Lighting for the built environment

LG7: Offices

The Society of
Light and Lighting

Lighting Guide 7: Office lighting

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Foreword

It has been ten years since the previous edition of Lighting Guide 7 was issued. This new edition has kept the design flexibility of the old one, but has built on it to emphasise the need to minimise energy use while maintaining a good visual environment for occupants.

It keeps a balanced approach to design options, covering, where ceiling heights allow, direct/indirect lighting or pure uplighting and, for spaces with lower ceilings, recessed downlighting. It has also maintained the extensive coverage of task lighting and daylighting techniques.

Modern offices have a wider range of screen types in use than when the 2005 edition was published. There are also far more multi-screen desktop set-ups, with two or even three screens being used on standard desks in many architectural, engineering and financial office spaces. Desktop screens have on the whole got larger, and while some have anti-reflective coatings, others, mainly used those for high-definition video and graphics work, have almost mirror finishes. The multi-screen desktop work environment makes it even more important to limit undue brightness of luminaires, as the screens in front of a user's face will be in slightly different orientations and so can pick up reflections from a wider area behind the user.

There are now many office workers who need to work on, or at least make reference to, hand-held tablets and large phones. While these typically have fairly reflective screen surfaces, they are easily moved by the user to avoid reflections from lights or windows. The greater use of laptop computers at work also means that lighting designers need to take more care with luminaire brightness. Many modern laptop screens do not have anti-reflective treatments as these can degrade high-definition images. Laptop screens are also often tilted back, to face the user looking down towards the laptop sat on a desk, and so the interiors of any ceiling-mounted luminaires become immediately visible.

It is perhaps fair to say that changes in screen technology and office work practices over the past decade have made some aspects of the lighting designer's work easier, but others far more difficult.

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1 Introduction

The office environment has changed considerably since the previous version of this lighting guide. While the fixed desk remains a central part of office life, tablet and touchscreen computers are now commonplace and allow those occupying office space to move around, effectively carrying their workspace to wherever they need to be or feel comfortable working.

The need to accommodate this flexibility has brought significant challenges to lighting designers used to dealing with fixed scenarios. This guide now considers how to light office space for flexible use where tablets, smartphones and touchscreen computers are being used.

Energy reduction in the built environment is a continuing challenge and the lighting within offices is a major contributor to the energy demands of a building.

Careful selection of luminaires and light sources along with appropriate controls can reduce energy demand. However, designers and installers can make a significant impact by talking to the people who will use the office at a very early stage of the design. By understanding their needs and work profiles, a more tailored approach can be considered which delivers the lighting they need using the minimum energy.

Speculative office lighting, and to a degree lighting for any large office, is still thought of as needing to be uniform across the office space. The notion of a working plane has been removed from this guide, with emphasis placed instead on the task area. Uniformity across a task area is important. However, uniformity across a whole office can make the space look bland and uninteresting. Using lighting as part of the interior design to add visual interest will improve the views of occupiers of an office as they look up and away from their desks.

While it is easy to think of office space as large open-plan areas in dedicated complexes, the majority of office space in the UK is actually in smaller premises, where the office is one room among many and, possibly, converted from some other use in the past. Regardless of the size and location of the office in question, lighting designers should seek to give the occupants an appropriately well-lit space in which to work.

Access to daylight in offices is known to be beneficial to the health and well-being of occupants. Where daylight can be used to provide illumination of an office space, designers should seek to make the most of this valuable lighting source. In order to do this, designers will need to engage with building owners and developers at the earliest stages of a project.

2 Approach to designing office lighting

2.1 Introduction

Lighting within office spaces has to achieve a number of objectives, perhaps more so than in any other environment. It will form part of a functional space, the holistic design of which needs to deliver a comfortable environment that promotes productivity over lengthy exposure to that environment.

It should also be attractive and contribute to the interior design of the space, making it a pleasant place to work.

It must provide a level of illumination on all surfaces that can be demonstrated to meet particular workplace legislation, such as the Workplace (Health, Safety and Welfare) Regulations 1992, which require workplaces to have suitable and sufficient lighting.

Lighting is a major user of electrical energy in an office and its energy use should be considered within the guidance of the Building Regulations Part L2 in England and Wales, as well as Scottish Building Standards – Technical Handbook

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Section 6 and the Department of Finance and Personnel Building Regulations for Northern Ireland. These documents have a particular focus on office lighting.

There are many ways to light an office space: with direct light from above, with indirect light bounced from the ceiling or a combination of both methods. A variety of factors will dictate or influence the choice of which technique to use. Low ceiling heights or exposed building structure may rule out certain methods or prescribe certain layouts. Other building services, such as chilled beams or exposed ductwork, may prevent the use of indirect lighting or provide ideal mounting locations for certain types of lighting. The client, interior designer or architect may have strong views on the style of lighting or the lit effect that needs to be created.

Designers of lighting for office environments have to consider the efficiency of both the luminaires to be used and the control system in use. The need for well-designed lighting is as important as ever and care should be taken to ensure that the long-term impact on the occupants of an office is not compromised in an effort to reduce energy consumption at the point of delivery when well-designed and carefully positioned lighting and controls could have a greater influence.

The design may either be for a known user or a speculative developer and it may be either a refurbishment or new build. The following section on design brief and information outlines the design process for each scenario to ensure that you have defined the brief, compiled the appropriate information and considered the needs of the users in relation to the physical restraints of each building type and the requirements of the owner or developer.

Once you understand the building and the constraints it imposes on the design, you will need to select the correct task illuminances for the tasks in each area and consider the effects of room decor on the lighting and the visual appearance of each space. You will then have to review the sections dealing with designing with daylight and with electric lighting in order to provide the required illuminances for each task.

The office accommodation that you are dealing with may not be in a large self-contained office building but rather in a smaller office that may, for example, be above shops, part of an industrial building or a conversion from other use, such as a storeroom. It could even be a series of office modules in shared office accommodation or some of the numerous areas where office work is carried out in many other sorts of building, such as the administration department in a hospital, a quality control office on a factory floor or a process control room.

See section 3 for more information

Section 3 outlines some of the special considerations for each of these office accommodation types.

In addition to determining the various office tasks that need lighting, the designer has to consider what additional feature lighting is required for each building. This can be as simple as extra spotlights on each floor to highlight noticeboards or artwork or as complex as programmed coloured light displays within an atrium. The external lighting of the building can be most important in establishing the presence of the client's building on the high street or in the community. Signage, security, pedestrian access and car park lighting must all be considered with respect to the building's usage and periods of operation. These issues are covered in section 11.

See section 11 for more information

The need for emergency lighting (comprising standby lighting, safety lighting and escape lighting) has to be assessed for any office building. The client should be consulted on whether there is any requirement or particular risk that requires

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standby lighting so that all or part of the office building can continue to function, if only at a reduced level, during power failures.

Extra low voltage (ELV) lighting control and switching systems are commonplace in new medium to large buildings and these can incorporate control for safety or emergency escape lighting. The lighting designer should check that any such system will allow for a fail-safe situation in the event of a mains power loss (i.e. the control system does not require a power supply in order for the emergency standby or emergency lighting systems to operate).

See section 12 for more information

For those seeking advice on a specific room type, section 12 in this guide gives detailed design notes on the individual room types that you are likely to find in an office building. These are set out in two main groups: primary office spaces, which include areas such as open-plan, deep-plan and cellular offices, and secondary office spaces, which include archives, kitchens and meeting rooms. The vital circulation spaces, such as corridors, stairs and lift lobbies, and back-of-house areas, such as plant rooms and storerooms, are also covered.

2.2 The designer

It is easy to think of the designer of a lighting installation as one person; however, in truth, the design will often be developed by a group of people with one person providing the design direction and others moulding that design to satisfy specific requirements. Choices made by the interior designer, for example, can influence colour and reflectance, thereby having a direct effect on the efficiency of a lighting installation. The heating and ventilation system designer can also have an effect, for example by specifying the temperature in a location to be outside of the optimum operating temperature of the luminaires.

In some instances, it may be appropriate to have a dedicated lighting designer to provide the design direction.

Clients can have different amounts of influence on the route a design takes and should be consulted at an early stage. A key part of the designer's role is to fully interpret the client's vision as well to ensure that the design meets statutory requirements. Office lighting is essentially functional and has to consider the occupiers' health and well-being, as well as any specific aesthetic aspirations.

Control of lighting is an equally important part of the design process and in complex buildings it may be necessary to bring a specialist designer into the team.

2.3 Importance of understanding the office use

The term 'office' is so overarching that it encompasses a wide range of uses. Each needs to be considered individually and therefore generalisations should be avoided. A small office converted from a storeroom in the corner of a warehouse will need a very different approach to an office 30 storeys high in a multi-use tower development.

Designers should discuss how the office will be used with the client before commencing any design work. Some items to include in such a discussion are:

- How is daylight being optimised?
- What tasks are to be performed?
- Will there be any video calling from desks, portable computers, tablets, etc?
- Will portable display screens be used?
- Will there be any alternative uses and, if so, how often?

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- What are the hours of operation and do they vary?
- What will the decor and furniture colours and textures be?
- Is there a fixed furniture arrangement or does the space have to be flexible?
- If a large office, will a 'corporate look' be required?
- Is there any unusual visual contrast with adjacent spaces?
- Are there any heritage issues that have to be considered?
- Are there any specific requirements regarding the colour of light?
- Are there any particular occupational health requirements to accommodate?
- Who will be controlling the lighting and is automation required?
- Will emergency lighting be required and what type is preferred?

Designers will encounter situations where the user of the office space is unknown, such as in speculative development. In the situation where the client is a developer, it may not be possible to determine the final use of the office.

See section 6 for more information

In such situations, it is common practice to provide a 'blanket coverage' approach to ensure that appropriate illumination levels are present across the space. Refer to section 6 for further guidance. This approach can have a significant impact on energy use, particularly if the user has a low density of staff to floor area.

2.4 Scale of illuminance

The *SLL Code for Lighting* describes the scale of illuminance in accordance with BS EN 12665: 2011. The scale sets out the levels between which a perceptual change in illumination levels can generally be observed. These levels are used to define maintained average illumination levels in this guide and are recognised as benchmarks in lighting design.

Scale of illuminance (lux)														
20	30	50	75	100	150	200	300	500	750	1000	1500	2000	3000	5000

Typically, lighting design for task areas in offices will be either:

- 300 lux for mainly screen-based tasks, which can include minor paper-based tasks such as note-taking
- 500 lux for mainly paper-based tasks.

Adjacencies to the task area can be illuminated to the immediately lower level in accordance with the scale of illumination.

Where designers feel the need to use a different value, such as 400 lux, they will have to justify that choice and ensure that the building owner understands and accepts the move away from the recognised scale of illumination.

2.5 Horizontal or cylindrical illuminance?

Traditionally, lighting design in offices has focused on the working surface, with consideration given to areas around that surface in order to provide good illumination where a task is being carried out and some visual comfort when the person undertaking the task looks up and into the distance.

The working practices of office-based staff have changed considerably since the first edition of this guide. A combination of improved video conferencing facilities, the growing use of tablet computers and the drive to reduce energy has

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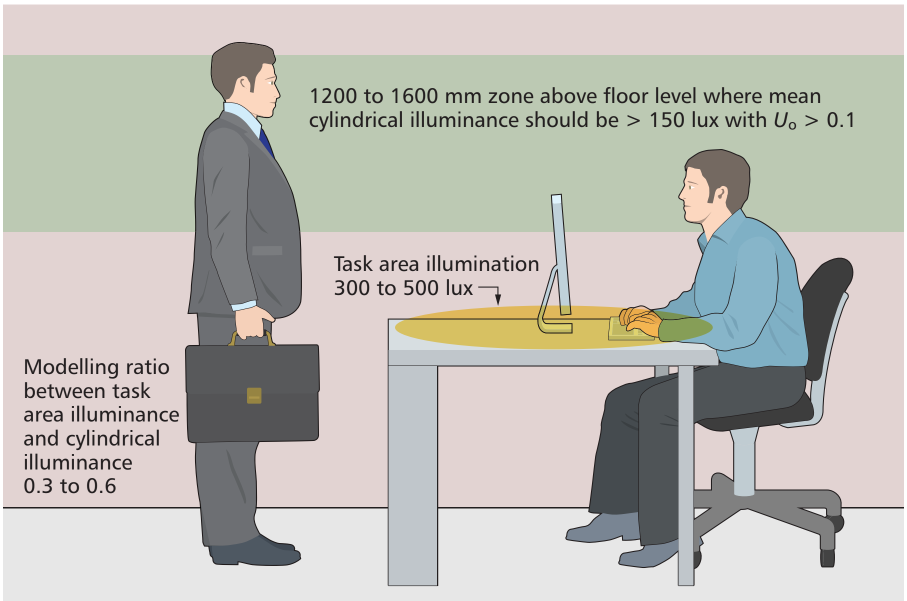
resulted in more meetings being held online or using software such as Skype. Training can also be delivered in this way to someone sitting either at a desk or in a breakout area using a tablet.

Consequently, it is now as important to address the illumination of a person's face as their working area. BS EN 12464-1: 2011 introduced the need to consider the vertical element, particularly at face height – be that a normal sitting (1.2 m) or standing (1.6 m) position – the preferred reference being the cylindrical illuminance measurement.

Cylindrical illuminance can be thought of as the illumination on a vertical object (or person) averaged to take account of light falling on the surface of an imaginary cylinder surrounding that object or person (Figure 2.1). Clearly, people are not stationary and could move their head in any direction. It is important to understand how much illumination there will be on their face when looking in any direction.

It is also important to understand if their location in a room is limited to a particular area or if they will move around. Providing an acceptable level of task-related cylindrical illuminance across an entire office space is less energy efficient that concentrating on areas where occupants are expected to be working.

Figure 2.1 Application of cylindrical illuminance



2.6 Modelling ratio

Modelling is a term used to refer to the balance between diffuse and direct light. Completely diffuse lighitng, such as an uplit-only lighting scheme, can look bland. Conversely, a direct lighting scheme with no diffused elements can produce strong contrast. Having a mixture of the two types will help to define shapes, colours and textures.

The modelling ratio is a comparison of the cylindrical illuminace value with the horizontal illuminance value and is expressed as the difference from unity or as a percentage.

An acceptable modelling ratio for office environments is considered to be 0.3 to 0.6 (or 30% to 60% of the horizontal illuminance value).

2.7 Client/user types

The number of combinations of actual client and eventual end user are numerous and all affect the design process in different ways. A client wanting a new office

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block built with the specific needs of their existing workforce in mind will have a slightly different perspective to an entrepreneur wanting an office block created for a new venture, where the workforce and indeed the whole company structure is yet to be formed. A speculative developer may not have a clear idea of the sort of tenant that will eventually occupy the office building.

2.8 Working with known occupiers

Where the designer is involved with new office space for a specific client then it is important that they liaise with the client to determine the types of tasks that will be carried out in each area of the building. The needs of a publisher, where many people have to carry out varied and sustained reading tasks, is very different to a recruitment agency, where there may be a lot of face-to-face interviewing and little paperwork. It is also important to establish what display screen equipment is to be used, where it is to be installed and the way the users intend to work with the equipment.

Often, the best way to get a feel for the tasks and the way a company operates is to visit the user's existing premises. This usually provides valuable insights into the tasks, equipment and working practices of the departments and the staff in them. However, if the user is a new start-up company or is moving into a new area of operations, they may not have similar existing office space. In this case it may be possible to find premises where similar tasks, equipment or operating methods are employed.

It is also important to establish with the user the type of interior decor that they prefer or are likely to choose. This will ensure that likely surface reflectance can be taken into account in preliminary lighting calculations. It is often easier with a known user to confirm what window-screening techniques are to be used and to establish that office layouts are compatible with the intended lighting solution. With a specific end user of an office building it is usually easier to define any non-task or decorative lighting required. This can be lighting for artworks, feature lighting or external lighting of the building.

Some companies have furniture layouts which are very static over time and fairly fixed patterns of employment. This means a fixed layout of lighting, either general or localised, can be effective. Others companies have a requirement for rapidly changing work teams or even areas for hot-desking, where staff do not have a permanent desk but claim a desk only when in the office. In this case reduced background lighting with relocatable task lighting may be more effective. Also, local control of lighting is likely to be more important in such areas. For areas where there will be relocatable walls, the lighting levels need to be related to the likely sizes of the partitioned offices, as for a fixed layout of luminaires. The smaller the office module, the lower the resultant lighting levels will be (see section 6.20).

See section 6.20 for more information

The lighting design may be for a known user intending to fit out a space within a speculative office building. The building may have been left with just central power supplies up to distribution boards in risers on each floor or have been partly fitted out with lighting of lift lobbies and even primary circulation spaces on each floor. The designer of the lighting for the fit-out will need to liaise with the designers of the landlord's services and lighting to establish what provision has been made for the fit-out.

2.9 Speculative development

Lighting for speculative offices should seek to be as flexible as possible within the remit given by the building owner. By the very nature of the concept, in a speculative development there will be no firm information on occupier use on which to base any design. The designer will need to consider a number of issues such as:

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- the type of tenant being sought
- the impact on interior decor
- the effect on lettable market rates.

See section 4 for more information

It is therefore essential that the lighting designer consult the building owner to identify specific needs on a project-by-project basis (refer to section 4).

2.10 Change of use

Lighting installations can be installed for many years without the need for anything other than regular maintenance and lamp replacement. During that time, the space they illuminate can change considerably. Where offices are to be created out of space used for other purposes, consideration should be given to the appropriateness of the existing lighting.

Premises used for industrial applications will usually have a lighting design centred on providing localised lighting where it is required. Such a situation may require extensive modifications to the position and type of lighting in the space to make it suitable for office-type work, particularly if the space is large enough to accommodate a large number of people. Where a space is changing use to form an office, it is important to understand all of the factors affecting the lighting.

It may be that, in a small office conversion, part of the solution to providing a suitable lighting design is actually achieved by placing office furniture to match the existing lighting positions rather than amending the lighting to suit a preferred office layout.

2.11 Importance of identifying the correct luminaire/lamp type

Whether the lighting design involves a new scheme entirely or alterations to an existing installation, it is important that the correct type of luminaire and lamp are used. Lighting in offices can have a significant effect on the occupants, with consequential effects on levels of alertness, well-being and productivity. An office fitted with bare batten-type fluorescent luminaires, for example, may represent a glare source and result in eye strain in contrast to luminaires fitted with a properly designed controller or diffuser.

The colour of the lamp can also have an effect on the user of the space. Warmer colours, such as 2700 K (warm white), will be more relaxing, while 4000 K (cool white) generally makes people feel more alert.

Extremely cold light sources nearer to 6000 or 7000 K can distort colour appearance or give the occupants of the room an unhealthy pallor.

In some instances, it may be worth conducting research with those who will occupy the office to determine preferences regarding the colour of the lighting source.

Mixing lamp colours should be avoided within the same space unless it is done for artistic effect.

2.12 Coordinating the lighting design

Lighting, particularly electric lighting, can only be effective when considered alongside the decorative finishes, textures and layout of an office space. Discussion with the architect or interior designer is crucial to understand what the reflective spaces of the office will be like. Lighting which is to be recessed into a ceiling void will have to be coordinated with other services, such as cable containment, pipework, ductwork and sprinkler systems, as well as structural elements of the building. If these items are not coordinated, the position and orientation of luminaires may be compromised.

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Figure 2.2 Decorative spot lighting located too close to a wall, resulting in excessive glare and poor uniformity across the vertical surface

Figure 2.2 shows some decorative spotlights mounted too close to a perimeter wall due to poor coordination with the ceiling arrangement.

2.13 Portable display screens

Both touchscreen desktop computers and tablet computers are commonplace in office environments. As the screen position in relation to lighting sources can change constantly, it is extremely difficult to provide a lighting design that will reduce reflections and glare at all times. Where a building owner has indicated that they use such devices, it may be worth establishing the usage pattern, in particular determining where the devices are mainly used. For example, if tablet use is predominantly in communal areas, such as breakout space, then the use of up-lighting may be the most appropriate option.

2.14 Web cams and desktop video conferencing

The use of web cams or desktop video conferencing (such as Skype) should be determined early in the design process, as lighting for such an application may need to take a different approach to that for an office which is used predominantly for data processing work. Cylindrical illumination considerations should have a major influence as faces will need to be clearly visible.

