectrum as a function of their wavelength [nm].

Circadian Rhythm
The human ‘biological clock’, which is responsible for regulating our physiological activities, including when to wake, eat, and sleep. These processes are heavily influenced by the presence or absence of light.

Color Rendering
Color rendering describes how well a light source is able to reveal colors of various objects in comparison to an ideal source. The index is derived from eight common test colors, and indicates how naturally colors are rendered in the light of a lamp. A CRI of 100 is the best possible rating, and means the source will render the colors 100% accurately.

Color temperature
The term color temperature is used for the light color of white light. It is expressed in Kelvin [K]

Color temperatures in Kelvin	
Warm white	3000K
Neutral White	4000K
Daylight White	5000K

Connected Wattage
See “System Wattage”

Contrast
Contrast is quantified by the luminance ratio of adjoining zones. Contrast is the difference in color or brightness of an object in comparison to its surroundings.

CRI
Color Rendering Index. See “Color Rendering”.

CSA
The Canadian Standards Group is an independent, not-for-profit member-based association dedicated to advancing safety, sustainability and social good. They are an internationally-accredited standards development and testing & certification organization. The CSA mark appears on billions of products around the world.

D

Degradation
In lighting technology, the term degradation describes the drop in the luminous flux of an LED source.This process is extremely slow and only becomes noticeable in older LED fixtures after about 50,000 operating hours. After this period, the LED continues to emit light, but the luminous power will be noticeably lower (70% of the original output). This ageing process can be accelerated by adverse operating conditions such as overheating.

Directed Light
Through the use of internal reflectors, light from a source is redirected out of the fixture in a specific direction towards an area that needs to be illuminated. Directed light is frequently used for task lighting.

E

Efficacy
Luminous efficacy specifies how efficiently the consumed electrical power [P] is converted into light. How much luminous flux is produced per watt of consumed electrical power.

$$\eta = \frac{\Phi}{P}$$

Egress Lighting
Egress lighting specifies the amount of light that must be provided in a specific place in the event of an evacuation. Escape routes must be illuminated in such a way that people can find their way out of a building as quickly as possible. Egress lighting requirements are regulated city and state legislature, and is dependent on the building use and type.

Emergency Lighting
Emergency lighting are luminaires that can function independently from their main power supply through either a backup generator or a battery. In the event of a power failure, they will still illuminate escape routes. Emergency and safety lighting requirements are specified by legal regulations.

Eye Adaptation
See “Adaptation”

F

Footcandle
Footcandle [fc] is the unit for illuminance. It is calculated as the amount of luminous flux that falls onto an area

$$E = \frac{\Phi}{A} \qquad E = \frac{I}{r^2}$$

G

General Illumination
See “Ambient Lighting”

Glare
Glare is caused by a direct view or reflected view of an unshielded light source, and is perceived as excessive brightness that is physically or psychologically uncomfortable. Reflected glare occurs when light reflects off of an exceptionally shiny surface such as a wet asphalt road, glossy paper, or a computer display.

H

Half Beam Angle
See “Beam Angle”

I

IES File
An IES file is a photometric data file that contains the luminous flux and the luminous intensity information as measured from all directions. IES files can be viewed as a delimited text file or opened with lighting design software.

Illuminance
Illuminance [E] is the ratio of luminous flux that falls onto an area and is measured in footcandles [fc]. A recommended level of illuminance can fall onto eithe a horizontal or vertical plane.

$$E = \frac{\Phi}{A} \qquad E = \frac{I}{r^2}$$

Indirect Light
Indirect light is light that has been diffusely reflected either by a component of the luminaire or by the ceiling before it reaches the viewer.

Isofootcandle Diagram
A luminaires light distribution plotted as the illuminance level on a horizontal surface at a set mounting height. See “Light Distribution”.