The contrast between faces and background will not always be something that can easily be controlled when video conferencing is employed at individual desks; however, the following can have a detrimental effect on image quality:

— light sources in direct view of the camera

— highly patterned backgrounds

— high contrast ratios between background and faces caused by dark colours or poor background lighting

— uplit schemes producing high luminance values or poor balance.

2.15 Hot desking

As the cost of office floor space continues to increase, occupiers are reducing the number of desks compared with their staff numbers. This practice works on the basis that some staff spend a lot of time away from their desks and their jobs are mobile in nature.

Such staff will not have a fixed desk but will be encouraged to use either a dedicated hot-desking area or the desk of an absent colleague while they are in the office.

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Figure 2.3 Typical hot desk arrangement

Where staff are using colleagues' desks, the lighting will usually not be a cause for concern; however, specific hot-desking areas may need to be treated in a different way. They will frequently be used by staff with laptops and tablets, so the position of the display could vary considerably (Figure 2.3).

Consideration should be given to indirect lighting for hot-desking areas. This may include an element of direct lighting, provided that adequate glare control can be achieved.

2.16 Reuse of equipment

Luminaires consist of active and passive components. The active parts, such as lamps or LED arrays and control gear, will have a specific working life, usually dependent on how well they have been maintained and how much waste energy, in the form of heat, they have been subjected to. The passive parts, such as the case and controller (provided it has adequate ultraviolet (UV) stability), could last significantly longer than the active components.

Designers should discuss with building owners the benefits of reusing relatively new existing equipment in any refurbishment programme. Where the active components of a luminaire are less efficient than current technology or have reached the end of their working life, it may be worth exploring the possibility of retrofitting new equipment into the existing case.

2.17 Getting the most out of daylight

Lighting design can be considered in two broad forms: the use of daylighting and the use of electric lighting in the design process. Daylighting is a passive form in that it requires no external energy input to deliver lighting into a space. Depending on a number of factors, such as the use, shape and form of a building, the amount of daylight that can be utilised will differ.

Considering these elements in depth before commencing any electric lighting design can sometimes have a significant effect on the energy consumption of a building, particularly when linked to a well-designed control system.

2.18 Energy use

See section 8 for more information

Electric lighting in buildings is a major user of energy and any new office lighting design needs to take into consideration how much energy it will use and how to get the most out of a given amount of electrical energy input in terms of lighting output. However, energy reduction should not be the prime driving force. Lighting should be well designed and deliver a comfortable and well-illuminated environment for a building's occupants. (Energy use is covered in section 8.)

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2.19 Maintenance of office space

The amount of light emanating from a luminaire depends on a number of factors, each of which will affect the ability of the light source/luminaire combination in an installation to deliver its optimum output and effectively act to de-rate the design. This is done to make sure the installation is still delivering the intended illumination level immediately prior to maintenance being carried out. As the light output falls between maintenance activities, it follows that the illumination when the installation is new or has just been maintained may be higher than the design intended unless suitable controls are used. Luminaires, based on both fluorescent lamp and LED technologies, are available that can limit the output in the early life of the installation or after maintenance has been carried out and increase that output as the installation ages. The use of such luminaires should be carefully considered, particularly where they can also reduce energy use during the early phase of an LED module or lamp's life.

See the *SLL Code for Lighting* for more information

The way in which the light source/luminaire combination is utilised can be determined by reference to manufacturers' data, along with the reflectances of the room surfaces, the dimensions of the room and the height of its working plane. This is known as the utilisation factor (UF) and, once determined at the design stage, should remain constant, provided that the room dimensions and surface colours do not change. More information on determining a suitable utilisation factor can be found in the *SLL Code for Lighting*.

While the UF can be determined as a constant during the design of the lighting installation, the way in which the installation is maintained throughout its life can have a significant effect on its ability to deliver the illumination levels intended during its design. Traditionally, when deciding how best to address this effective de-rating of the design, the lighting designer will consider four factors :

— the lamp survival factor (LSF)

— the lamp lumen maintenance factor (LLMF)

— the luminaire maintenance factor (LMF)

— the room surface maintenance factor (RSMF).

More information on maintenance factors, including a detailed description of the above can be found in the *SLL Code for Lighting*. However, as an overview, the four factors multiply together to give an overall maintenance factor (or de-rating factor to take into account the frequency of maintenance being applied). The LSF considers how long the light source will last on average before failing and takes account of the number of hours during which the lighting will be in use per year. The LLMF considers how the lighting output from individual light sources will degrade over time. Again, hours of use are a consideration. The LMF considers how often the luminaire housing the light source will be cleaned and the RSMF considers how often the reflective surfaces of the room will be cleaned. Both of these factors consider the cleanliness of the environment in which the lighting is installed.

It should be noted that non-constant light output LEDs may have a less favourable LLMF than other lighting sources and designs will need to reflect this. Manufacturers' data should be checked.

It is obvious that the longer the period between lamps being changed or cleaned, the worse the degradation of lighting output will become and, in order to accommodate building owners' requirements to minimise maintenance events (and associated cost), lighting installations in the past have sometimes been over-designed in terms of maintenance factors to compensate for the long maintenance intervals.

It is important to discuss with the building owner the maintenance regime they intend to put in place. The effects on energy use of over-designed lighting installations due to extended maintenance must be considered within the overall design, installation and lifetime operation of the lighting. It may also be appropriate to discuss with the building owner the concept of monitoring the lighting levels and changing lamps, cleaning luminaires, etc. when the levels drop below an acceptable minimum. Such an approach will allow the building user to better match maintenance intervals and cost to the changing use of the space in which the lighting is installed.

2.20 Illumination of walls and ceilings

It is a popular misconception that lighting in an office only needs to be applied to the task area. Anyone sitting at a desk and generally looking in one direction, be that at a computer screen or at paper documents, needs to be able to regularly look away into the distance in order to avoid eye strain. That distant view should ideally be to the outside; however, it could be a long view within their office. In either scenario, the illumination level of the distant view should not be significantly different to that of their task area.

Problems can be encountered from excessive levels of daylight, particularly on sunny days, and it is relatively easy to control this by the use of translucent blinds (allowing the view to continue through them), which can reduce the contrast between the task area and the long view to acceptable levels. The colour of the walls, ceiling and floor can also help to reduce the contrast from outside.

For example, a small window in an office with a reasonable view of the sky may present a significant contrast with the task areas in the office. By painting the office wall around the window in a light colour and using light-coloured furniture, the perceptible difference in contrast will be lower than if the wall surrounding the window is a darker colour (Figure 2.4).

Where a view to the outside cannot be provided or where the window-to-floor ratio is low, the lighting designer should consider providing additional illumination levels on the walls and ceiling beyond those already recommended. These surfaces could represent the long view for the occupants of an office and therefore they may need to be provided with additional illumination to reduce the level of contrast between them and the task area. Again, lighter colours for wall and ceiling finishes will help.

Figure 2.4 Light-coloured finishes help to reduce contrast with windows

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Table 2.1 Recommended maintained illumination on walls and ceilings

Luminance distribution	Ceiling	Walls	Floor	Furniture and major objects
Surface reflectance	0.7–0.9	0.5–0.8	0.2–0.4	0.2–0.7
Illuminances on surfaces	$E_m > 50$ lux with $U_o > 0.1$	$E_m > 75$ lux with $U_o > 0.1$	As designed	As designed

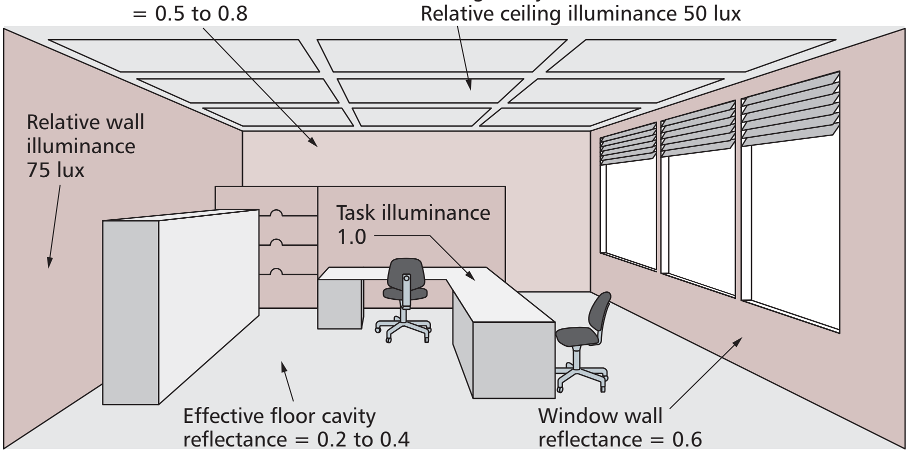

Figure 2.5 Illumination on walls and ceilings

The recommended maintained illumination on walls and ceilings is given in Table 2.1. The recommended levels have been reduced from those given in the previous version of SLL Lighting Guide 7; however, designers should be careful to consider each office on its individual merits. The luminance of a reflecting surface, such as a wall or ceiling, will be affected by more than the illuminance falling upon it from a light source; the colour, texture and opacity of the surface play a major role in how someone would perceive that surface if it were part of their distance view. The levels therefore should not be considered simply as targets to achieve, but as starting points to a well-balanced lighting design.

Illuminance is the amount of light falling on a surface from a light source such as a fluorescent lamp.
Luminance is the amount of light being reflected by a surface.

An example might be an office in a predominantly glazed building. An occupant may have a view to the outside during the daytime; however, at night that view disappears and is replaced by a transparent wall with a black background. The illumination of the wall will result in a small amount of light being reflected and so the luminance will be low. Installing light-coloured blinds or curtains will have a significant effect on way the 'wall' is perceived (Figure 2.6).

Where a lighting design is based on localised task lighting with a general background illumination, it can sometimes be difficult to provide specifc illumination levels on walls and ceilings without lifting the general background level to a point which negates the advantages of a localised task lighting design.

Again, the specific circumstances of the office to be lit should be considered. For example, a large open-plan office with its assorted contents may provide sufficient visual interest to the distance view so that achieving a minimum illumination level on walls and ceiling is less important (Figure 2.7).

Wall and ceiling illuminance in a smaller office will be more apparent. Here localised lighting could be provided via a limited number of indirect luminaires.

2.21 Glare

The issue of how to limit glare presents an ongoing challenge to lighting designers. Disability and discomfort glare can be difficult problems to resolve, particularly if not considered early enough in a project.

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Figure 2.6 Comparison of room with blinds raised and lowered showing the effect of changing the window wall reflectance

Figure 2.7 Open-plan office showing how furniture and general office life distracts from illumination on walls

The introduction of LEDs into mainstream office lighting has brought the issue of glare back to the fore. LEDs are a point source of illumination and are therefore much more apparent if within someone's direct or peripheral view than a fluorescent lamp would be.

Having said that, the changing use of technology in offices means that fewer people remain in fixed positions, sitting in front of fixed display screens, choosing instead to use laptops, tablets, smartphones, etc. While those sitting in fixed locations should benefit from a lighting design that provides considered glare control, it may not be possible to ensure that the needs of all users of an office are catered for by the lighting and interior design alone. In situations where users of portable equipment are standing or moving around with their screens nearer to the horizontal plane than the vertical, users may need to adjust their position relative to a source of glare.

See the *SLL Code for Lighting* for more information

Please refer to the *SLL Code for Lighting* for more information on glare.

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2.22 Direct current power supplies

We have become accustomed to lighting in our buildings being supplied at mains voltage from an alternating current (ac) supply. Incandescent lighting as well as low- and high-pressure sodium- and mercury-based lamps have all required relatively high voltages either to strike or to directly produce any meaningful lighting output. In addition, alternating current supplies have traditionally been easier to manage from a circuit protection point of view; however, they have a number of disadvantages, most notably, the issue of flicker in fluorescent lighting and poor quality in LED products.

The improvements in LED technology and the use of microprocessors in the control circuits have allowed direct current (dc) supplies to be considered for a variety of applications – lighting among them.

2.22.1 Power over Ethernet (PoE)

Providing power supplies across Ethernet connections has been common practice for some time, most notably in telephony where voice over internet protocol (VoIP) has seen data cabling used to provide the power to the telephone handset as well as the voice signal. The ability to increase the working load of power supplies over Ethernet connections has improved considerably though and we now have the opportunity to consider such power supplies for dc LED luminaires.

PoE makes use of the same cabling as is used in offices to provide a data connection between the main data switch equipment and each computer in the office. Additional cables of the same type can be installed at the same time as the data cabling with the advantage of reducing the cost of installation. There would also be no need to install additional power cabling for the lighting installation if it was required in the same vicinity as the data cabling.

For lighting designs utilising a localised approach to task lighting, PoE could easily provide power at the data connection points for dc powered LED desk lights.

Traditionally, power supplies to lighting have been designed on the basis of making power available regardless of the need to use it. This has meant that a ‘live’ cable has been present either within a luminaire or within a light switch. PoE is an active system that requires any connected luminaire to request power from the supplying power switch. Connected items are known as ‘powered devices’ (PD) and each PD has an associated class within which it operates. Table 2.2 details the relevant classes and their associated power limitations.

LED lighting supplied via PoE is most likely to use either Class 4 (PoE plus) or manufacturers’ proprietary systems, which are unclassified. Classified systems are capable of supporting 30 W at the power switch. It should be noted that the value will be lower at the luminaire due to circuit losses, but should not be allowed to fall below those shown in Table 2.2. Manufacturers should be consulted if unclassified systems are to be used.

Table 2.2 PoE classification

	PoE	PoE plus
Class	1, 2, 3	4
Maximum power per switch port	Up to 15.4 W depending on class	30 W
Maximum power to powered device	Class 1 (0.44–3.84 W) Class 2 (3.84–6.49 W) Class 3 (6.49–12.95 W)	25.5 W
Cable type	Cat5e, Cat 6 or Cat6A	Cat5e, Cat 6 or Cat6A
IEEE definition	802.3af	802.3at
Minimum number of pairs used	2	2

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3 Office types

3.1 Introduction

Offices are perhaps the most varied of commercial spaces, ranging from converted bedrooms in domestic accommodation to large open-plan floor plates in high-rise buildings. Clearly, each type has common criteria to meet; however, it would be impractical to treat the design of each in the same way.

Compromise is much more likely to occur in small spaces where there are constraints, such as furniture positions, and where window location is fixed, particularly with regard to daylight and the balance between providing adequate daylight and controlling glare.

3.2 Self-contained office buildings

The larger purpose-built office building is normally designed with the full range of secondary office spaces as well as the main working office spaces (Figure 3.1). These secondary areas can be adapted parts of the office's space or specially created rooms. Spaces such as meeting rooms, reprographics, resources areas and atria play an important role in the efficient running of the office and should be well lit.

Often the self-contained office building is built to impress, with high-quality entrance, reception and lift areas. The lighting design and the resulting visual environment must help to achieve this goal. The quality of the luminaires themselves, in terms of build quality and surface finish, has to be considered. Feature luminaires may be required in entrance halls and lobbies. Special lighting effects, such as colour washes, fixed or moving logos and the framing or highlighting of artwork or special features, may be required.

Figure 3.1 Typical open-plan office with good use of natural and electric light

3.3 Mixed development

In order to provide a good mix of use and ensure that developments are used throughout the day, planning authorities encourage developers of large projects, such as high-rise towers, to incorporate other types of use within their development. These can include retail, leisure and residential accommodation.

Where mixed developments include office lighting, consideration should be given to the impact of the other uses on the office space.

An example would be the entrance to office accommodation from a retail mall. As retail illumination levels are generally higher than those in offices, it may be necessary to increase the level of illumination at the entrance or reception to the offices to minimise the visual impact of the transition between the two spaces.

As mixed use developments will have different operating times for the various businesses they house, consideration needs to be given to lighting to and from the

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Figure 3.2 Mixed use development in central London incorporating retail and office accommodation

office accommodation. Will the access, for example, be via an area that may not normally be illuminated at 8.30 am? In such a situation, discussion with adjacent occupiers will be necessary to ensure that lighting for a safe means of access and egress can be maintained.

3.4 Smaller offices

The majority of offices are small units above shops, converted houses or in small units on business or industrial estates. These buildings tend to have more cellular office space and are generally less adaptable. Due to the lack of scale in the building, many of the usual office functions are combined in single rooms. Thus, the photocopying may be carried out in the corner of the reception area or the meeting room may be a part-time office. Often the lighting designer has to take account of such problems when determining the type and style of lighting for each space.

Many historic buildings are used as offices. In cities such as Bath, York, Edinburgh and London, many Georgian, Victorian and Edwardian houses in the city centre have been converted for use as offices. This includes grade I listed properties in prominent positions as well as many older properties which have no historic or architectural importance. For most of these, where the interiors have been fitted out to modern standards, the lighting can also be fairly straightforward and modern in style. Sometimes there will be a need to take into account unusual ceiling heights or make allowances for careful routing of wiring through the building.

With many listed properties, not only must the interior lighting fit in with the interior style of the house, but also it must not spoil the view into the property from the outside. Looking up at a grand Victorian facade and seeing fluorescent

Figure 3.3 Historic buildings in Piccadilly Circus used for office and retail accommodation

lights on chain suspensions or brightly coloured luminaires inside may, in some people's eyes, be somewhat disconcerting.

In some circumstances it would be more appropriate to specify chandeliers with compact fluorescent or LED equivalents to incandescent lamps for, say, the principal first floor rooms of a listed Georgian house. These will be visible from the street and would appear correct for such grand rooms. It is likely that task lighting would be needed to provide adequate lighting levels on desks. The use of potentially bright chandeliers in rooms where display screens are in use needs particular care, although the relatively small room sizes give a user–screen–light geometry that means that reflections in screens are unlikely.

3.5 Shared office space

Many small organisations share office facilities within a single building. Each company has its own office space in one or more rooms, drawing on the common, centrally owned facilities as and when required. Such serviced office accommodation offers small companies the advantage of only having to pay for central services, such as copying, reception, meeting rooms and sometimes restaurant facilities, without having to make an initial investment in space, furniture and staff. These buildings can vary from the executive serviced offices seen in many major cities, where users can impress their clients by renting an office space or meeting room for a day, to thriving communities of designers and artists in converted factories with simple finishes and services. The lighting design should reflect these differences.

In these situations the lighting designer is required to provide adaptable lighting in the office modules so that an individual company can alter the lighting in a

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changing number of rooms or spaces to suit their specific needs. Often, a start-up company will have one large office room; then, if the business develops successfully, they will rent extra rooms. Some companies with specific lighting requirements may need to adapt the lighting of each room as they take them over. As rooms rented subsequently can be scattered throughout the building, due to adjacent rooms already being rented to other companies, at some point the company may agree with the landlord to move all their operations to one suite of adjoining rooms if they become available. Other companies fail and move out. This constant flux within the building means that the lighting has to be adaptable.

For the common areas, the lighting can be fairly standard with the observation that these spaces cater for a constantly changing workforce with many different needs. Within many larger office buildings you are likely to find most types of primary office space, such as open-plan and cellular offices, typical secondary spaces, such as kitchens, meeting rooms and circulation spaces, and back-of-house areas, such as plant rooms and storerooms.

3.6 Areas where office work is carried out within other building types

Almost all buildings have small spaces where office work is carried out. The small local garage will have an office in the corner where the administration is done. Factories have production and quality control offices on the shop floor and perhaps accounts, finance and personnel offices alongside the production areas. Someone using a display screen in a small production office in the midst of assembly lines deserves the same quality of lighting as the executive in the private suite. Realising this ideal is not always easy.

Small offices on the factory floor are often self-contained boxes to provide some degree of privacy and sound insulation. In these cases, lighting can usually be provided in the normal way in or on the ceiling, boosted by local task lighting as appropriate. Where the office tasks are provided in partitioned-off areas, it may be necessary to provide just extra task lighting on or by desks to supplement the overall lighting of the factory floor.

4 Speculative development

For designers of speculative office space where the working spaces are usually flexible and not designed for specific users or tasks, a more general lighting approach is needed.

Designers should discuss with developers how they intend to market the speculative development and what flexibility needs to be applied to the design. Very often, furniture layouts are unknown; however, if such information can be obtained, a much more appropriate and energy efficient lighting design can be achieved.

Balancing the need to provide an adequate level of illumination with sufficient relative surface illuminance is always going to be challenging in a building that has no known final occupier.

The lighting design provided for speculative offices is most likely to be a compromise, based on the following constraints:

- the need to provide a lighting installation which will appeal to any prospective tenant or owner and show what can be achieved in the space
- the need to work within a budget aimed at a bare minimum requirement
- the need to provide flexibility for any prospective tenant or owner
- the need to provide a design that is marketable to prospective tenants

— the need to provide a design and installation which can readily be used without modification should the tenant or owner choose to do so.

Of these five points, the need to provide a design and installation which can readily be used is the key element and this should serve as a basis for achieving the rest.

See section 2 for more information

We know that a space needs to provide more than just horizontal task lighting; this guide provides recommendations for the relative surface illuminances on walls, ceilings, etc. (see section 2). To achieve the recommended guidance levels in a space that may change almost as soon as the developer completes the installation, could result in wasted equipment and the associated energy and cost involved with that installation. It is important therefore that a discussion takes place with the developer about what is expected of the lighting installation before the building is let/sold and what tenants or future owners will be expected to provide.

In some instances, it may be appropriate to provide only a limited amount of background illumination if, for example, the future tenant is known and has agreed to cover fit-out costs separately.

The end users could be carrying out almost any type of task or working on different types of display screen. This could involve the use of tablet computers, where the angle of the screen in relation to the lighting is constantly changing. For this reason the exact nature of the lighting and decor to be provided must be established with the building's owner or developer.

Designers should bear in mind that adopting a general approach rather than specific requirements is likely to result in higher energy use. Again, this should be discussed with the building's owner or developer in case it has an impact on the energy performance of the building.

Figure 4.1 shows a typical desk layout for an open-plan office. Information such as this, obtained early enough in the design process, can allow a lighting design to be tailored to the environment with the added benefit of utilising energy efficiently.

For almost all speculative buildings, the owner is likely to require the design of all shared building lighting, such as that in reception, stairs, lobbies, etc. In some

Figure 4.1 Typical desk layout for an open-plan office

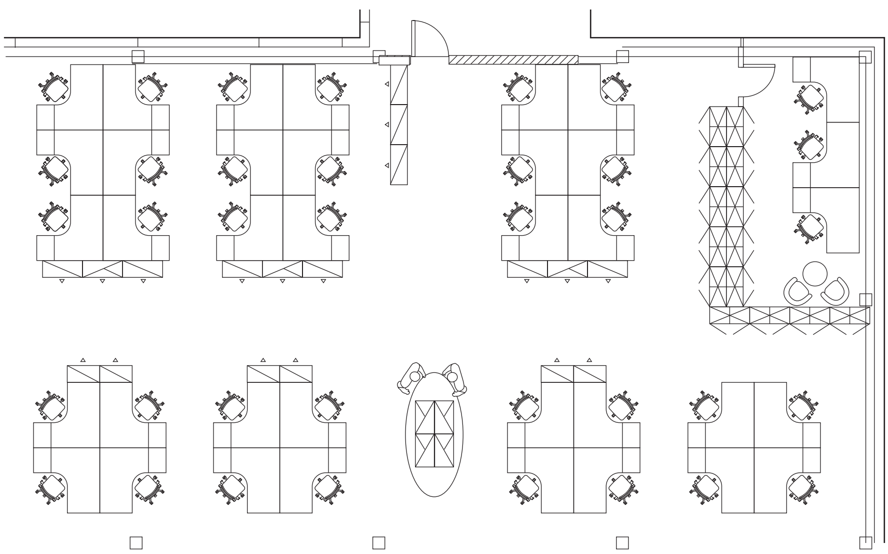

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Figure 4.2 Typical Category A fit-out in progress

buildings, the landlord's lighting may be extended to the primary circulation space on each floor. The tenant is often just provided with central power supplies up to distribution boards in risers on each floor for their future lighting needs. The designer must consider how far to go in allowing flexibility for future tenants' lighting. Providing too much flexibility in distribution board size or control provision may incur unnecessary costs for the landlord; but too little flexibility may make the building less attractive to potential tenants.

There are a number of standard terms for the degree of provision within a speculative building:

- a 'shell and core' office includes finishes and fit-out to landlord areas only, with services capped off within the riser at each floor and office areas left as a structural shell
- a 'Category A fit-out' extends finishes and services into office areas to create usable open-plan space
- a 'Category B fit-out' provides all services to the tenant's requirements.

Before starting the design process for any tenanted floor space, it is important to establish with the building owners (and possibly the letting agent) the types of user to whom the space will be marketed. While speculative office space provides a blank canvas for potential tenants, it is likely that the building owner or developer will have a particular type of tenant in mind.

The design of the lighting can have a positive or negative effect on potential tenants. For example, some may see a general background level of illumination as the ideal starting point from which they can provide localised lighting as appropriate. Others may view the same background level of illumination as something that will incur cost to bring up to a satisfactory level.

The first group may appreciate that a general background level of illumination, particularly at the low end of recommended illumination levels for office space, has a direct impact on the energy that the installation will consume from the start. They may see the addition of local lighting and its impact on the energy footprint of a building as something over which they want to have control.

It may therefore be acceptable to provide a lighting design that delivers a consistent average illuminance across a space. The level of that illuminance can

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be determined in consultation with the building owner or developer, depending on the tenant target group and how the space will be marketed.

A major component of any successful lighting design is the control system and, in particular, its flexibility to adapt to future changes in office layout. Flexibility is an important factor in the success of speculative office space and a lighting design which lends itself to a number of control options may be something that appeals to a building owner or developer, particularly if it improves the lettable value of the space.

See section 6 for more information

The space planning flexibility also needs to be established. This will help to determine the likely effect of partitioning options on the illuminance levels and the degree to which the partitions cut off long views of luminaires across the space. Most speculative space is marketed as totally open plan with possible partitioning options indicated. The lighting design will need to take into account these optional partition arrangements and allow for suitable task lighting levels and uniformities from a fixed lighting grid in a range of cellular office modules. (See section 6 for more information on lighting design.)

It is important to liaise with the architect or interior designer on finishes and window types and their screening. Once these points and the possible partition layouts are established, lighting design principles can be established that will allow the correct degree of flexibility in letting options. However, not all possibilities can be allowed for. For example, it is possible that what was intended as a group of small factory start-up units may end up being let to one high-intensity computer-based user, such as a call centre.

Installing lighting that can cope with too wide a range of possible users may be either very expensive or provide a poor compromise for all. Adaptable design options, and their costs, should be explored with the building owner.

5 Daylighting

5.1 Introduction

The importance of daylighting in an office space, in terms of both the benefits in energy reduction and the health and well-being of the occupants, cannot be overstated.

Most people prefer to work in a daylit space. This could be because of the visual stimulus that the changing patterns and intensities that weather systems bring to a daylit space, or simply the need to have a connection with the outdoors.

In addition, as we continue to make efforts to reduce the energy we consume in our daily lives, the use of this notionally free and zero-energy source of illumination should be maximised (notionally free because more daylight means more solar gain which will require the use of energy to control any associated heat gains).

The daylight illumination of an office depends on the size and position of the windows and the size and proportions of the room as well as the internal room surface reflectances. It will also depend on any obstructions, both internal and external. Windows also provide a valuable visual contact with the exterior, and even when a workstation is far enough from the window to provide minimal daylight illumination, the fact that the occupant can see a window will give the impression that they have some daylight. Privacy can also be a problem and should be considered, as well as the sun's penetration in terms of glare, both direct and reflected. Blinds or some other sun screening device may be necessary.

See SLL Lighting Guide 10

More information on daylighting can be found in SLL Lighting Guide 10: *Daylighting – A guide for designers*.

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5.2 Daylight factor

The contribution of daylight to the illumination of an office space is determined in a different way to that of electric lighting. To begin with, there is one very important constraint: we do not control the position of the sun. Second, the openings in the building, such as windows and rooflights, are designed to address other issues as well as lighting, namely solar gain, privacy and aesthetics. A further uncontrollable factor is the position of adjacent buildings and their shading effect on the office.

A method is therefore required to bring these factors together and determine how great an influence they have on the amount of illuminance available from daylight. The term 'daylight factor' is used to describe the ratio of available illuminance in a space to the illuminance outside under an overcast sky.

BS 8206-2: 2008 states that an average daylight factor of greater than 2% across a space should result in that space appearing to be predominantly daylit.

An average daylight factor of greater than 5% indicates that electric lighting will not normally be required during the daytime.

It should be noted, however, that there are limitations to the daylight factor approach. For example, the building's location or its orientation are not considered. The issues of glare and visual comfort are also absent from the daylight factor approach.

Daylight modelling software is now available which can encompass these factors.

See SLL Lighting Guide 10 for more information

More information on daylight factors and how to calculate them can be found in SLL Guide 10: *Daylighting – A guide for designers* and BS 8206-2: 2008.

5.3 Uniformity of daylight

See SLL Lighting Guide 10 for more information

While an appropriate daylight factor is important, consideration should also be given to the uniformity of daylight. A satisfactory level of uniformity should normally be achieved if more than 80% of the task area has an unbroken view of the sky and if the room is not too deep. BS 8206-2: 2008 gives an equation for limiting room depth, which in a normal office is usually in the range of 6–8 m from the nearest window wall. Rooms with windows on at least two walls usually have better uniformity of daylight. More information on uniformity of daylight can be found in SLL Lighting Guide 10: *Daylighting – A guide for designers*.

5.4 Daylight autonomy

In addition to the daylight factor and the uniformity of daylight, daylight autonomy should be considered. Daylight autonomy is a way of showing the length of time for which a given amount of light is available. It is represented as a percentage of the annual daylight hours during which a particular point in a space (such as a task area) has sufficient daylight to allow the artificial lighting to be switched off.

5.5 The importance of early involvement

Often, decisions about window space, size and location within a building's envelope are made to suit a particular architectural theme as well as to meet statutory requirements, such as the Building Regulations requirements on window to floor minimum ratios. Poor window design can impact on a number of performance and energy objectives. Typically:

- solar gain
- daylighting
- glare
- thermal performance

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— convection of cold air

— views in and out.

Clearly, there are a number of factors to take into account when design teams plan the windows in a building. Early discussion is therefore key to making sure that daylighting is kept as a high priority in the balancing of the various, and sometimes conflicting, requirements. For instance, solar gain is usually controlled via external shading or soft-coat low-emissivity glazing (with a low solar transmittance and high visible daylight transmittance), whereas glare is usually controlled by the occupants through internal blinds.

5.6 Controlling the effects of daylight

While daylight is uncontrollable in terms of its presence and intensity, there is a need to make the most of what it offers.

Passive control, such as fixed shading, can be used to limit the amount of light entering an office. External shading is usually used to combat solar gain, while internal blinds are usually used to limit glare or simply to reduce levels of daylight as required by the occupants of the space. Automatic control of blinds can be used for a combination of both functions. In addition to automatic control of blinds, active control of electric lighting can work in unison with daylight sensing to reduce levels of artificial illuminance adjacent to windows, in atria and below rooflights, hence reducing energy usage.

5.7 Refurbishment and conversion

5.7.1 General

Options for maximising daylighting in existing buildings that are undergoing refurbishment or conversion from another use are often restricted, particularly if the facade is to be left untouched. Where offices are in historic buildings, there is the possibility that facades could be listed, with the result that any shading would have to be limited to the interior.

Desk positions may well be compromised by the shape and size of any existing room and the most efficient use of the space may not be best suited for the available daylight. A number of options can be used to introduce light into a space (Figure 5.1), such as:

— light shelves

— sun pipes

— rooflights

— atria

— clerestory windows.

Some options require much greater architectural input than others, and will not be as effective under an overcast sky. An early discussion with the building owner regarding the options available is recommended.

5.7.2 Change of use

Where offices are to be created out of space previously used for other purposes, the optimum utilisation of daylight may not be the highest priority for the building owner. While many spaces involving change of use will inevitably result in some degree of compromise, the benefits of making the best use of available daylight should not be overlooked by the designers.

There are some relatively straightforward ways of optimising daylight in rooms with less than ideal daylighting provision. Colours of wall, ceiling and floor finishes can have a dramatic effect and should be as light as possible. In smaller offices, the desk surfaces can represent a large proportion of the reflectance in the room and therefore dark furniture should be avoided where possible.

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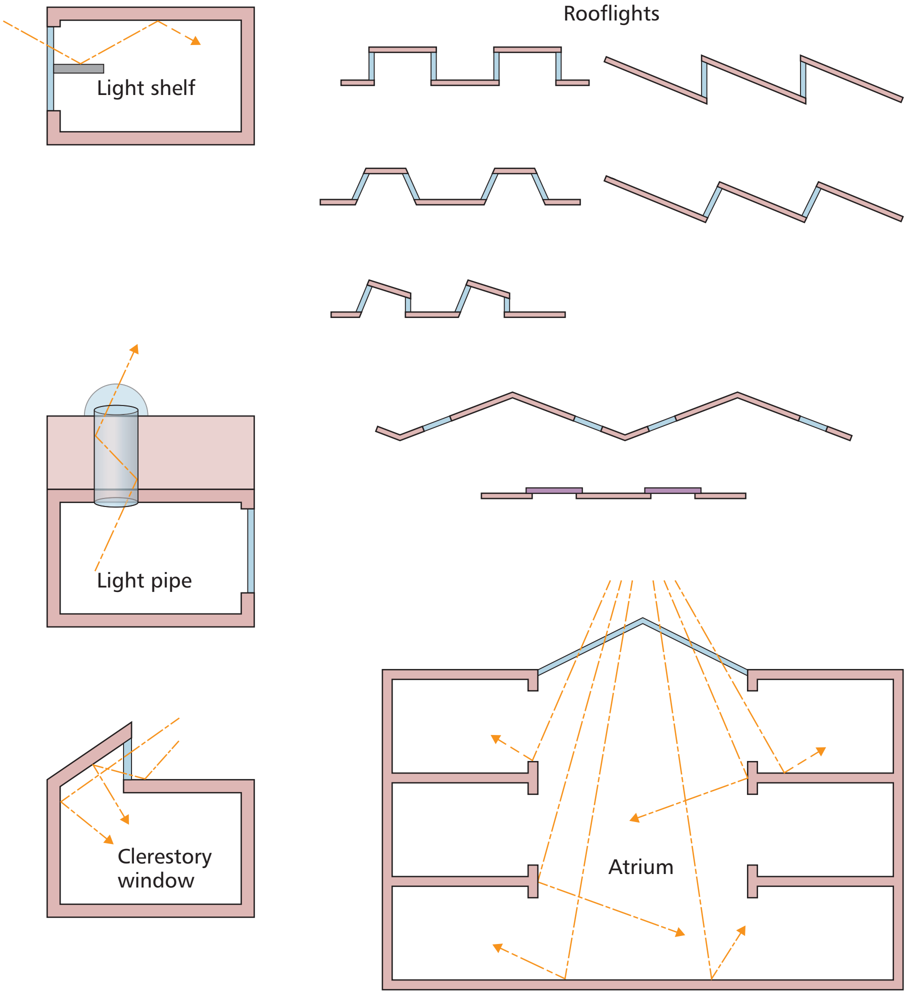
Figure 5.1 Alternative methods of introducing additional daylight into existing buildings



5.7.3 Colours and reflectance

The effect an interior colour scheme has on how lighting is utilised in a room is not something that many building owners consider when creating or refurbishing an office. Colours and textures can have a significant effect on the amount of light that interiors reflect. The importance of texture should not be overlooked. For example, an office with a dark carpet is only likely to reflect 10% of the light striking the floor. It may seem obvious that a dark carpet will not provide much reflectance, however most building owners would probably guess that a light carpet is significantly better. At 30% reflectivity, a light carpet is perhaps not as good as most may think. This is in part due to its texture causing multiple reflections, most of which will not be back into the room.

While an office can benefit significantly from a large amount of daylight, the colour of that light is a key factor in making the occupants feel more alert. Strong colours on walls and floors will change the perceived colour, as reflected light from those surfaces no longer represents the colour of daylight (Figure 5.2).

Yellow walls or floors for example will make the lighting feel warmer, which has been shown to affect the alertness of occupants.

See *SLL Lighting Handbook* for more information

More information on reflectances can be found in the *SLL Lighting Handbook*.

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Figure 5.2 A converted office space with a strong blue content to the decor resulting in a blue cast

5.7.4 Window shading options

Window shading can be an effective way of controlling daylight; however, it can also be used to reduce solar gain in a building. A third use may be for privacy reasons and therefore any use of shading may have to be a compromise between the three requirements.

Figure 5.3 Example of horizontal solar shading

Fixed shading is usually on the outside of a building and is often some form of horizontal structure above a window, which effectively becomes an overhang. Occasionally, vertical shading options are used; however, they can have a significant impact on the view from the building. This type of shading is usually passive, in that it remains fixed in one position regardless of the position of the sun.

Active shading options are usually installed either in the occupied space or within a gap between the panes of a glazing system. These can sometimes be manually adjusted; however, it is now more common to see such systems controlled by a building management system (BMS) and prioritised to control solar gain.

Where such systems are installed, it is advisable to include occupant-override manually operated blinds as well so that occupants can exert their own control if desired.

Further information can be found in the BRE report *Solar shading of buildings*.

5.7.5 Working with what you have

The relationship between window and desk positions in many refurbishment or conversion projects is often a compromise and the optimum position for maximising the benefits of daylighting is not achievable. It is important to identify any constraints and inform the building owner as early as possible so that compromises can be discussed and the best solution found before the design progresses too far.

An excessive amount of daylight can usually be controlled through solar shading or blinds, preferably external. Usually oversized windows will be a concern to those having to consider the issues of solar gain, particularly in windows facing south-east through to south-west. A coordinated effort to address the problem is recommended.

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Figure 5.4 Monitors positioned to avoid direct glare from daylight

Suboptimal use of daylight can be supplemented with electric lighting. Perhaps the more difficult situation for a designer to deal with is a compromised desk position which results in a high level of glare, either directly to the occupier or via their display screen (Figure 5.4). It may be that some solar shading is required.

Where windows represent a particularly large proportion of the wall area in a south or south-westerly direction, then shading may also be needed to address the heat build-up in the room through solar gain. A combined solution may be appropriate and options for this should be discussed with the building owner.

5.8 New build

5.8.1 General

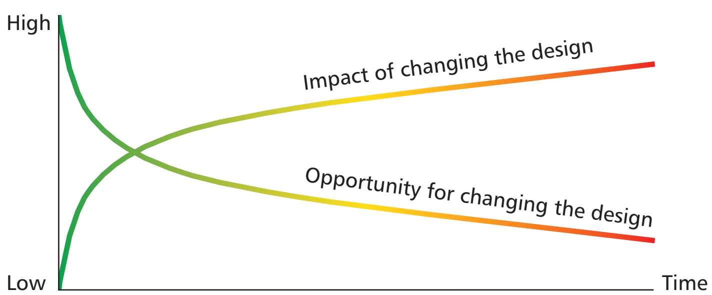
New building projects should consider the provision of quality daylight in office spaces as one of the key prerequisites. Each project is different and the final design will ultimately be a balance of factors; however, daylight provision will have an effect on the occupants and energy use of the building over its whole life and therefore should be given due consideration.

Further information can be found in the BRE report *Site layout planning for daylight and sunlight: A guide to good practice*.

5.8.2 Influencing design

The lighting designer should ideally be on board with a project team at the outset of the concept stage. This is the point in a design where the most effect can be had for the least impact. If fundamental decisions are left too late, the cost and impact on a building design can be significant. Figure 5.5 shows how the opportunity to change a design with little impact is greatest at the outset of a project, but decreases quickly as time passes.

Figure 5.5 Opportunity/impact curves



5.8.3 Orientation

Building orientation is often decided upon to meet criteria such as ease of access, aesthetics or to obtain the most usable space from a piece of land. The drive to reduce energy use on buildings has led designers to look at facades on east and west elevations, where low winter sun can be difficult to control, as well as to consider the use of internal spaces on these elevations to avoid overheating through solar gain. Daylighting is an important factor to be considered here.

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Ideally, large north-facing windows would provide the most suitable daylight without the risk of direct solar glare. Any decision on building orientation should take this consideration into account.

5.8.4 Corporate themes

If an organisation wishes to apply a 'corporate look' to their offices, the lighting designer needs to clearly understand the implications of the required colour scheme. More information is available in section 6.4.2.

5.8.5 Speculative development

See section 4 for more information

Daylighting for occupants in speculative development will always be difficult to determine as the designer may not be aware of how the space will be used. Where possible, a developer or building owner should be encouraged to make the building interior as light as possible and introduce elements such as atria or shallow-plan floor layouts to optimise daylighting, even if the tenant has a relatively dense occupancy. (See section 4 for more information on speculative development.)