L

LED
LED is the abbreviation for light-emitting diode. LEDs are electronic semiconductor components which emit light in the colors red, yellow, green or blue when power is applied. LEDs emitting high-energy frequencies can also generate white light with the help of an additional internal luminous coating. White light can also be generated by RGB color mixing.

Light Color
The light color of a lamp is described by the color temperature in Kelvin [K], see “Color temperature”.

Light Distribution
The term light distribution refers to the spatial distribution of luminous intensity. The form and symmetry of the light distribution can be determined by this information. This data can be graphed as either a polar curve, as an axial candela display, or can be viewed as an isofootcandle diagram.

Light Meter
Light meters can measure the illuminance of daylight or artificial light on a surface. Some have integral chromaticity reading information and can tell you the color temperature and the CIE X and Y coordinates of the light.

Limburg Collection
The Limburg Collection features specialized interior luminaires made of glass. The current collection comprises over 800 unique luminaires created to assure unsurpassed quality. These luminaires flawlessly enhance the lighting and design in both public and private architecture.

LLF
The light loss factor (LLF) for a lighting design is dependent on the type of lamp, the design of the luminaire, the cleanliness of the environment, and the site’s maintenance intervals.

Lumen
The unit for luminous flux is a lumen [lm], which measures the output emitted by the lamp in all directions in the visible spectrum.

Lumen Method
A quick method of calculating the number of luminaires required in a space based on the desired illuminance level, the surface area to be lit, and the type of luminaire to be used.

Luminaire Efficacy
See “Efficacy”.

Luminance
Luminance [L] is measured in luminous intensity [cd] per unit of area [A]. It is typically used to describe the perceived brightness of a luminous or illuminated surface. The luminance value is highly dependent on a surface’s reflectance.

$$L = \frac{E \cdot \rho}{\pi}$$

Luminosity
The total amount of energy emitted by a source per unit of time.

Luminous Flux
Luminous flux [⍰] defines all of the radiant energy (light) that is emitted by a lamp in all directions. Measured in lumens [lm].

Luminous Intensity
Luminous intensity [I] is the relationship between the luminous flux that is emitted at a small spatial angle and the size of that spacial angle. Luminous intensity is a measure for the light emission from a light source in a specific direction.

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

M

MacAdam Ellipse
A Macadam ellipse is an elliptical region on the chromaticity diagram that contains all colors that are indistinguishable to the average human eye. Adjacent ellipses are ‘just distinguishable’ in terms of color.

Maintained Illuminance
The maintained illuminance level defines the average level of illuminance on a surface over time. As a fixture gets older, its light output will diminish due to several light loss factors.

Maintained illuminance = Light Loss Factor x Output of brand new fixture

Mounting Height
The mounting height indicates the height, or how far away, the light source is from the surface to be illuminated. A bollard’s mounting height is equal to the fixture height. A pole-top luminaires mounting height will change depending on the specified pole height. A recessed or surface ceiling fixtures mounting height will be equal to the room’s ceiling height.

P

Photometric Data
The direction and intensity of the radiation emitted from a luminaire is collectively called its photometric data. This can be influenced by shields, diffusers, louvres or reflectors and can be represented in a luminous intensity distribution curves and is documented in an IES file.

Polar Curve
A luminaires light distribution curve plotted on a polar coordinate system. See “Light Distribution”.

Protection Class
Luminaires must be designed to keep foreign bodies and water out of the fixture and away from the internal electronic components. The IP code number system, “Ingress Protection”, is used to identify the protection class with two code numbers. The first code number after the IP (1 to 6) indicates the degree of protection against foreign bodies, while the second code number (1 to 8) stands for protection from water. The higher protection class always includes the lower class.

Pupil
The pupil is a hole in the eye that allows light to enter and travel back to the retina. The size or dilation of the pupil changes the amount of light that is allowed to enter the eye.