6 Electric lighting

6.1 Introduction

This section looks in detail at the various lighting techniques available to the designer to provide a suitable visual environment for office work. These techniques include lighting directly onto the task area from luminaires on, or suspended from, the ceiling; indirect lighting via the lighting of the ceiling and upper walls by freestanding, furniture-mounted, wall-mounted or suspended indirect lights; lighting from combined indirect/direct lights suspended from the ceiling; and, finally, lighting the task area with local lights combined with one of the above luminaire types to provide the general lighting of the space.

This section also considers the lighting of vertical elements, such as people's faces. The use of video for communication via webcams, tablets and smartphones is giving a greater importance to the vertical component in office lighting design.

The selection of the type of lighting most suitable for the space depends on:

- the physical constraints of the space
- the proposed decor
- user and designer preferences
- capital cost
- energy consumption
- maintenance costs.

Electric lighting needs to provide the appropriate lighting level for all tasks carried out in the space without causing glare or leading to wide variance in luminance between the various surfaces of the space.

Office lighting is about more than just illuminating a work surface, task area or someone's face. Those working in offices may do so day after day for hours at a time with no change in their field of view other than to look up and away from their task. Ideally, a view to the outside or into another space should be provided. However, if this is not practical, then consideration should be given to the environment and to how lighting is provided away from task areas, in order to make them both visually attractive and provide relief for the eyes.

6.2 The importance of early involvement

The importance of well-designed electric lighting in an office space, both in terms of the benefits in energy reduction and for the health and well-being of the occupants, cannot be overstated. Often decisions about electric lighting are made on the basis of aesthetics alone or on the basis of cost. Offices are working spaces and, while the look of an interior as well as the cost of lighting it are important factors, the occupants of the space will have to live with it on a daily basis.

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Early discussion is therefore key to making sure that the electric lighting for an office project considers the users of the space as the priority.

6.3 Refurbishment and conversion

6.3.1 Working with what you have

Refurbishment projects can vary widely and each will need to be considered against a number of factors. It may be possible to utilise the existing electrical and lighting installations with only minor modifications, such as new luminaires or modified switching positions if the room layout changes. On major refurbishment projects, however, the extent of change may be so great that the lighting designer is effectively dealing with a new project.

Lighting designers should also consider the way in which the refurbished space is to be used. Modifying installations that already exist should result in lower project costs and less waste; however, they may not be appropriate for the way in which the office is to be used in the future.

Well-intentioned reuse of an existing general lighting installation could result in excessive energy use if, for example, the occupancy level of the office were to drop, making a localised lighting scheme the most appropriate choice.

Energy use falls into distinct areas and new electric lighting in refurbished and converted buildings needs to be considered.

The four areas to consider are:

(*a*) energy use of the luminaires during their operational phase – this period could be 15 years or more so it is important to understand how much energy (including losses) any selected luminaires will use as the cumulative effect over the luminaires' operating life could be significant

(*b*) energy use during installation

(*c*) energy use in the manufacture of the luminaires and the mining and processing of the raw materials used to make the luminaires (this is known as embodied energy)

(*d*) energy used in the disposal of old redundant luminaires.

Items (*a*) and (*d*) are important considerations when undertaking refurbishment projects. While the lamps are a service item and electronic components that make up the control gear should have a lifespan of around 15 years, the body of a luminaire could well be expected to last the life of the building in which it is installed.

Consideration should be given to reusing such parts of a luminaire where possible and installing new control gear and lamps within the existing body.

It should be borne in mind, however, that a point is reached in a luminaire's life when the painted surfaces discolour or lose their reflectance. If that is the case, the cost of stripping down the fittings, repainting and reassembling the gear could be far greater than the cost of new luminaires.

6.3.2 Change of use

Where a space which previously served another purpose is converted to operate as an office, it is important to discuss the conversion with those who will be using that space.

Typically, change of use on a large scale will result in a total refurbishment and therefore a new lighting design will probably be required. Existing lighting circuits may be retained, which could limit the scope of the design; however, in general the approach could be the same as for a new project.

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Most change of use occurs on a much smaller scale, where, for example, a storeroom is changed into an office to gain a little extra space. It may be that the existing lighting is adequate or it may require some supplementing to raise illumination levels beyond those provided for its original use.

Compromises can be made in such situations but only with the agreement of those who will actually be occupying the space.

6.3.3 Colours and reflectance

Establishing exactly what is intended to be changed or altered during a refurbishment or reallocation of use is particularly important with regard to colours of finishes and their associated reflectances.

It is easy to assume that any refurbishment will result in at least a new coat of paint; however, this may not be the case. Smaller offices in older buildings, for example, may have restrictions or limitations on alterations to finishes. Areas of conservation may impose restrictions on internal space visible from outside which means that decor has to remain unchanged.

See section 2.20 for more information

A change in wall and ceiling colours, carpets and furniture can have a significant effect on the lighting design and the lighting designer should seek confirmation on these elements as early as possible in order to provide the most suitable and energy-efficient design for the refurbished space (see section 2.20).

6.3.4 Display screens

The vast majority of offices have display screens of some kind and it is important to design a lighting installation which provides a comfortable environment for prolonged viewing.

Refurbished or converted office space will probably have areas where compromises have to be made. These could include unusually high or low ceilings, which make the placement of luminaires, optimum balance of illumination level, glare control and uniformity difficult to achieve.

It is important to remember that display screens are easily repositioned and therefore the siting of screens to reduce glare in particular may be part of a lighting solution.

See section 10 for more information

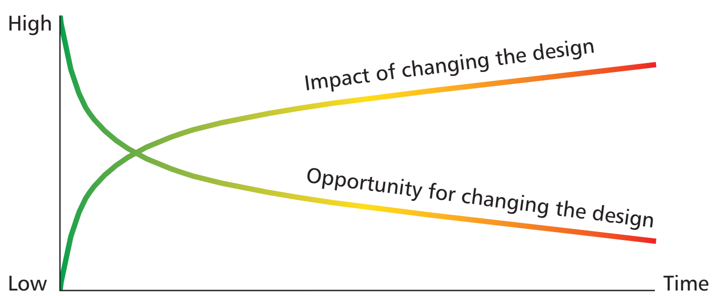
Where ceilings are particularly low, there may be no other option than to provide a localised lighting scheme with desk-based luminaires and general background lighting in order to minimise the effects of glare on display screens. (Section 10 covers the use of tablets and touchscreen displays.)

6.4 New build

6.4.1 Influencing design

The lighting designer should ideally be on board with a project team at the outset of the concept stage. This is the point in a design where the greatest effect can be achieved for the least impact. If fundamental decisions are left too late, the cost and impact on a building design can be significant. Figure 6.1 shows how the opportunity to change a design with little impact is greatest at the outset of a project, but decreases quickly as time passes.

Figure 6.1 Opportunity/impact curves



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6.4.2 Corporate themes

Some large organisations will have a corporate look to their offices and the lighting designer needs to understand the company's requirements clearly. For example, if the building owner always uses dark blue carpets in their offices, this needs to be considered within the design.

Where dark corporate themes are present, the building owner should be advised that these will have a direct effect on the amount of illumination required within the space. In addition, such a theme will result in a higher capital cost for the lighting installation as more luminaires will be required to achieve a given level of illumination. This will also affect the energy used by the office lighting.

Conversely, where a particularly light theme is used, there could be significant savings in the number of luminaires required to achieve a given level of illumination.

6.4.3 Development for known users

It has been relatively easy in the past to address lighting design for known users, particularly if the designer is familiar with their other properties. Following a well-established theme for a known client may, however, lead a designer to ignore the latest developments in lighting, which could be detrimental to the client in the long run.

While applying an established approach to a lighting design can be beneficial in terms of quality, reliability and risk reduction, the designer should not be afraid to challenge that design if a better approach or improved products become available.

6.4.4 The physical restrictions of the space

One of the most obvious restrictions when it comes to selecting lighting types is room height. This can vary from as low as 2.1 m to lofty heights of 4–6 m in banking halls or double-height spaces. If the proposed space has a floor-to-ceiling height of less than 2.5 m then it is difficult to use indirect lights successfully without causing bright patches on the ceiling above them, that may appear as images on any display screens in the area. With a ceiling height below 2.3 m, direct lighting is likely to be the only viable option and, even then, point source lighting, such as some LED types, should be avoided.

Generally, in spaces with a ceiling height greater than 2.5 m, floor- or wall-mounted indirect lighting can be considered, as there is sufficient height above the luminaires to allow a wide distribution of light without over-lighting the area of ceiling directly above them. Suspended indirect lights or indirect/direct luminaires generally need a greater floor-to-ceiling height as the units have to be suspended far enough below the ceiling to provide a good distribution of light across it but high enough above the floor to avoid being a physical danger or a visual intrusion to those walking or working below.

In all high spaces the problems of access for relamping and maintenance must be considered before using ceiling-mounted or suspended luminaires. If adequate maintenance access cannot be provided to high-level lighting, then wall- or column-mounted indirect lights may be more appropriate, although the efficacy may not be as great.

6.5 Lighting styles

There are many ways of lighting an office space, each with its own advantages and disadvantages. Each also strongly affects the lit appearance of the space and the balance of surface luminances within the space.

Table 6.1 shows the main styles of lighting along with the main advantages and disadvantages of each style. It progresses from pure direct light down from the ceiling, through various intermediate styles to pure indirect lighting. With exclusively direct light the floor and lower walls are well lit but the ceiling

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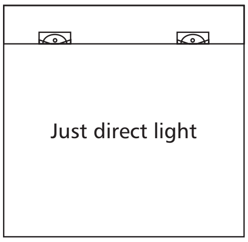
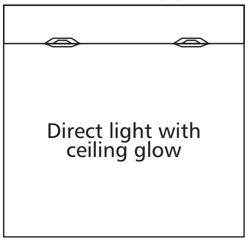
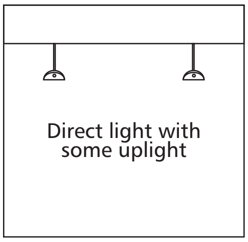
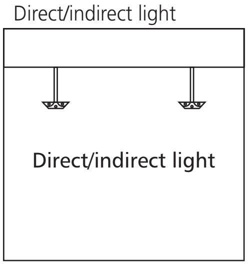
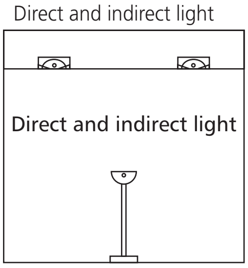
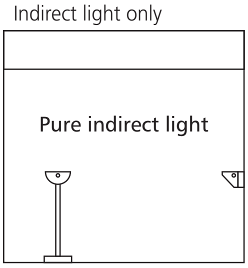
Table 6.1 Advantages and disadvantages of each lighting style

Lighting style	Advantages	Disadvantages
Direct light only 	Efficient delivery of light to task area Less energy required than for uplighting styles Usually the lowest capital cost for installation	Poor illumination of walls and ceiling Possible issues with glare and reflections in computer screens Uniformity can be poor Can feel oppressive, leading to poor productivity Poor cylindrical illuminance Lack of visual interest
Direct with ceiling glow 	Efficient delivery of light to task area Less energy required than for uplighting styles but more than for direct lighting only Usually a lower capital cost for installation than for a style using uplighting Some minimal ceiling illumination	Poor illumination of walls Possible issues with glare and reflections in computer screens Improved uniformity over direct-only style but can still be poor
Direct with some uplight 	Improved ceiling and wall illumination over direct-only styles Feeling of a larger space can be achieved Lighting can be used to add visual interest and achieve better interaction with the interior design Improved uniformity over direct-only styles Improved cylindrical illuminance over direct-only types	Will probably involve increased cost over direct-only styles Increased energy use over direct-only styles Lower ceiling height may impact on usable space
Direct/indirect light 	Much improved ceiling and wall illumination over direct-only styles Feeling of a larger space can be achieved Lighting can be used to add visual interest and achieve better interaction with the interior design Improved uniformity over direct-only styles Improved cylindrical illuminance over direct-only types	Will probably involve increased cost over direct-only styles Increased energy use over direct-only styles Lower ceiling height may impact on usable space
Direct and indirect light 	Improved ceiling and wall illumination over direct-only styles Flexibility to site direct and indirect components to best suit the room or individuals' needs Feeling of a larger space can be achieved Improved cylindrical illuminance over direct-only types	Will probably involve increased cost over direct-only styles Increased energy use over direct-only styles Loss of floor space Obstructions on floor may lead to accidental damage Issues with glare and reflections in computer screens
Indirect light only 	Good uniformity when used with appropriate ceiling height Positioning is not critical so gives more flexibility for unusual rooms or individuals' needs Feeling of a larger space can be achieved Lighting can be used to add visual interest and provide better interaction with the interior design Good cylindrical illuminance	Likely increased cost over direct-only styles Increased energy use over direct-only styles Shadow-free environment may feel bland Obstructions on floor may lead to accidental damage

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and upper walls are not so well lit; this can create a rather gloomy feel to the space. By allowing light to flow from the luminaire onto the ceiling adjacent to it, the ceiling brightness increases. By installing suspended direct luminaires with some uplight component, the upper part of the room will be better lit. Purpose-designed direct/indirect luminaires allow the designer to tailor the flow of light downwards and upwards to suit the room and the occupants' needs. A combination of direct lights and separate indirect lights is sometimes needed and, while this solution can provide the same quality of lit environment, it usually carries a higher capital cost. Using exclusively indirect lighting means that the ceiling and upper walls are lit to a higher level than the task area. This approach could be distracting in some circumstances and could also lead to a rather bland environment.

With any style, the overall visual appearance of a space and the amount of light available from inter-reflection is strongly affected by the room decor and surface reflectance. In every design, the energy usage and the use of controls must be considered so as to minimise running costs and to comply with the Building Regulations. More detailed sections follow on direct lighting, direct/indirect lighting, a combination of direct and indirect luminaires and indirect lighting that examine in depth the design implications for each of these styles.

6.6 Providing services to luminaires

Within most interiors there are aspects of the electrical installation, such as switching positions and containment restrictions, that have implications for the lighting options selected. Also the type of lighting method chosen affects the degree of flexibility available for future changes to the lighting layout and hence the lighting of altered workspace layout.

With freestanding indirect lights the electrical supply is usually supplied at floor level. This means that there are a number of aspects of the electrical system that need to be considered. Due to the relatively high power load, and even higher starting load with discharge lamps, it is recommended that the number of indirect lights that can be plugged into a single circuit is checked with the manufacturer. Where personal computers are using the same circuit, data errors may occur when starting the indirect lights, due to voltage spikes appearing on the circuit. This means that a separate floor power system may be preferred for supplying floor-mounted indirect lights. To avoid other equipment being plugged into these circuits, nonstandard plugs and sockets can be used. This arrangement allows the central control and switching of the indirect lights but also results in another set of floor services in addition to the normal power, data and telecom services. Where false floors are in use this may not be a problem but where floor trunking is utilised then difficulties may arise due to overcrowding. Floor-supplied indirect lights can, however, be an advantage where they remove the need for lighting supply trunking and conduit in an otherwise congested ceiling void.

Extra low voltage (ELV) control systems for lighting, such as Digital Addressable Lighting Interface (DALI), may require an extensive cabling network if centralised control is required. BS 7671: 2008 *Requirements for Electrical Installations* (17th edition), advises that ELV circuits, such as those for DALI installations, should not be mixed with those at mains voltage (230/400 V in the United Kingdom) unless the cabling used for the ELV system is rated to the higher of the mains voltages present. Designers should plan early during the design process for containment associated with control systems.

Where refurbishment of a lighting installation is being undertaken, it may be possible to use the existing mains wiring for the new luminaires; however, centralised DALI control may need a separate containment system for its associated cabling and this may not be possible depending on the level of acceptable damage

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to retained finishes. Again, early planning of control philosophies should identify any such problems.

The use of ceiling-mounted or suspended luminaires will free up floor space and remove the need for additional power outlets; however, the major disadvantage is that, in general, the lighting array is fixed. This tends to make the use of the space less adaptable where full-height partitioning is required, unless individual luminaire regulation is used. Where direct lighting luminaires are recessed, they need to be physically coordinated with other services in the ceiling. Surface-mounted luminaires can be considered unsightly in certain spaces and may interfere with air distribution across the ceiling from supply air grilles in mechanically ventilated buildings.

Unless a system of track mounting or similar is proposed, then indirect/direct luminaires are as fixed as pure direct lights. There is, however, the possibility of exchanging the luminaire or altering the number of lamps or the ratio of indirect to direct lighting. This can provide a range of task illuminances and introduce some visual variety across large spaces. Freestanding indirect lights, on the other hand, can provide a flexible lighting source, as they can be moved around to suit new office layouts or re-spaced to provide varying illumination levels.

6.7 Lighting techniques

With any of the lighting styles it is possible to provide the required task illumination at desk height across the whole space, locally to groups of desks or to provide just background lighting levels across the space, boosted to the required task levels purely where and when needed on the desks. It may be more of a challenge with direct styles to provide an adequate amount of illumination on the faces of the occupants.

General lighting is perhaps the most flexible option, allowing the user to place a desk wherever needed and achieve the required task levels, but it does consume unnecessary amounts of energy in over-lighting corridors and ancillary areas of the office. Localised and task lighting techniques are described in detail in the next two sections before going on to discuss energy, controls and the various general lighting techniques using each of the lighting styles available.

6.8 Designing with localised lighting

Figure 6.2 Localised lighting over hot desk positions

The lighting installation within an office can be one of the major consumers of electrical energy and therefore any lighting design proposal should consider how best to provide a suitably lit environment while making the most out of the energy being input.

The task areas in any office need to have an appropriate level of illumination to allow the occupants to work effectively, and so the most efficient way of getting light onto those surfaces will have the largest effect on reducing energy consumption.

Localising lighting to a task area is the most effective way of achieving this aim.

Localised lighting is where one or more luminaires are positioned in the vicinity of the task area. This might be by luminaires in or suspended from the ceiling above desks or by freestanding light that may be a direct/indirect luminaire placed by a desk or an indirect light placed within a cluster of desks (Figure 6.2).

Generally, localised lighting is used to provide all the required task lighting on the desk although it is possible to use local luminaires to provide the topup lighting from a lower ambient level up to the selected task illumination level.

In smaller offices where lighting is designed for a building owner, a direct communication route is usually present to allow discussion of the best lighting

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solutions. As localised lighting can be tailored to suit individual needs, it should form part of any such discussions.

Speculative office development, however, or even a general lighting design (known as Category A, or just 'Cat A') for a known user, will usually result in a default to providing an overall general illumination to task lighting levels. This can be wasteful of both energy and capital cost over a localised scheme. While it is accepted that furniture, fixtures and equipment (FF&E) layouts are not generally known for Cat A fit-outs, and certainly not for speculative development, the assumption that localised lighting positions cannot be determined and therefore should be dismissed is changing with the introduction of 'Power over Ethernet' (PoE) and the suitability of LED for desk-mounted lighting where the glare issues associated with LED can be controlled much more easily.

Desk-mounted LED task lighting, for instance, can be powered via structured cabling running alongside that installed for a computer network. As it is common practice to install computer cabling in a Cat A scheme, the power for localised desk lighting could be installed in the same way.

See section 2.2.1 for more information

More information on PoE can be found in section 2.2.1.

Ceiling-mounted, localised lights that are set within or fixed to the ceiling are normally part of a relocatable ceiling tile system, where the individual tiles with the luminaire can be exchanged for an adjacent blank tile. Such a system relies on the mechanical services above the ceiling being sparse enough and the wiring system being flexible enough to allow some repositioning of the luminaires if required.

Suspended local luminaires can be associated with relocatable tiles or be suspended from a track system. This track can be powered track, as used for spotlighting, or a simple mechanical track in the main with the electrical connections being taken up by 'curly lead' to fixed electrical connection points or sections of powered track. Obviously, the more extensive the track system, the more flexible the lighting can be, but at a higher capital cost.

Freestanding localised lights that have a direct component should ideally be positioned so as to throw light from the side of the task area. Ideally it should be possible to have the light coming from either the left- or right-hand side of the desk, to suit the user. The spread of light should cover, as evenly as possible, the area of desk used for reading written text. Uniformity over the task area should be 0.6 or better. With some types of freestanding indirect lights the base or central column can provide a position for power and data sockets, allowing easier cable management and flexibility for some desk system arrangements.

Indirect luminaires can be used as localised lighting by positioning them within a cluster of desks. Then the highest levels of light are across the desks with the levels falling off between the clusters. This approach obviously requires integration with the intended furniture plans and the working practices of the office.

6.9 Designing with supplementary task lighting

Supplementary task lighting is used to provide the top-up lighting, from a lower ambient level up to the selected task illumination level. This allows a low general level of light to be provided across a large space with only the actual task areas being lit to the higher task illuminance level.

Generally, a one-step difference in line with the scale of illumination between task lighting and general lighting levels gives a reasonable balance between energy saving and visual comfort.

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Figure 6.3 Direct/indirect lighting

For example, 200 lux general lighting plus 100 lux task lighting in an office which is purely used for screen-based work (resulting in 300 lux on the task area) is a good balance.

Given the direct nature of local task lighting, and where cylindrical illuminance is being considered, a diffuse general lighting design will assist in achieving a satisfactory modelling ratio.

Task lights should be positioned so as to throw light from the side of the task area. Ideally, it should be possible to have the light coming from either the left- or right-hand side of the desk, to suit the user. The spread of light should cover, as evenly as possible, the area of desk used for reading written text. Uniformity over the task area of 0.6 should be achieved. It is important that the luminaire be provided with a local switch or, ideally, a dimmer control.

Positioning local lights in front of the user can result in low contrast between the text and background of any paper on the desk in front of the user and can even provide a source of reflected glare if the paper is glossy.

The luminaire should have a limited range of adjustment to allow the user some control over its position, but not so much that it will become a source of glare to other office users. The luminaire should not be positioned so low that deep shadows are formed by light being cast across the desk at too shallow an angle. It is recommended that the height should not be less than 0.5 times the width of the area being lit, i.e. to illuminate across 1 m of desk the height should be at least 0.5 m.

The light source in both the above types of desk light system should be of a good colour quality and have a low heat output. Suitable lamps would, ideally, be LED, although linear fluorescent lamps and compact fluorescent lamps with high-frequency control gear could be used.

If the task light is accessible to the user, it is vital to ensure that it is mechanically and electrically safe and is both cool to the touch and cool enough to work beside. This is especially important in public access areas, such as libraries, where the users may not be familiar with the operation of the lights.

LED lighting, particularly when used with an ELV direct current power supply of less than 50 V, could provide a safer and cooler option than many fluorescent

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types. LED modules or fluorescent lamps in close proximity to documents may cause UV damage over prolonged periods if not of sufficient quality or suitably shielded by an appropriate controller or diffuser.

6.10 Designing with direct lighting

Direct lighting uses luminaires that are designed to emit the majority of their light output directly down onto the task area. Any upward light emitted plays an insignificant part in lighting the task. Direct luminaires can be surface mounted, recessed into the ceiling or suspended. They are generally viewed as separate lit objects in the space and for this reason can appear bright if viewed against a dark ceiling or as a distinct and possibly distracting object when reflected in a display screen.

The downward flow of light from direct lights means that the lower surfaces of the room are lit in preference to the upper walls and ceiling. The extent of this varies from one luminaire to another. Those that emit some light sideways or upwards do provide a degree of direct light to the walls and ceiling. Downlights with a restricted distribution to the side, perhaps intended to reduce direct and reflected glare for display screen users, provide little light directly onto the walls. This can lead to rather dark walls unless the floor and working plane surfaces are pale in colour so as to reflect light onto the walls and ceiling. As described later, it is possible to deliberately wash light over the walls so as to offset their dark appearance. The walls and ceilings themselves should be light coloured so as to appear brighter (Figure 6.4). See section 6.14 for more detail on the effects of surface reflectance on the visual environment.

See section 6.14 for more information

Direct lights can be completely recessed into the ceiling, partially recessed, surface mounted or suspended. The completely recessed type gives just downlight with no light onto the surrounding ceiling. These are therefore likely to appear bright when compared with the surrounding ceiling and can, in extreme cases, cause problems with glare and reflections in display screens. As they are also likely to have the least sideways flow of light across the space, they may make the room appear gloomy, as the vertical room surfaces will not be well lit. It is normally better to choose luminaires that have some diffusing or reflecting element below the ceiling level which can direct a small proportion of the light across the ceiling (Figure 6.5).

Direct luminaires in offices do not always have to be LED or fluorescent. In tall spaces, luminaires using discharge lamps can often be used (Figure 6.6). This can mean greater efficiency than is achievable with fluorescent lighting, although

Figure 6.4 Open-plan office with direct lighting and light-coloured surfaces

Figure 6.5 Direct light with ceiling glow

Figure 6.6 Tall space lit with high-pressure discharge lighting

the same minimum colour rendering of R_a 80 should be met and glare limitation achieved where appropriate. With all high-level lighting a means of safe access for maintenance and re-lamping must be considered as part of the design process.

See section 7 for more information

Surface-mounted and suspended luminaires can easily be selected to throw a varying proportion of light onto the ceiling around or above them. This improves the lit appearance of the space and reduces the apparent contrast between the luminaire and its background. One possible problem with this type of luminaire is that they can interfere with air flow from supply grills and cause localised dumping of cold air. It is always necessary to liaise with the mechanical engineers involved in any air supply systems regarding the interrelationship of grills and luminaires. See section 7 for more information on interaction with mechanical systems.

See section 12 for more information

Direct luminaires can be arranged in a uniform grid to give a consistent level of illumination across the whole space or can be arranged in coordination with desk locations to give a localised boost to the lighting level on the desks with lower levels between. The former is the simplest solution when there is no knowledge of likely desk positions or where the locations will vary. Even with uniform grids of luminaires across a space, an additional investment in individual dimming luminaires makes it possible to have higher levels over desk locations and lower levels between. Section 12 gives more information on lighting levels for specific applications.

6.11 Luminaire layout with direct lighting

The luminaire layout adopted will depend on the type of installation, the illumination level selected and the constraints of the space.

A uniform layout across the space can be designed to give a consistent lighting level across the space. This allows desks to be placed in almost any position and still receive the designed maintained illuminance. Unfortunately, it can be rather uninteresting visually unless supplementary feature lighting of artwork, noticeboards or vertical surfaces is provided.

Non-uniform layouts of luminaires can provide more visual interest in the space and concentrate lighting just where it is most needed. Desks only occupy 25–30%

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See section 6.8 for more information

of a typical office space. So, where the working practices of the office mean that there are fairly fixed layouts of desks, then the luminaires can be positioned local to the desks, giving more light where it is needed and less over non-task areas, leading to energy saving. See section 6.8 for more details on localised lighting.

6.11.1 Partitions

Part-height partitions around desks may block some light to the desks in varying degrees depending on their relationship to the luminaires above. The higher the partitions or the further apart the luminaires, the worse this problem becomes. Over-desk storage furniture further exacerbates the problem. By using a greater number of lower output luminaires spaced closer together, the shadowing can be reduced. Conversely, designing a scheme with the fewest luminaires spaced at their maximum distance apart will usually lead to shadowing whenever partitions are used (Figure 6.7). Where it is known that high partitions or over-desk storage are to be used then task lighting, either freestanding or built into the furniture, must be included in the design.

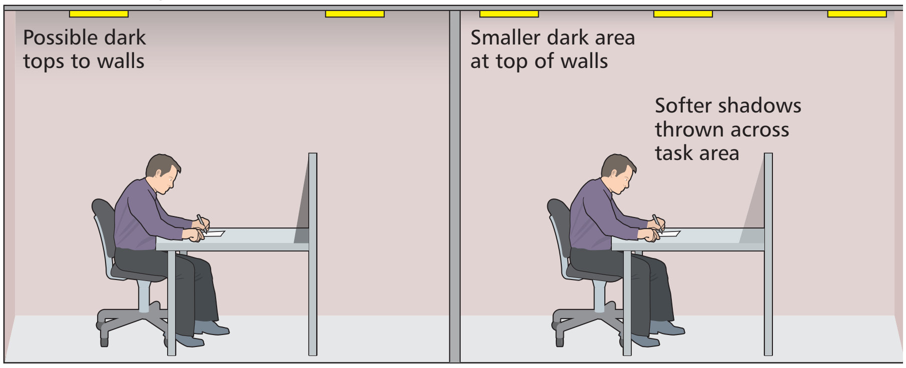

Figure 6.7 Wider spacing of luminaires leads to deeper shadows from partitions and furniture

6.11.2 Cellularisation

Where there are open-plan areas that may be divided into cellular offices, the selection and layout of luminaires needs careful thought. The layout of luminaires will need to relate to possible partition positions, such that when an office is created it has the correct number of luminaires to provide the required level of illumination. The lighting design will need to take into account these possible partition arrangements and allow for suitable task lighting levels and uniformities in a range of cellular office modules from a fixed lighting grid. See section 6.20 for more information on luminaire location in cellular spaces.

See section 6.20 for more information

6.11.3 Perimeters

It is important to consider the perimeter spacing of luminaires and their proximity to walls and columns. This is because some luminaires can produce bright patches on surfaces in close proximity (Figure 6.8). This is especially likely at the ends of a linear luminaire.

A gentle wash of light onto walls is to be encouraged but sharp transitions from light to dark can be distracting and can show up as distinct images in display screens. In general, the peak luminance of the scallop should not exceed 1500 cd/m^2. If this cannot be readily calculated it may be preferable to keep luminaires set back from walls. This may, however, lead to a reduced level of task illuminance on desks placed near to the walls as well as making the walls appear dark. Perhaps a better approach would be to use asymmetric luminaires to serve as wall washers since an even wash of light with slow rate of change is preferable to uncontrolled scalloping. Dimming control can be provided to alter the brightness of the wall in relation to the body of the room.

Figure 6.8 Bright patches on ceilings and walls

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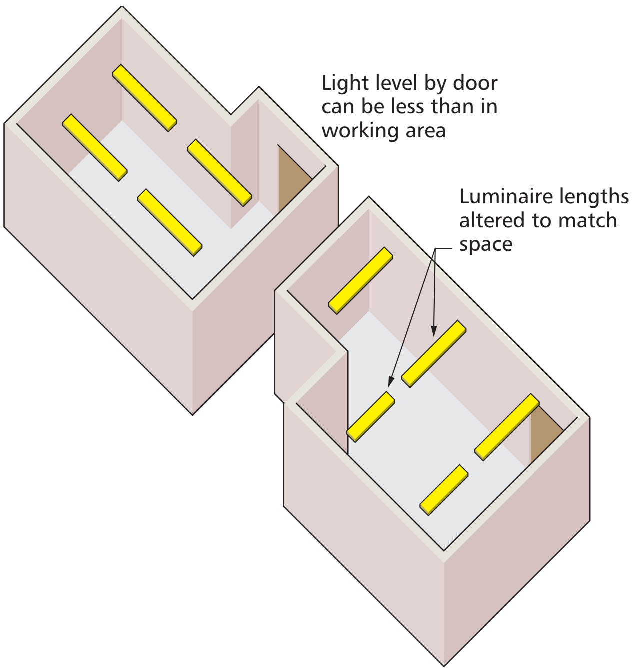
6.11.4 Irregular room shapes

In non-rectangular shaped offices the size and layout of the luminaires need not be uniform. Sometimes tailoring the number and size of the luminaires to match unusual room geometry can add additional visual interest to a space. For odd corners or recesses, circular fluorescent lights can be used or if the area is not a main task area a recessed spotlight can be used to highlight the recess. Figure 6.9 gives examples of situations where it may not be necessary to light small parts of an office and where changes to a standard type of luminaire are justified.

Figure 6.9 Irregularly shaped room



6.12 Direct lighting and display screens

In nearly all modern offices the lighting designer will have to take into account the use of display screens on most desks as well as portable equipment, such as laptops, tablets and smartphones. It may not be possible to identify the specific type of display screens to be used or have any indication of their locations; however, the designer should discuss with the building owner or developer the likely scenarios and approach the design on this basis. While many building owners or developers may not have made a final decision on locations of desks,

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etc., experience has shown that they do tend to know where they will not be positioned and this information is equally important.

With luminaires on or near the ceiling directing their light downwards, there is an obvious danger of them being visible in display screens below. Whether they can be seen or not will depend on the tilt of the screens and their relationship to the screen user and the luminaires. The use of laptops and tablets in many offices has allowed occupiers to be much more flexible about screen position and so minor adjustment of screens and screen positions is an acceptable method for avoiding any unwanted glare. If luminaires are likely to be seen, particularly in desk display screens, then it must be established whether they are bright enough to be a distraction to the user. This partially depends on the clarity, or sharpness, of the reflected image in the screen and partly on its luminance compared to the luminance of the information on the screen. The sharper the image, the more likely the eye is to notice it; the higher the luminance of the reflected image, the more difficult it is to read the screen information behind and around it.

If the screen has a smooth glossy finish then the luminaire image will appear as a sharply defined object, which the user can see clearly. If, however, the screen has a matt finish, then the reflected object is less well-defined and is less likely to distract the user (Figure 6.10).

Figure 6.10 Comparison of glossy and matt displays subjected to unwanted reflections

If the software running on the screen uses light characters on a dark screen background, such as white text on a blue background, then the reflected image will be seen against this dark background. If, on the other hand, the information is presented with dark characters on a light background then the reflections will be less visible against the lighter background.

Thus, if a luminance value for a luminaire is to be set such that it is unlikely to distract the majority of users running typical applications on standard screens, it should be established whether the screens in the area have matt finishes and whether the information on the screen is displayed as dark characters on a light background (positive polarity) or light characters on a dark background (negative polarity).

Although details of screen finish and software display cannot be established with certainty, early discussion with the building owner or developer about the screen types to design for is important.

6.12.1 Luminance limits

Table 6.2 shows luminance limits for luminaires which may be reflected in display screens when viewed from a normal working position.

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

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Table 6.2 Luminance limits

Screen high state luminance	High luminance screen (L > 200 cd/m²)	Medium luminance screen (L < 200 cd/m²)
Case A (positive polarity and normal requirements concerning colour and detail of the displayed information as used in office, education, etc.)	<3000 cd/m²	<1500 cd/m²
Case B (negative polarity and/or higher requirements concerning colour and detail of the displayed information as used for CAD, colour inspection, etc.)	<1500 cd/m²	<1000 cd/m²

Note: Screen high state luminance (see BS EN ISO 9241-302: 2008) describes the maximum luminance of the white part of the screen; this value is available from the manufacturer of the screen.

If a high luminance screen is intended to be operated at luminances below 200 cd/m² the conditions specified for a medium luminance screen shall be considered.

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

Direct lights within smaller cellular offices are unlikely to cause glare or screen reflections as the geometry of small rooms means that luminaires are unlikely to be seen in the screens. In open-plan areas, however, luminance limitation is needed due to the long views to the luminaires (Figure 6.11).

In areas where there are relocatable walls forming the cellular offices, care still needs to be taken in selecting the luminance limits for the luminaires in them as the offices may later be opened up to become part of the open-plan area and their luminaires may then be visible across the space.

It should be noted that in some dealing rooms there might be horizontally mounted information or keying screens and large numbers of screens per workstation and numerous workstations in different orientations. Such specialised installations require very careful consideration of the geometry and relative positions of the luminaires and screens. Proving the design by use of a full-scale mockup is invaluable in such cases.

Figure 6.11 Open-plan office

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6.13 Designing with indirect lighting

Indirect lighting uses luminaires where all, or almost all, of the light produced by the luminaire (typically over 90%) is reflected off some surface, usually the ceiling, before reaching the task area. Therefore it is important to ensure that these surfaces have a high reflectance. The lighting produced by an indirect lighting installation is typically diffuse, without strong modelling effects or distinct shadows. To avoid the space appearing bland, it is important to use the interior decor to create some variety and interest in the space. A bland appearance can also be minimised by spacing of luminaires sufficiently far apart to provide pools of light on the ceiling

Indirect lighting can be used to supply the general lighting to an entire area or be used to provide localised lighting in the centre of groups of workstations. The indirect luminaires can take several different forms, depending on the means of mounting the indirect light. The most widely used mounting positions are freestanding, floor-mounted units, units mounted on furniture, wall- or column-mounted units and units suspended from the ceiling. All these forms directly light the ceiling and upper parts of the walls and so indirectly light the working plane. To ensure maximum efficiency, the ceiling surfaces must be of a high reflectance matt finish.

Indirect lighting can be used successfully to light rooms containing display screens as the surfaces being lit by the indirect light act as large area, low-luminance luminaires. As long as the luminance of these surfaces is not excessive, any reflection seen on the screen is of a gradually changing low luminance.

As well as the standard types of indirect lighting there are other forms that are less common but can generally meet the requirements of using the ceiling as a large area, low-luminance luminaire, such as where asymmetric luminaires are mounted on high-level shelves or on a cove along the sides of ceiling bays or coffers. These then throw light out as evenly as possible across the ceiling.

6.14 Surface reflectance and decor

In order to ensure a reasonably efficient installation, the ceiling and upper walls should have a high reflectance. A minimum reflectance of 0.7 is recommended. To allow for dirt build-up and degrading of the surface, the design should aim for an initial surface reflectance of 0.8. Ceilings of lower reflectance can be used, but at the cost of additional installed load. If these surfaces are highly coloured,

Figure 6.12 Light-coloured surfaces can have a significant impact on the lighting design

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the light reflected back down onto the working plane will have some tint of this colour. White, or at least very pale colours, should be used for the major areas of the reflecting surfaces in indirect lighting installations. The surfaces should be matt, as a specular finish will produce high luminance images of the lamp when viewed from particular directions.

Rough surfaces have a lower effective reflectance than a smooth surface of the same colour due to all the crevices in the surface. Care should also be taken with old buildings as indirect light may highlight any defects in wall or ceiling surfaces.

It is important in uplit spaces to use the interior decor to create some variety and interest in the space. This could involve small areas of strong colour, picking out salient architectural features, for example, but care should be taken to avoid abrupt changes in reflectance. It is also possible to add variety to the space by introducing some feature lighting via gentle spot lighting of items such as noticeboards or art works. This should not be so bright that the objects become possible sources of reflection in any display screens in the area.

In addition, the colour scheme should be matched to the colour properties of the light source used. For example, an interior filled with blues and greens would look very subdued under high-pressure sodium discharge lamps but one filled with orange and yellow would be very vibrant (Figure 6.13). In this area, there is no substitute for seeing the proposed colours under the light source of interest.

It is sometimes assumed that a completely flat surface is necessary for a successful indirect lighting installation. This is incorrect. In fact, a degree of shape or structure in the main reflecting surface can go a long way towards providing some variety in the appearance of the space. However, the structure should have as smooth a profile as possible to minimise abrupt changes in luminance. Similarly, inclined ceilings, while requiring more thought in the calculation of light levels and the distribution of the lights, can provide very interesting spaces. For ceilings with exposed structure, care should be taken to avoid sharp contrasts between directly lit and unlit areas as these may appear as distinct objects when reflected in display screens.

Figure 6.13 Office reception using warm lighting to highlight colours

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6.15 Design criteria for indirect lighting

For indirect lighting to be successful it is essential that the luminance of the reflecting surfaces be limited. It is recommended that:

— the average luminance on the major surfaces used for reflecting light, such as the ceiling, should be less than 500 cd/m^2

— the maximum luminance of any point on the major surfaces reflecting light should not exceed 1500 cd/m^2

— the value of luminance should change gradually across the surfaces, i.e. there should be no sudden changes in luminance across or between surfaces.

The calculation for maximum ceiling luminance over a single indirect light will give a guide to the expected maximum in the final installation. However, it should not be forgotten that the adjacent indirect lights in a real installation would add perhaps an additional 25% to the calculated maximum value from a single indirect light. Where mobile, freestanding units are being recommended, the client/user should be reminded that standard symmetric units should not be moved close to walls or columns as this will reduce the efficiency of the indirect light and produce a high luminance patch on the wall or column. Such a patch is likely to be a source of annoyance to display screen users both in terms of direct glare and by being reflected in their screen.

6.16 Luminaire selection for indirect lighting

The desirable photometric properties of freestanding, furniture-mounted and suspended indirect lights are that they should have as high an upward light output ratio as possible and spread the light emitted over as wide an area as possible without allowing a view of the lamp or luminaire interior. Unless the luminous intensity distribution of the luminaire has a widespread distribution there is a risk of having a high luminance spot immediately above the indirect light and hence of exceeding the maximum luminance criterion. For wall-mounted indirect lights, the luminous intensity distribution should be asymmetric to avoid high luminance spots above 1500 cd/m^2 immediately above the unit on the wall or ceiling.