Q

Quality Characteristics
The quality characteristics of lighting are determined by the perception of its performance, visual comfort and how it affects the spatial mood and atmosphere. It can be quantified with the level of illumination as measured by illuminance and luminance, a fixtures light distribution, the limitation of glare, the luminaire optical performance as defined by a fixtures BUG rating, and by the color rendering index and color temperature of the source.

R

Reflected Glare
See “Glare”

Reflectance
A surface‘s reflective characteristics are defined by its physical properties such as color and texture. The rougher and darker the material, the less reflective it will be. This value ranges on a scale of 0% (blackbody) to 100% (perfect mirror). Light-colored surfaces reflect more light than dark colored surfaces.

Retina
The retina is the inside lining of the eye and is comprised of special photosensitive cells. The retina converts the light into electrical impulses, which are carried through the optic nerve to the brain. There are three types of photoreceptor cells: rods, cones, and photosensitive ganglion cells.

RGB
The sequence of letters “RGB” is an abbreviation for the the primary colors of red, green and blue. These light colors can be added together in various ways to reproduce a broad spectrum of colors. When all three are mixed in equal proportions the result is white light. In order to obtain a better white light color, it is possible to work with an additional white light source (RGBW color mixing).

S

Solid Angle (Spacial Angle)
The solid angle [Ω] describes the relationship between the size of an illuminated surface and the square of the distance between the light source and the surface. It is a two-dimensional angle in a three-dimensional space.

$$\Omega = \frac{A}{r^2}$$

Spectral Power Distribution
A spectral power distribution describes the characteristics and intensity of electromagnetic waves in the visible range emitted from a source. Each wavelength of visible light has a certain spectral color. In daylight, the intensity of all spectral colors is relatively homogeneous, with a slightly predominant blue component. A lamps spectral power distribution can be graphed by the intensity of each wavelengths emitted. This type of graphical representation is helpful for comparing lamp types.

Steradian
The steradian (sr) [Ω], also sterad, is the unit for the solid angle or spatial angle.

$$\Omega = \frac{A}{r^2}$$

System Wattage
The connected power of a luminaire measured in watts [W]. This value defines the total power which the luminaire consumes. This value covers all the installed components e.g.: the lamp or module and power supply, ballast or drivers.

T

Task Lighting
When ambient lighting alone does not provide an adequate amount of light to perform tasks such as reading or writing, task lighting can be added. Task lighting is focused on certain areas where increased attention is required by the occupant.

U

UL
UL is a global independent safety science company with more than a century of expertise innovating safety solutions from the public adoption of electricity to new breakthroughs in sustainability, renewable energy and nanotechnology. Dedicated to promoting safe living and working environments, UL helps safeguard people, products and places in important ways, facilitating trade and providing peace of mind.

Uniformity
Uniformity describes how dramatic the transitions are from strongly illuminated areas to dark areas. If a space is uniformly lit, the transition to a more strongly or less strongly illuminated area will be gradual. Typically this is measured by luminance ratios of neighboring zones. In a single zone, for example a parking lot, the uniformity is typically measured as the ratio of maximum to average illuminance or the ratio of maximum to minimum illuminance.

V

Visible Spectrum
The wavelengths of light that are visible for human beings range from 380 to 780 nanometres [nm].

Visual Comfort
Visual comfort refers to the well-being of the human eye through the quality of illumination, in particular with respect to color rendering and a harmonious distribution of light.

Visual Performance
The percepted visual performance of a fixture is determined by the level of perceived brightness. This is how bright or dark we perceive a surface to be and is highly influenced by the surface's degree of reflectance.

Visual Task
Visual tasks in a space are identified as the physical tasks that a person will need to carry out when in that space. The degree of difficulty of the visual task is determined by the light-dark and color contrasts, as well as by the size of the details and the speeds and duration with which the contrasts are perceived. The more difficult the visual task, the higher the recommended illuminance level will be.

W

Work Plane
The workplane is a horizontal plane located at the nominal working height in an interior room. Typically this plane is located 30 inches above the finished floor.

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