A related aspect of indirect lights is that there should not be a very sharp cutoff in the luminous intensity distribution at any angle because this could produce a step-like change in luminance on the ceiling or wall of the interior. One other feature of indirect lighting that requires careful consideration is the reflectance of the underside of the luminaire when suspended indirect lights are used. Such indirect lights are seen in silhouette against the ceiling so, unless they have fairly light undersides, a sharp change in luminance will be evident.

Because most indirect lights rely on upward-facing reflectors, it is essential that ease of maintenance is carefully considered when selecting the indirect luminaire and designing the installation. Easy access is essential if good light output is to be maintained. Floor-mounted indirect lights may offer the possibility of replacing units for ease of maintenance. Maintenance, and safety, may be enhanced by ensuring that the indirect light is fitted with a removable glass cover, but to ensure full lamp life and to aid the self-cleaning of the lamp and reflector the cover should not be sealed. This is to allow a convective air stream to pass through the indirect luminaire when the lamp is lit. Freestanding indirect lights should incorporate tilt switches to ensure that the unit switches itself off if it is knocked over.

6.16.1 Mounting height and locations

Indirect lights rely on height to shield a direct view of the lamp and interior from the occupants. This is the reason why the vast majority of floor-mounted indirect lights are at least 1.8 m high. Similarly, wall-mounted and furniture-mounted indirect lights should have their top surface located at about 1.8 m above the floor.

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This minimum height imposes a limit on the ceiling height that is acceptable for indirect lighting.

As a rule of thumb, most commercial floor-mounted indirect lights should be used with ceiling heights of between 2.5 and 3.5 m above floor level. Indirect lights can only be successfully used with ceiling heights below 2.5 m if particular attention is paid to the luminous intensity distribution and steps are taken to avoid the creation of a high luminance spot immediately above the indirect light. Ceiling heights greater than 3.5 m can be used but at extra cost in terms of installed power. If indirect lighting is required in a space with a ceiling height above 3.5 m, wall-mounted or suspended indirect lights should be considered, as long as safe maintenance access can be ensured.

Care should be taken when positioning large indirect lights over, or close to, a desk or work surface. The effect of direct radiant heat from the body of the indirect light on the users nearby should be considered when selecting indirect lights. Large indirect lights can themselves act as an obstruction to the lit ceiling above. Although any shadow thrown by the indirect light would be very soft – due to the large lit area of ceiling – it may locally reduce the total illumination.

6.16.2 Suspended indirect lights

In this case the major requirement is to ensure that the units are suspended far enough below the ceiling to provide a wide soft spread of light onto the ceiling. A distance of 1 m is recommended with a minimum of 0.5 m to the top of the luminaire. There is often a temptation in very large spaces to install a few high wattage units to save money. This may well result in several high luminance spots appearing on the ceiling.

In all cases the fittings need to be suspended well above normal head height to prevent users of the space feeling that they may strike their heads on the units. A minimum height of 2.3 m is recommended. A light-coloured body is recommended so that the luminaire does not appear as a dark object against a light ceiling.

6.16.3 Cove lighting

Cove lighting again aims to throw light evenly onto the ceiling from a ledge or recess high up on the wall (Figure 6.14). Unless luminaires with purpose-designed reflectors are used, there is a danger of the back wall of the cove and the ceiling adjacent to it being very brightly lit.

Great care has to be taken to ensure that the luminance of the surfaces in the cove does not exceed 1500 cd/m^2. Depending on the cove's distance below the ceiling, it may be difficult to light the ceiling evenly beyond the first 2 to 3 m from the cove, due to light falloff on the ceiling. If the ceiling is curved gently upwards from the cove, then the ceiling illuminance is likely to be more even. The average

Figure 6.14 Cove lighting in a meeting room

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See the *SLL Code for Lighting* for more information

illuminance on the task area can be calculated using the lumen method once the utilisation factor has been calculated by the methods given in the calculation section of the *SLL Code for Lighting*.

6.17 Designing with direct/indirect lighting

This section considers designs where the intention is to provide the illumination for the working area by using luminaires designed to provide both indirect and direct light (Figure 6.15).

Figure 6.15 Combined direct and indirect lighting installation

The combination of direct lighting and indirect lighting can be very effective, as the two types of lighting are in many ways complementary. By combining indirect and direct lighting, a lit environment can be produced which has well-lit walls and ceilings, while having some directional element to provide modelling. The horizontal illumination is good without either creating a gloomy interior or having over-bright ceilings and walls and the illumination of people's faces is improved over direct-only lighting. The exact proportion of indirect light to direct light is not critical in most circumstances, although the room's visual characteristics would be markedly different as the proportions change. At one extreme are indirect lights that provide direct light through translucent elements on the bottom of the luminaire or from reflectors to their side. At the other extreme are suspended direct lights that allow a reasonable proportion of soft indirect light through slots or diffusers in the top of the luminaire.

In general, luminaires giving more light output upwards are called 'indirect/direct' while those emitting more downwards are referred to as 'direct/indirect' luminaires.

The switching and control of the luminaires needs to be carefully considered. With many luminaires the option exists to switch or dim the direct and indirect elements of the luminaire independently. This can be useful as it allows the users another degree of freedom in selecting their preferred visual environment. It can, however, lead to some problems. The indirect light from one unit may affect a number of users and any reduction of the luminance of the ceiling may make the direct element of the luminaires more prominent to some users.

In order to ensure a reasonably efficient installation, the ceiling and upper walls should have a high reflectance. A minimum reflectance of 0.7 for the ceiling is recommended. To allow for dirt build-up and degrading of the surface, the design should aim for an initial surface reflectance of 0.8. If these surfaces are highly coloured, the light on the working plane will have some tint of this colour. White, or at least very pale colours, should be used for the major areas of the reflecting surfaces. The surfaces should be matt, as a specular finish may produce high luminance images of the lamp when viewed from particular directions.

When using direct/indirect lights it is important to ensure that each component meets the luminance criteria given in sections 6.12 and 6.15. The direct lighting elements still need to have luminance limits suitable for the intended display screens and their use and the indirect component still needs to provide an even wash of light over the ceiling. However, if the ceiling is uniformly lit then it is acceptable to allow the luminance of the direct component to increase to match the average luminance of the ceiling.

6.18 Luminaire selection for direct/indirect lighting

Where fluorescent lamps are being utilised, the luminaires can provide the indirect and direct light either from separate lamps and reflectors, or from the same lamp or array of lamps. LED, however, is a directional source and so separate arrays will be required for the direct and indirect elements.

Luminaires which use a common source for both direct and indirect elements can be highly efficient. The more typical light sources used are LED or fluorescent lamps although high-pressure discharge lamps and compact fluorescent lamps can be used.

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Figure 6.16 Recessed modular luminaires with suspended reflector

Adding an indirect element to LED luminaires can help to alleviate the problems that such a lighting source can introduce. Being a point source of illumination, LED can be a source of discomfort glare if installed inappropriately. By illuminating a ceiling above the luminaire, the contrast between the LED array and the background in the viewer's visual periphery is reduced, making the lamp intensity less obvious.

One type of combined luminaire comes complete with its own indirect light 'canopy' (Figure 6.16). This may take the form of large white wings that catch and redirect the indirect light. These are usually suspended so that light spreads up onto the ceiling above. However, it is possible for the wings to be integrated into the ceiling in place of one or more ceiling tiles.

In these cases it is important that some light spill from the luminaire provides illumination onto the ceiling surrounding the luminaire to reduce the contrast between the lit wings and the unlit ceiling beyond. Luminaires can also be positioned within larger coffers that are part of either the ceiling or the structural soffit. This coffer forms a large upper reflector that utilises the indirect light from the luminaire (Figure 6.17).

Suspended direct/indirect luminaires should be hung far enough below the ceiling to provide a wide soft spread of light onto the ceiling. In all cases the

Figure 6.17 Luminaires in coffered ceiling

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fittings need to be suspended well above normal head height to prevent users of the space feeling that they may strike their heads on the units. A minimum height of 2.3 m is recommended.

Where a luminaire has one LED array or lamp for the direct light and a separate one for the indirect light it can usually be arranged to have a single driver or set of control gear for each array or lamp. Separate gear allows the indirect and direct lighting components to be controlled individually if required. This can provide permanent background lighting across the office space from the indirect component with user control of the direct component over their workstations. It can also be used to provide reduced level lighting for cleaning or when under standby power supply.

For suspended direct/indirect lights it is important to realise that the luminaire body will be viewed against a relatively bright ceiling. This means that the body should be pale in colour to avoid the contrast of a dark body against a light background, as this effect may be noticeable on a display screen. Another way to avoid this problem is for the sides to be made of a translucent or light mesh material. It is important that the luminance of the sides does not exceed the design luminance of the ceiling against which they are to be viewed.

6.19 Designing with a combination of direct light and indirect light

The combination of fixed direct luminaires and separate indirect luminaires can be effective, as the two types of lighting are in many ways complementary. By combining indirect and direct lighting, a lit environment can be produced which has well-lit walls and ceilings while having some directional element to provide modelling. The horizontal illumination is good without either creating a gloomy interior or having over-bright ceilings and walls. The exact proportion of indirect light to direct light is not critical in most circumstances, although the room's visual characteristics would be markedly different as the proportions change.

Such lighting usually takes the form of direct high-efficiency lights within the ceiling combined with freestanding or wall-mounted indirect lights to provide well-lit ceiling and upper wall surfaces. Sometimes the indirect lights need to be added to a direct lighting scheme to relieve a potentially dark and gloomy ceiling.

It may be appropriate to add indirect lights to an area to soften or alter the effect of an existing direct lighting installation. When this is done, it may be necessary to reduce the light output of the direct lights so as not to provide an excessive horizontal illuminance. This can sometimes be achieved by the removal of one lamp in a twin lamp luminaire, provided they have separate control gear, although often the diffuser or louvre will need to be changed to improve the light control – this may well reduce the light output and affect the luminaire's light distribution. Where the two systems are to be used together, care is needed to ensure that high luminance images of the indirect light do not appear on the flanges or louvre elements of the direct lights.

When using separate systems of floor-standing indirect lights and ceiling-mounted direct lights it is important to ensure that each system meets the general criteria laid down in the appropriate sections for direct lighting and for indirect lighting. The direct lights still need to have luminance limits suitable for any intended display screens and their use and the indirect lights still need to provide an even wash of light over the ceiling. However, if the ceiling is uniformly lit, then it is acceptable to allow the luminance of the direct light to increase to match the average luminance of the ceiling. Indeed if the direct light luminance is much lower than that of the ceiling, it is possible for the direct light to appear on a display screen as a dark object against the brighter ceiling.

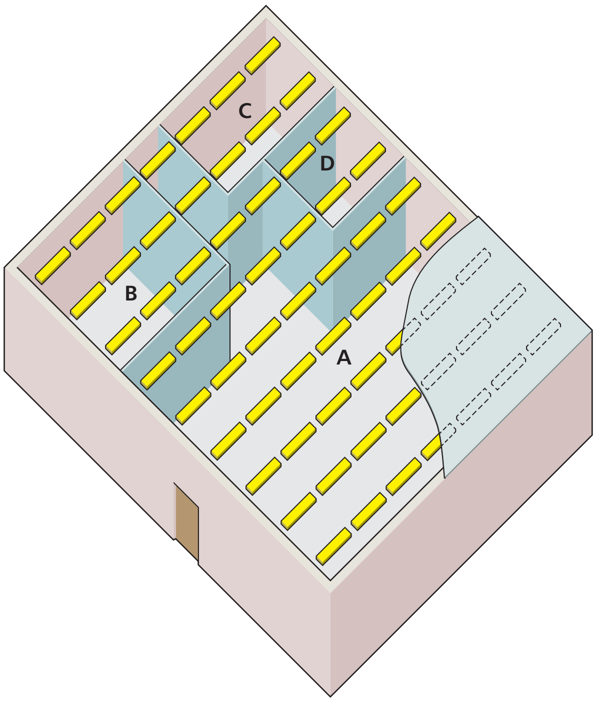
6.20 The effect of relocatable walls on lighting levels

The light level provided by an array of luminaires varies depending on the size of the room they are lighting. In a completely open-plan space, a point in the room receives light from many luminaires. If a wall is put up then light from some luminaires is cut out and replaced by a small amount of light reflected back from the wall. With a fairly narrow light distribution from the luminaires this effect will be minimised, but with a wide distribution the effect of partitions will be greater. The amount of light reflected back from the partitions also depends on the reflectance of the partitions. With glass partitions this effect is less noticeable, although the lights in the adjoining office could be switched off and therefore not contribute any light through the partition (Figure 6.18).

Figure 6.19 shows an open-plan office with three cellular offices. The proportion of luminaires to office area is the same but, as the spaces get smaller, from A to D, the room index decreases and so the utilisation factor decreases. In this example, the lighting level in the large open-plan space A is the highest. In the large office B it is slightly lower, falling further through the medium office C and it is lowest in the small office D.

Figure 6.18 Adjacent rooms with glass partitions

Figure 6.19 Open-plan office with three cellular offices showing influence of luminaire layout



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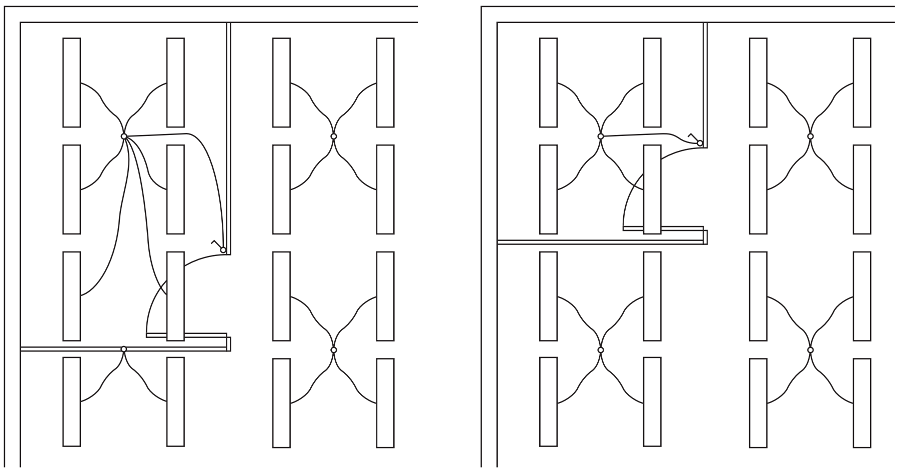
Obviously, if the designer is to meet the required task lighting level in any possible office space they need to know the size of the smallest practicable office. If the required lighting level can be met in the smallest module then, assuming that the ratio of lights to floor area remains the same, the lighting level in the larger spaces will exceed this amount.

Care needs to be taken if the building owner or developer asks for partitions to be freely located without regard to luminaire spacing. If the wall is too close to a row of luminaires then not only will there be a bright patch of light on one side of the wall but the lighting level on the other side of the wall will be lower as there will be a greater floor area per luminaire. If there is also the possibility of a partition actually being positioned under a luminaire there is the additional risk of not being able to maintain, clean or re-lamp the luminaire. There will also be a sound path over the partition if the luminaire is of the coffer or open louvre style.

With relocatable walls the method of controlling the lighting needs careful thought. If each possible cellular office space needs to have its own control over the lights in that office then a flexible switching system is needed. Modular wiring systems which use lighting control modules for luminaire or circuit control are suited to this situation. It is also possible to provide a programmable system where each luminaire can be separately addressed and controlled from a central system.

LED lighting designed to be operated on a direct current (dc) power supply can be controlled much more precisely than conventionally wired alternating current (ac) supplies. Technologies such as PoE, when coupled with dc LED lighting, can give the flexibility to individually set each luminaire output to match the shape and size of a space quickly through software control.

Figure 6.20 Flexible lighting controls for a partitioned office space



7 Interaction with mechanical systems

7.1 Introduction

The interaction between mechanical building services systems, in particular cooling systems and lighting, can sometimes be overlooked. However, given the sensitivity of lamps and LEDs to changes in ambient temperature, coupled with the increase in integration of lighting and mechanical systems, consideration should be given to how they will interact in a particular setting if colour shift and poor lamp efficiency are to be avoided.

Lamps and LED arrays are designed to give their optimum output and stated colour temperature at a given atmospheric temperature. If lamps are cooled below this temperature, their colour will shift and their efficiency will fall. This can result in the lighting installation delivering below its design intentions.

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7.2 Cooling methods

Traditionally, mechanical cooling in office spaces has been dealt with by either cooling air before it is supplied into a room or by using local cooling units that employ a fan to force air across a cool surface. Either method can result in differing temperatures across an office ceiling.

7.3 Centralised cooling systems

Figure 7.1 Supply diffuser and suspended luminaire

In large buildings, the air supplied to its office space can be chilled centrally and supplied via insulated ductwork to where the cool air is needed (Figure 7.1). This method will result in supply diffusers being positioned within the ceiling and air supplied via them at, typically, 6–8 °C below the ambient temperature of the space being cooled. Air extraction from these spaces can be via dedicated extract grilles or via a plenum ceiling incorporating perforated ceiling tiles.

While such a system has no obvious connection to the lighting within the space, care should be taken to avoid positioning luminaires too close to supply diffusers due to the Coanda effect. First applied by Henri Coanda, this phenomenon results in air which leaves a confined space, such as through a supply diffuser, tracking a surface close to its exit point, such as a ceiling. As long as the surface remains smooth, the effect can carry air across a ceiling for some distance, depending on its discharge rate. Where a luminaire is recessed into a ceiling and has a smooth curving reflector, it is possible for air to flow into the luminaire and across the lamp.

Where air is extracted via a ceiling plenum, the rate of any air flow through the ceiling will depend on the location of the extract ductwork above it. For example, a space 20 m long and 7 m wide with an extract point above the ceiling at one end of the room will see a higher extract air flow close to that end. The end of the room farthest away will have a consequently lower level of extraction.

Again, this may not appear to be related to the lighting installation; however, higher extract air flow at one end of a room can result in the luminaires, particularly if they are open, being subject to different ambient conditions across the space. This leads to slight changes in light output, and possibly colour, from the lamps in these luminaires.

7.4 Fan coil units

The principle of fan coil unit (FCU) operation is to run a cooling medium, such as chilled water, through a series of finned pipes, similar in appearance to a car radiator and known as a cooling coil. A fan is then used to push air across that cooling coil and into the space to be cooled.

These units can be wall- or floor-mounted and are usually hidden away in ceiling voids with only their supply diffusers and, sometimes, extract grilles readily visible. Often, the system will supply air to a space via supply diffusers and extract it to ceiling voids through perforated ceiling tiles in the same way as centralised cooling systems. Employing FCUs can give a more balanced flow of air across the luminaires in a space than can be achieved through specific extract grilles and can avoid the possible problems with single point extract encountered in centralised cooling systems because each FCU deals with a proportion of the air.

7.5 The natural cycle

By its very nature, cool air will fall to the ground and displace warm air, which will rise. If the supply of cool air is maintained, then a cycle will develop. However, it is not simply a case of supplying a space with cool air at any given point and expecting such a cycle to begin and efficiently provide cooling to the whole space. Inevitably, such an approach would lead to localised stagnation and the cooling effect would not be uniform. In addition, any pipe or duct carrying a cooling medium, such as chilled water or air, would have condensation building up on its outer surface if the coolant temperature was too low. Any condensation finding its way into luminaires could lead to component failure in addition to the associated safety concerns.

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Figure 7.2 Example of lighting and mechanical services coordination

7.6 Chilled beams

In order to reap the benefit of not having to run fans constantly within FCUs, and to take advantage of the natural cycle created by falling cool air, the chilled beam concept is becoming increasingly popular in office developments.

Essentially, a chilled beam is a cooling coil which is stretched into a linear section of flow and return pipework, each with a series of radiating fins attached. Because the cooling surface is spread over a much greater area, uniformity in the cooling effect can be achieved without the need to use energy to run fans. The risk of condensation on the cool pipework still exists, however, and to prevent its formation the cooling medium cannot run at temperatures as low as those used in FCUs.

In addition, the humidity within the space has to be carefully controlled to make sure any potential water source for condensation formation is limited.

See CIBSE Guide B for more information

For more information about the mechanical aspects of office cooling solutions, please see CIBSE Guide B: *Heating, ventilating, air conditioning and refrigeration* or the BSRIA *Illustrated guide to mechanical building services*.

7.7 Integrated services

In much the same way as lighting has to be carefully placed in a ceiling to optimise the use of luminaires, components associated with the supply and extraction of air from a space also require careful placement. This can often lead to the preferred location of luminaires and supply diffusers being in the same place.

When additional services such as fire alarm smoke detectors, public address speakers, sprinkler heads and movement detectors are added into the equation, it is easy to see how a ceiling can become congested, with the inevitable need for compromise.

The need for mechanical services and luminaires to be in the same locations within ceilings for optimal performance, along with the architectural preference for minimal ceiling congestion, has led to the development of integrated cooling and lighting solutions.

7.8 Air-handling luminaires

Where cool air is provided from an FCU, it is sometimes possible for the air return path to pass through a recessed modular luminaire. This combining of extract point and luminaire has the advantage of reducing ceiling congestion and placing both luminaire and extract point at preferred positions.

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Care should be taken, however, when selecting such luminaires and consideration should be given to a number of factors since poor design can lead to lamps running below their optimum temperatures when air flows across them:

— the type of lamp used and its operating temperature; T5 lamps, for example, operate efficiently at a higher temperature than T8 lamps, while LED arrays operate more efficiently at typical office temperatures

— the air path through the luminaire; air should ideally pass through the sides of the luminaire and not over the lamps.

7.9 Integrated chilled beams

The nature of chilled beams means that they occupy a large proportion of ceiling space and so integrating lighting into them is sometimes the only option (Figure 7.3).

A number of manufacturers offer chilled beams with integrated lighting and presence/absence control.

The issues of integrating lighting are similar to those of air-handling luminaires, the difference being that lamps may be subject to cold air falling from the chilled pipework within the beam rather than the return air temperature.

Figure 7.3 Integrated chilled beams installation

7.10 Impact on lighting

Light sources, be they fluorescent, LED or any of the high-pressure lamp types, are designed to operate optimally within a specific temperature range. Moving outside these ranges will affect the efficiency of the lamp, resulting in a lower output and a change in the colour of light emitted (colour temperature).

The effect of temperature on lamps is well known and can be accommodated at the installation design stage, provided the interaction of the various design elements is understood.

Differences in ambient temperature across a ceiling can be caused by either pre-determined control of mechanical systems or by unplanned interaction, such as unbalanced extraction from an office space.

Where a number of luminaires are installed in a common space and are subject to overall control, then drifts in colour temperature and output will not be readily noticeable. However, with the advent of better and more precise control of heating and cooling systems, particularly in large open-plan spaces, the effect on lighting can be quite pronounced.

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Integrated chilled beams are usually controlled independently of each other, which allows the temperature around any integrated lamps to differ depending on whether the chilled beam is operating or not. Because the lamps are so close to the chilled water circuit within the beams and may be subject to falling cold air passing over them, they are likely to suffer a change in colour temperature.

In relatively small spaces, this may not be noticeable, but in large open-plan spaces, particularly where several beams can be viewed simultaneously, differences in colour temperature will be noticeable.

When designing or advising on the use or installation of systems that integrate lighting with mechanical chilled services, the location of lamps within the air-handling luminaire or chilled beam and the air path should be carefully considered.

While not directly related to lighting design, the control of the mechanical systems should be clarified and, where fluctuations in temperature of adjacent chilled beams are likely to occur, careful selection of integrated chilled beams should be made.

Typical operating temperatures of mechanical chilled services and optimal operating temperatures of commonly used lamps are shown in Table 7.1.

Table 7.1 Typical operating temperatures of common lighting sources and chilled services

FCU air supply	Typically 6–8 °C below the ambient temperature in the space to be cooled
Chilled beam surface temperature	Typically 14–18 °C
T5 lamp optimum operating temperature	Typically 35 °C around the lamp
T8 lamp optimum operating temperature	Typically 25 °C around the lamp
LED optimum operating temperature	Typically 25 °C

Figure 7.4 shows typical performance curves for T5 and T8 linear fluorescent plus LED arrays over the ambient temperature range that is likely to be encountered in cooled office space.

It can be seen that the output of T5 lamps is affected to a greater extent than T8 or LED as the temperature around the lamp falls. If integrated cooling/lighting solutions are not properly designed, there could be a noticeable difference in illumination levels, depending on whether the mechanical systems are cooling the space at any given time.

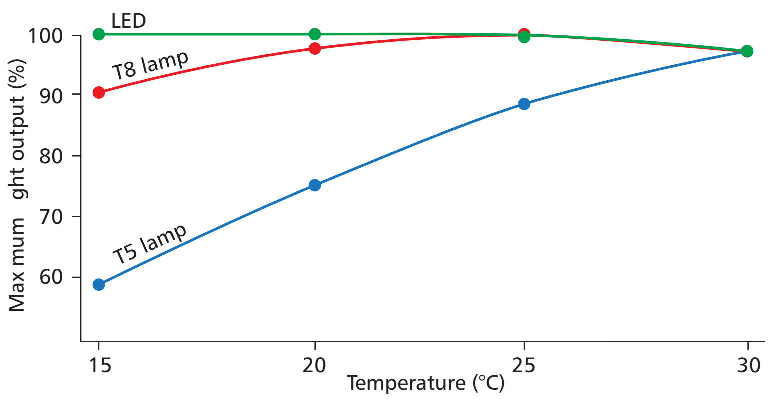

Figure 7.4 Typical performance curves for T8, T5 and LED drivers

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It should also be borne in mind that the lighting installation could contribute to the heating or cooling load. Over-design of lighting systems or energy inefficient equipment could have a direct impact on the energy used by the mechanical systems.

For detailed information and specific lamps' characteristics, the lamp manufacturer should be consulted.

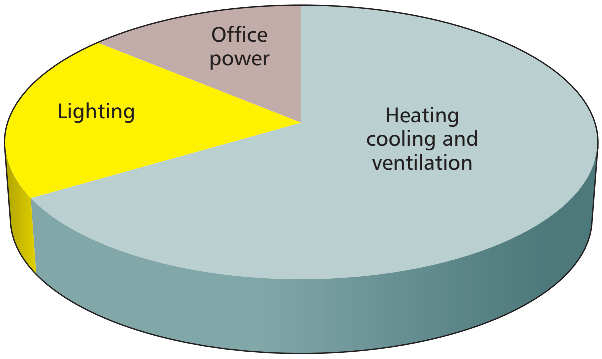
8 Energy use

8.1 Introduction

The amount of energy consumed by an office lighting installation, compared to the overall building energy use, is significant. Typically, it will be the second highest group in a heating/cooling, lighting and power comparison.

In the United Kingdom, the Department of Energy and Climate Change (DECC) publishes office lighting energy consumption figures as a percentage of total office energy consumption; the true figure will depend on the type of office, how it is used and where it is located. Figure 8.1 shows the three main groups of energy use within an office and it can be seen that heating, cooling and ventilation is by far the largest consumer of energy. Lighting is the second highest.

Figure 8.1 Energy use in offices



It should be borne in mind that these figures are averaged across a year and are based on what could be considered a general office.

The impact of energy use must therefore be considered when designing an office lighting installation. For example, the various Building Regulations across the UK require that the energy used by a building be controlled within specified energy targets and lighting has a part to play in ensuring the building achieves or surpasses those targets.

In addition, many organisations insist that the building they occupy has an environmental assessment rating, such as that offered by the UK's Building Research Establishment Environmental Assessment Method (BREEAM) or by the Leadership in Energy and Environmental Design (LEED) method controlled by the US Green Building Council.

8.2 Things to consider

As with all building types, energy usage is a combination of the energy consumption of the individual luminaires and the length of time that they are in use. The time for which any particular group of luminaires is switched on depends on whether there is work being carried out in that area or if there is sufficient daylight to allow the lights to be turned off. Of course, this assumes that people or automatic systems will turn off those lights on occasions when they are not needed.

The first step in minimising energy use is to avoid over-specifying. A competent designer should aim to provide a solution that is as close as possible to the maintained illuminances for each task specified in the schedule of task

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See the *SLL Code for Lighting* for more information

illuminances contained in the *SLL Code for Lighting*. If the actual maintained illuminance is below the requirement then the task may well be performed below normal expectations, leading to low output or an increased number of mistakes. If the level is too high then significant amounts of energy could be consumed unnecessarily by the installation throughout its life.

See section 9 for more information

The easiest way to reduce the energy consumed by lighting is to limit its use to only those times when it is needed. This can best be achieved through the use of appropriate controls. See section 9 for more information on controls.

In areas where tasks are being carried out with varying task lighting levels or where there are users with varying lighting needs (age or performance related) then it is normally most efficient to provide general background lighting that supplies the minimum illuminance required and have task lighting or localised lighting available to boost the lighting levels for those specific users who need it. Task lighting under the control of a user also improves that user's sense of being in control of their environment.

The next step in avoiding unnecessary energy use is to specify the most efficient luminaires that will provide the illumination levels and lighting quality required for any given area. This means looking for luminaires with high utilisation factors and low energy consumption. The use of high efficiency lamps or good quality LED arrays should help to reduce energy consumption.

Luminaire efficiency is made up of a number of elements. The quality of the LED array or lamp is obviously important, as is the control equipment driving the LED array or lamp. Perhaps not always considered is the quality of the reflective surfaces within a luminaire body. The reflector may be a mirrored surface in whole or part, but could easily be just the inside of the luminaire body. In this situation the internal surfaces of the luminaire should have a high reflectance white or specular finish in order to ensure that as much light as possible is leaving the fitting and not being dissipated into the luminaire body as heat.

Light output ratio (LOR) is the measure in percentage terms of the amount of light leaving a luminaire. A higher LOR indicates a more efficient luminaire, although care must be taken to ensure that the light output is in the direction required.

See section 2.20 for more information

The ceiling and walls of an office could easily be considered as an extension of the luminaire's reflective surfaces. If dark colours are used in an office space, any efficiency in the luminaire design could be negated. See section 2.20 for more information on reflectivity of surfaces.

See section 7 for more information

The ambient temperature in which LED arrays and lamps are required to operate will have an effect on both colour temperature and their efficiency. See section 7 for more information on interaction with heating and cooling systems.

8.3 Assessing energy use (LENI, etc.)

There are two recognised ways of determining, or perhaps benchmarking, a lower limit for the efficiency of a lighting installation and both are favoured by legislation.

The first considers the efficiency of each LED array or lamp and its associated luminaire and is given in luminaire lumens per circuit watt. Luminaire lumens per circuit watt are defined as the lamp lumens multiplied by the light output ratio (LOR) of the luminaire and then divided by the total circuit watts for the luminaire. So, to get a high figure you need some combination of efficient lamps, efficient luminaire optics giving a high LOR and low energy consumption by the control gear. A correction factor can then be applied if lighting controls are used.

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This method allows for easy legislation and also gives luminaire manufacturers some certainty of being able to produce luminaires that meet legislative requirements without having to rely on interaction with other elements of a lighting installation design, such as the colour or texture of walls.

While this approach puts minimum efficiency limits on luminaires, it does not limit the number of luminaires being installed.

A second approach is the Lighting Energy Numeric Indicator (LENI).

The method described above can be applied to a lighting design at the concept stage and, if luminaire types or quantities change, as long as they meet the minimum efficiency target, they will be acceptable.

LENI looks at the lighting installation as a whole and considers how it will be used. In some cases this allows for a more accurate prediction of the eventual lighting energy use. Some countries that accept the LENI approach expect emergency lighting to be included in the calculation as well, so it is advisable to check before undertaking the design.

LENI considers how often the total lighting power requirement, plus any control system power requirement (known as parasitic power), is used during both daytime and night-time. Factors such as automatic daylight dimming, automatic adjustment for lamp decay and automatic control systems are also taken into account.

Once the parasitic power and night-time and daytime loads are known, the LENI is determined by adding them together and dividing by the floor area of the building. The result is given in kW·h/m^2 per annum.

Comparison can then be made with the acceptable limits published by government, clients or other controlling bodies.

As an example, in England, the UK Government includes a form of LENI in the *Non-domestic building services compliance guide* for Part L of the Building Regulations.

8.4 The energy balance (energy vs well-designed lighting)

While energy reduction has become the driver for both new and refurbished buildings, a balance needs to be struck between providing good quality lighting and minimising the energy it uses. Office lighting can have a detrimental effect on the occupants' health and productivity if not properly designed. While it can be relatively easy to design a lighting scheme that only illuminates a designated task area and cuts energy use to a minimum, such a scheme would ignore the occupational health and well-being of the users.

Background lighting and the illumination of walls and ceilings will clearly use energy but such elements of the lighting design should not be omitted simply to satisfy energy-saving goals.

Lighting designers need to analyse more carefully how the space will be used, so that localised lighting can be considered for the task areas. This will allow the relatively high illuminance levels required on task areas to be delivered in the most efficient way while ensuring that background lighting is properly considered and appropriately designed.

In addition, this approach allows greater freedom to add visual interest to background lighting designs (Figure 8.2), which is particularly useful in large open-plan spaces where a flat uniform level of background lighting can look uninspiring.

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Figure 8.2 Visual interest in ceiling lighting design

8.5 Environmental assessment methods

In addition to legislative requirements for the reduction of energy, it is now common for building owners or developers to use an external environmental assessment method to determine the impact of their building on the environment.

Such methods go further than looking solely at the immediate energy use and will consider the impact of other elements. For example, how will maintenance be carried out and how will occupants travel to and from the building?

Issues such as the impact of light pollution caused by facade or access lighting to a building are also considered.

Popular environmental assessment methods in use within the UK are:

— Building Research Establishment Environmental Assessment Method (BREEAM) – for more information, visit www.breeam.org

— Leadership in Energy and Environmental Design (LEED) method controlled by US Green Building Council – for more information, visit http://www.usgbc.org/leed

— Royal Institution of Chartered Surveyors (RICS) SKA Rating – for more information, visit http://www.rics.org/uk/knowledge/ska-rating-/about-ska-rating/

BREEAM is the dominant assessment method for the United Kingdom, where whole building projects are being considered; however, some building owners will chose to apply LEED instead. The RICS SKA Rating was developed for partial refurbishment or fit-out of spaces where whole buildings are not subject to a BREEAM or LEED assessment.

Lighting designers should establish at the outset whether an environmental assessment method is being applied and discuss any specific requirements with the appointed assessor.

8.6 Legislative requirements

As discussed in section 8.1 above, the impact of office lighting on the overall energy use of a building is significant. Legislation in many countries will impose restrictions on how a lighting designer can approach a project and it is important that those restrictions are understood before commencing with the design.

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Most legislation considers the energy use of a building against a predetermined target level for a notional building of similar type. The contribution of lighting is one element which should be considered as part of a holistic approach if the building is going to offer its occupants the best possible experience within the constraints of the energy targets set for it. Simply treating each element, such as lighting, facade performance and mechanical plant efficiency, as separate items may lead to unnecessary compromise.

In the United Kingdom, the English, Welsh, Scottish and Northern Irish governments are responsible for setting their own Building Regulations requirements and guidance. Each should be consulted as appropriate; however, as an example, in England, the Building Regulations under Approved Document Part L require that new non-domestic lighting installations approach lighting efficiency in one of the two ways described in section 8.3 above.

9 Control of lighting

9.1 Introduction

The most rudimentary form of lighting control is the manual light switch and this can still be an effective means of control if the occupants of a space are diligent in switching off lighting when not required.

A number of problems can present themselves with a manual control solution, however, particularly in large offices.

- For many reasons, the perception of lighting levels differs between individuals and is therefore subjective. While one person may turn lighting off for most of the day in an office that is well lit by daylight, another may feel the illumination level is not high enough and leave the lighting on all day.
- In large offices, individuals may see it as someone else's responsibility to turn off lighting. Often, in this scenario, no one actually takes the initiative.
- Some people feel morally responsible for reducing energy where they can and will actively switch of lighting that is not required. Others won't even notice that the lighting is switched on.
- In large organisations, the cost of the energy used is not seen by individuals and so there is no incentive to switch lighting off.
- Manual switches should ideally be located close to their associated luminaires, which can prove difficult in large open-plan spaces. For example, the *Non-domestic building services compliance guide*, which supports the Building Regulations Approved Document Part L2 in England, recommends that switches be located generally within 6 m of their associated luminaire, or a distance equal to twice the height of the luminaire above the floor, if this is greater.

It is therefore appropriate to consider an automatic control system for lighting installations where no individual or specific team of people is responsible for turning off lighting which is not in use.

Building Regulations in the United Kingdom acknowledge and encourage the use of automatic controls, including the automatic control of dimming above pre-set daylight thresholds, control of output as LED arrays or lamps age and for presence and absence detection.

Where LED arrays are used, automatic early life output reduction, to ensure that over-illumination is controlled, should save significantly on energy use and can only be achieved via an automatic system.

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BRE Digest 498: *Selecting lighting controls* gives further advice on how to control lighting in office environments.

9.2 Control functions

There are a number of control functions that an automatic system may cover; these are detailed in the following sub-sections.

9.2.1 Absence and presence detection

Absence detection and presence detection may at first appear to be the same thing but from different points of view; however, they differ in terms of the way that switching occurs and are suitable for different operating environments.

— *Absence detection* – Absence detection operates by providing the occupier of a space with a light switch, allowing them to switch the lighting on when they enter a space. The lighting is then switched off automatically when the control system has not detected movement for a predetermined period of time.

Such systems are suited to smaller offices, cellular offices within a large open-plan arrangement and meeting rooms, where occupants would know to turn on the lights when they arrived. Absence control gives users a direct input to the control of their lighting and allows them to leave it switched off if they so desire.

— *Presence detection* – Presence detection does not require any human interaction and will switch on lighting when someone is detected in the controlled area. Lighting will then remain on for a predetermined period of time unless further movement is detected. It is suited to large open-plan offices where no individual is likely to be responsible for switching lighting on when required.

Where occupiers of a large office, would like some additional control, presence detection can be linked to local override manual switching and appropriate zoning to give more local control.

Whereas absence detection systems can be left switched off if there is sufficient daylight, presence detection systems would need additional daylight linking control to perform this function.

Presence detection systems may not be suited to areas of fast-moving foot traffic or where a hazard may present a risk if not illuminated as soon as someone enters the area. Presence detection systems will always have a delay due to the need to detect movement before switching the lighting on.

9.2.2 Daylight linking

There will be occasions when the level of illumination from daylight in an office is sufficient to allow the whole or part of the electric lighting to be dimmed or switched off. Daylight linking of controls allows a control system to dim or switch off lighting as appropriate. Where daylight linking is installed, it is usual to have at least the first row of lighting adjacent to the window on a different switched circuit.

Dimming is the preferred option as it allows gradual reductions in the provision of artificial illumination and this can lead to greater energy savings than direct switching. See BRE Digest 498: *Selecting lighting controls* for more information.

9.2.3 Constant illuminance adjustment

For a lighting installation to deliver its design illuminance after the initial fall-off in output from its LED arrays or lamps, it will effectively be over-designed to begin with. Where suitable luminaires and control gear are used, control systems can be programmed to dim luminaires at the beginning of their life and slowly increase the output as the lamps age so that a constant illumination level is achieved. An added benefit is that under-running LED arrays and lamps initially can save energy.

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Lamp depreciation is generally measured in terms of hundreds of hours. However, the output of an LED array may take thousands of hours to fall to a stable design level. Large LED lighting installations therefore would generally benefit from the use of constant illuminance control.

9.2.4 Time-out control

The cost of an automatic control system can represent a significant proportion of the overall lighting installation cost. Where large offices are likely to fair better in a comparison of cost for lighting versus control, smaller offices may need a different approach.

Simple mechanical time-out light switches are an inexpensive way of allowing infrequently accessed areas to be controlled, ensuring that lighting is not left on by accident. However, care needs to be taken to ensure that occupants are not left in the dark and larger or unusual spaces may need a mix of mechanical and manual switching.

9.3 Human interaction

The operation of automatic control systems and how they serve the needs of an office's occupants must be considered from the outset of a project. Automating lighting control works effectively when it can be seen to assist the occupants of an office. If the occupants perceive that the system is working against them, either through lack of understanding or as a result of poor commissioning, they are more likely to seek to disable any such system.

The designer of a lighting control system should consider providing readily understandable guidance for occupiers so they do not feel the need to challenge the operation of the system. Guidance could include:

- a basic description of control functions that occupants will notice in operation, such as absence and presence detection, as well as daylight linking
- parameters under which the system is operating, such as time-out on absence and daylight levels affecting daylight linking.

9.4 Control for energy

See section 8 for more information

Lighting represents a significant proportion of the energy used in an office and the most effective way of reducing that energy use is to control the lighting installation effectively. Office lighting should only be switched on when required and automatic control systems are the most effective way of achieving this goal, particularly in large offices.

See section 8 for more information on energy use.

9.5 Control for comfort

Automatically controlling lighting to switch off when no one is present, or when the daylighting contribution removes the need for electric lighting, is the most effective way of saving energy in a lighting installation. However, lighting control can also be used to improve comfort for occupants.

The simplest form of comfort control is the dimmer switch. Allowing occupants to control the level of lighting in their immediate space can have a significant effect on their comfort. As each of us has a different opinion on what is comfortable, care should be taken when offering dimming facilities in offices with more than one occupant.

Lighting can have a positive or negative impact on the occupants of an office. Our bodies are used to the lighting around us changing as the day passes. Daylight is constantly changing due to sun position, height and intensity as well as colour, particularly at the beginning and end of the day. Cloud cover can make such changes appear relatively quick and random.

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It is possible, with the appropriate control system and associated luminaires, to mimic to some degree the changing sky and the lighting diversity it brings throughout the day – the theory being that this will have a positive impact on the occupants' well-being.

While such systems are not common, they may be appropriate in some situations.

10 Tablets and touchscreen displays

10.1 Introduction

The type of work carried out in offices of all sizes and types continues to evolve. While the aspiration to move to the 'paperless office' has turned out to be impractical for many office users, there is an ever-increasing array of electronic devices being put to use and each needs to be considered when designing suitable lighting.

Inbuilt cameras in tablets and smartphones encourage the increased use of video calling via software such as Skype. This has resulted in the need to provide good quality, low-contrast lighting on the faces of an office's occupants.

Tablets, smartphones and, to some degree, laptop computers could have their screen in any orientation during use and this, of course, makes it difficult for the lighting designer alone to fully address the issue of glare.

It should also be borne in mind that keyboard finishes on laptop computers can be as great a problem as screen glare, particularly if they are of a gloss or semi-gloss finish and are positioned directly below a source of illumination (Figure 10.1).

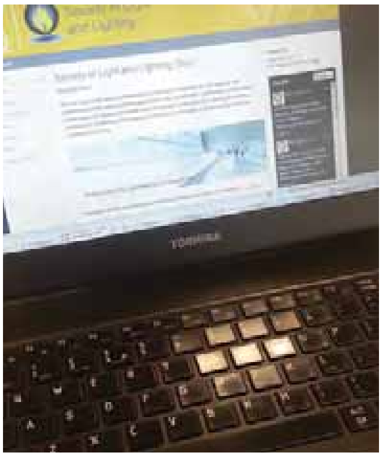

Figure 10.1 Example of keyboard glare

Where such devices are used, the lighting design can only be effective if it forms part of an overall approach to office management. Other elements would need to include some understanding on the part of office staff that it will not always be possible to provide a glare-free environment which allows them to work in any part of their office.

10.2 Understanding how the office will be used

It is important to establish early in the design process if the lighting design is to be based solely on fixed display screens or make provision for handheld and portable devices.

Laptop computers are becoming much more portable, to the point where office staff can move around while carrying on with a particular task. Tablet computers are being used for many tasks that traditionally were associated with sitting at a fixed desk position, such as reading email, conference calling or holding voice or video conversations via dedicated software.

While lighting design for an office which is limited to fixed working positions is relatively straightforward to define, making allowances for staff being mobile will need a different approach. It could be difficult to change a design intended for fixed desk use to one capable of dealing with mobile staff once the design process has commenced.

Where occupiers of an office are known, it would be worthwhile discussing working patterns and adjusting the lighting design to suit.

As an example, if tablet or mobile phone use was usually something that occurred in a breakout space rather than in the general office area, it might be worth considering an indirect lighting design for that particular space, hence minimising the chances of any direct glare from above.

10.3 Personal or business use

It is common for office staff to bring personal devices, such as mobile phones and tablets, into the work environment. Such an arrangement may be formal or

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informal and the lighting designer will need to consult with the building owner if such use is to be considered within the lighting design.

Where business use of tablets or touchscreen devices is expected, then the situation needs to be carefully addressed.

10.4 Desktop touchscreens

Although lighting designers have had to deal with display screens of varying types for a number of years, they have usually been in a relatively fixed orientation with minimal movement in the vertical plane. The introduction of the touchscreen on desktop computers has resulted in much greater articulation of the associated screens, to the point where some can be laid completely flat.

Touchscreens present an additional issue in that they generally have a glossy screen and therefore fingermarks are easily visible, particularly if viewed from any angle other than directly in front.

10.4.1 Conventional vertical or near-vertical displays

Conventional desk-mounted display monitors are increasingly being provided with touchscreen facilities and, in most respects, can be treated by the lighting designer in the same way as non-touchscreen versions, with particular attention being paid to the use of glossy screens and associated issues with reflections. Where display monitors are designed to fold flat on the desk, the guidance below should be followed.

10.4.2 Horizontal and lay-flat touchscreen display monitors

Where horizontal or lay-flat touchscreens are to be used, indirect lighting is the most appropriate design to apply. Ceilings should have a luminance no greater than 500 cd/m^2 and any ceiling-mounted equipment that could cause a bright or dark spot should be avoided. Uniformity is an important factor for the ceiling in this scenario and should be no lower than 0.4.

Where an indirect lighting design cannot be used, consideration should be given to providing some form of screening for the touchscreens as a barrier to direct reflections.

It should be borne in mind that as touchscreens are self-illuminated and usually have a screen-based keyboard, input devices may not require any external source of illumination. Background levels can therefore be suitably reduced and an average of 300 lux with a uniformity of 0.6 should be acceptable. In certain circumstances, and where the only activity being carried out is via touchscreen input, the level of background illumination could be lower.

If illumination levels are too high, the backlighting of the screen will need to be increased so that the user experiences a lower contrast between the screen and the periphery.

A decision to provide a lower level of illumination should be discussed with the building owner and, if possible, with the users of the space. Any decision to reduce the level significantly could have an effect on the ability to use the space in the future should its application change.

10.5 Tablets and smartphones

Tablets and smartphones differ from other forms of input and display devices in that they are self-illuminated. There is no requirement to provide a general level of illumination in order for the user to adequately see what they are doing as there is with a traditional keyboard/screen (Figure 10.2).

Furthermore, tablets and smartphones have adjustable backlighting so the user can adjust the brightness to their own personal preference.

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Figure 10.2 Typical tablet use in a meeting room

This leaves the lighting designer with the task of providing sufficient background illumination to give the tablet or smartphone user adequate peripheral illumination to avoid a stark contrast between the screen and surroundings.

The nature of tablet and smartphone use is that they are obviously portable and can be used equally easily when sitting or standing; horizontal illuminance therefore is not the determining factor. Such devices usually have video calling cameras incorporated so the mean cylindrical illuminance of the lit space is perhaps a better guide to a suitable level of illumination.

It should be possible to provide a mean cylindrical illumination of around 100–200 lux for areas where only tablets or smartphones are being used. With regard to an electric lighting design, an indirect lighting scheme would be the most likely to minimise the impact of glare on the screen.

10.6 Electronic paper devices

Electronic paper devices, such as e-readers, use ambient lighting to provide illumination of the screen's display. They cannot therefore be treated in the same way as tablets and smartphones, although they will present a challenge to the lighting designer, in that they can obviously be used in any orientation, both sitting and standing.

Electronic paper devices usually have a matt screen but, as the technology develops, this may not always be the case. As matt screen devices are designed to replicate the experience of reading from a paper document, an environment aimed specifically at e-reader use should be treated as any other office where paper-based tasks are carried out. In the event that glossy screen devices are developed, they will need to be treated in the same way as tablets and smartphones.

10.7 Fixed visual indicator displays

As home-working is becoming more popular, new and refurbished office accommodation is often created with fewer desks than staff, the theory being that if a number of the staff are away or working from home, there is no need to provide them with desk space.

In such situations, hot desking is encouraged and user display terminals, such as that shown in Figure 10.3, are becoming common.

Display and input terminals are increasingly being used for control of assets in office accommodation, whether indicators for meeting room bookings, lift access terminals or for access to photocopiers and printers (Figure 10.4).

Where installed, these devices will need to be provided with an adequate level of illumination which avoids any direct or indirect glare source. While it is possible to move desk-based equipment slightly to avoid a specific glare problem, fixed visual displays are, by their very nature, 'fixed' and therefore any problem not addressed during the design phase may represent an ongoing problem, annoyance or a health and safety hazard for users of the office.

Figure 10.3 Hot-desk booking display terminal

Figure 10.4 Photocopier display terminal

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11 Emergency and standby lighting

11.1 Introduction

Emergency lighting (sometimes referred to as 'emergency escape lighting') is provided to ensure that, during failure of a building's main lighting system, there remains a level of artificial illumination which will allow safe egress from the building by an unambiguous route.

Emergency lighting must be viewed in a different way to general office lighting, and in accordance with the provisions in the Building Regulations for many countries including England, Wales, Scotland and Northern Ireland.

In commercial properties, including offices, it is recommended that, in addition to defined escape routes, all areas over 60 m^2 should be provided with emergency lighting.

It should be borne in mind that a loss of power to the workplace is not uncommon. It is, in fact, common enough for building occupants to view it with irritation rather than panic. The sudden loss of lighting can put people in danger should they attempt to move about. Therefore, the need for emergency lighting is vital as it is more likely to be put to use during its lifetime than other emergency systems, such as a fire alarm system.

The building owner should be asked if there is any requirement or risk assessment that requires standby lighting so that all or part of the office building can continue to function, if only at a reduced level, during power failures.

If so, the circuitry or control system for the lighting will have to be arranged so that all or part of it can be supplied from a standby generator or an uninterruptible power supply (essentially a central battery system). If only part of the lighting is to be supplied then careful thought has to be given to how the circuitry will be arranged.

For example, if half of the lighting is to be supplied via a generator then either half the lamps in the luminaires or half the luminaires need to come on. Luminaires can be supplied with twin terminal blocks so that the lamps inside can be supplied half and half, one-third or two-thirds depending on the number of lamps inside. This method is more expensive and does require two sets of wiring to be provided to all luminaires. It does, however, ensure that the uniformity of the lighting is maintained across the space.

The alternative is to arrange the wiring to the luminaires in a chequerboard arrangement so that every other luminaire comes on. This is less costly but does lead to poorer uniformity across the space. Where there is an automatic lighting control system this can usually be configured to turn off some lamps in each luminaire, where the appropriate ballasts have been provided, or to turn off some of the luminaires during a power failure. This approach gives maximum flexibility, as the ratio of standby lighting provided can be varied from department to department depending on how critical their function is.

Safety lighting needs to be provided where processes have to be shut down or made safe in the event of a power failure. In most office buildings this is likely to apply to areas such as kitchens, communications rooms, print rooms, etc. Escape lighting will need to be provided throughout the office space to allow the orderly evacuation of the building in the event of an emergency or power failure. Medium to large buildings usually warrant the installation of a central battery system. This means that one or more secure, ventilated rooms have to be provided in the building to house the battery/inverter units. Refer to SLL Lighting Guide 12: *Emergency lighting* for more advice on safety and escape lighting.

See SLL Lighting Guide 12 for more information

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11.2 Siting of essential escape lighting – initial design

It is important to identify specific escape routes before commencing on the design of an emergency lighting system. This should be done in consultation with the architect (if appointed), building owner, Fire Officer and Building Control Officer. At this stage it would also be advisable to identify any specific requirements that the buildings insurers may wish to impose. Following consultation with these parties, the initial design is conducted by siting luminaries to cover specific hazards and to highlight safety equipment and safety signs. Typical locations where such lighting should be sited include the following:

- near stairs, so that each flight of stairs receives direct light
- near any other change in level
- near externally illuminated escape route safety signs, escape route direction signs and other safety signs that have to be illuminated under emergency lighting conditions
- at each change of direction
- at each intersection of corridors
- near to each final exit and outside the building to a place of safety
- near each first aid post, so that 5 lux vertical illuminance shall be provided at the first aid box
- near each piece of fire-fighting equipment and call point so that 5 lux vertical illuminance shall be provided at the fire alarm call points, fire-fighting equipment and panel
- near escape equipment provided for the disabled
- near disabled refuges and call points (also to include disabled refuge two-way communication systems, including disabled toilet alarm call positions).

For the purpose of the above, 'near' is normally considered to be within 2 m, measured horizontally.

There may be instances where other measures reduce the need for emergency lighting. The use of vision panels, for example, in doors opening onto escape routes may provide the recommended levels of emergency illumination within the adjacent room.

The principal documents covering the need for emergency lighting in various types of premises within the United Kingdom are as follows:

- The Regulatory Reform (Fire Safety) Order 2005 (England and Wales)
- BS 9999: 2008 *Code of practice for fire safety in the design, management and use of buildings*
- BS EN 1838: 2013 *Lighting applications. Emergency lighting*
- BS 5266: 2011 *Emergency lighting. Code of practice for the emergency lighting of premises*
- Building Regulations 2010 Approved Document B *Fire safety* (England and Wales) (2013 Amendment)
- Scottish Building Standards Technical Handbook: Non-Domestic, Section 2 *Fire* (2015)
- Building Regulations (Northern Ireland) 2012 Part E *Fire safety*.

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11.3 Additional escape lighting

After siting luminaries at the locations listed in section 11.2 above, consideration should be given to installing luminaries at other locations, including the following:

- lift cars – although not considered as part of the escape route, emergency lighting is required since failure of the normal lighting could result in people being confined in a small dark space for an indefinite period
- moving stairs and walkways
- toilets with areas exceeding 8 m^2
- external areas in the immediate vicinity of exits.

11.4 High-risk task areas

In addition to the above, emergency lighting should also be provided for areas in which high-risk tasks are undertaken. These include areas such as plant rooms, lift motor rooms, electrical switch rooms, kitchens and any area where a safety hazard is present and may become a danger to people moving about in darkness.

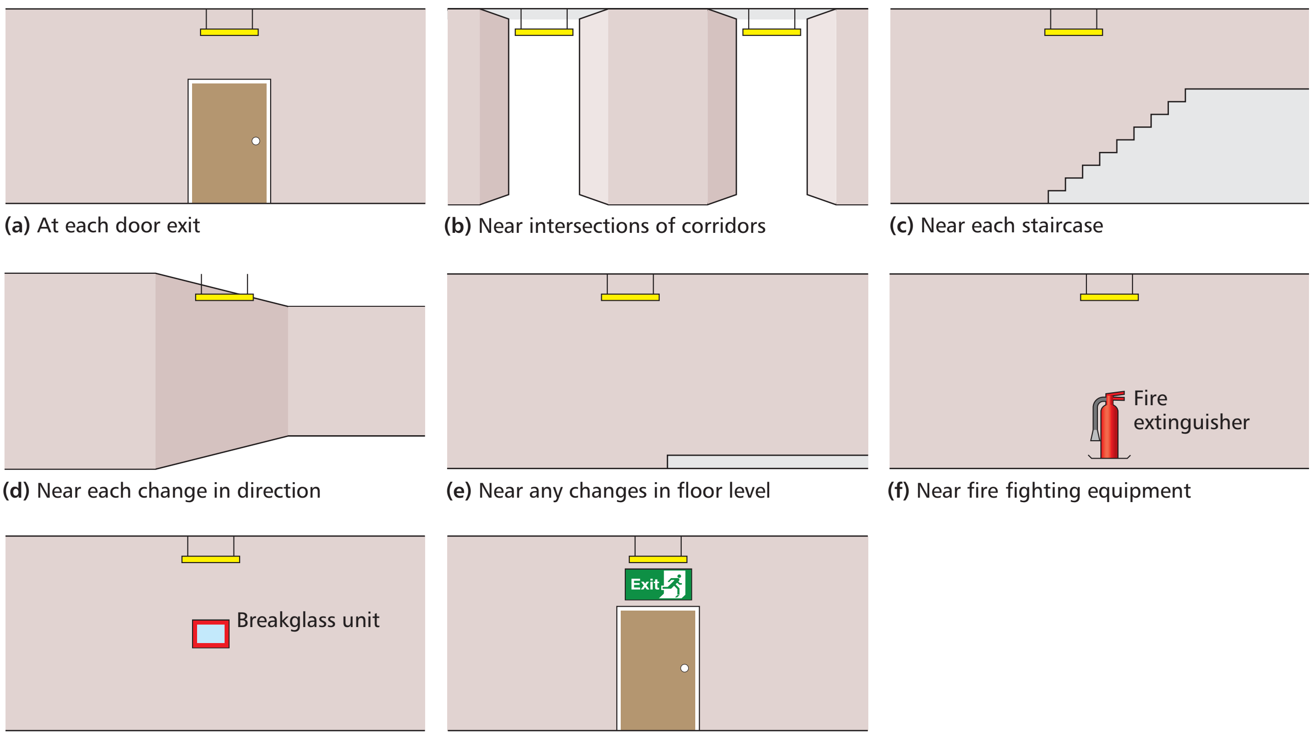
The level of illumination recommended by BS EN 1838: 2013 is no less than 10% of the maintained illuminance required for carrying out normal tasks, or 15 lux, whichever is the greater. Uniformity should be a minimum of 0.1.

11.5 Illumination of safety signs

Safety signs, including exit signs, can be illuminated either internally or externally from a remote source. The specific requirements for exit signs are given in the Health and Safety (Safety Signs and Signals) Regulations 2010 in the United Kingdom and BS EN 1838: 2013 *Lighting applications. Emergency lighting*.

All emergency exit signs within a particular building should be uniform in colour and format, as well as being located in sufficiently close proximity to the door to ensure that their association is unambiguous. Signs should be sited to ensure that a clear contrast is apparent between the sign and its surroundings (Figure 11.1).

Figure 11.1 Positioning of emergency exit signs



(a) At each door exit
(b) Near intersections of corridors
(c) Near each staircase
(d) Near each change in direction
(e) Near any changes in floor level
(f) Near fire fighting equipment
(g) Near each fire alarm breakglass unit
(h) To illuminate exit and safety signs

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Signs which display only text are no longer permitted within the United Kingdom and should be replaced with signs showing the graphical representation.

Signs complying with BS 5499: Part 1(23) (combined graphical and text signs) may still be used if they are to be installed in a building which currently has this type of sign.

Self-luminous signs may also be used as exit signs. If used, however, these must also comply with the appropriate legislation or code. Care should be taken when using in the presence of luminaires switched via presence detection. A self-luminous sign will only work when charged from an adjacent light source. A sign located in an area where the general lighting is usually switched off due to inactivity should not be self-luminous.

11.6 Lighting levels for escape routes

Defined escape routes have specific recommendations in terms of minimum illumination. It is essential that a minimum level of illumination is maintained along escape routes during a main lighting failure. A minimum of 1 lux in corridors up to 2 m wide is recommended by BS 5266-1: 2011. Uniformity should be no more than 40:1 between minimum and maximum illumination levels. Glare limits should be observed in accordance with BS EN 1838: 2013.

11.7 Open spaces

Open spaces are considered to be where no defined escape route exists.

An example would be an open-plan office. In this situation, the office furniture might hinder the safe escape of occupants if the lighting system failed.

In England and Wales, the Building Regulations recommend that areas over 60 m^2 be provided with emergency lighting. Due to the size and nature of such large spaces, they will also include areas previously referred to as undefined escape routes. In such situations, occupants of a space may take several different routes to the nearest exit.

The recommended minimum illumination level for such situations is 0.5 lux excluding a 0.5 m border around the perimeter.

Glare limits should be observed in accordance with BS EN 1838: 2013.

Uniformity should be no more than 40:1 between minimum and maximum illumination levels.

While this recommendation is a minimum level, designers are advised to assess the dangers from loss of main lighting on an individual project basis, dependent on the hazards present.

12 Detailed room design information

The following sub-sections provide detailed design notes on individual room types that are likely to be found in an office building. Individual information is given on the types of tasks that are commonly carried out in these spaces and the types of lighting that are normally suitable.

12.1 Introduction

The *SLL Code for Lighting* describes the scale of illuminance in accordance with EN 12665: 2011. The scale sets out the levels between which a perceptual change in illumination levels can generally be observed. These levels are used to define maintained average illumination levels in this guide and are recognised as benchmarks in lighting design.

Scale of illuminance (lux)														
20	30	50	75	100	150	200	300	500	750	1000	1500	2000	3000	5000

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Typically, lighting design for task areas in offices will be either:

- 300 lux for mainly screen-based tasks, which can include minor paper-based tasks such as note-taking
- 500 lux for mainly paper-based tasks.

Adjacencies to the task area can be illuminated to the level one step below in accordance with the scale of illumination.

Where designers feel the need to use a different value, such as 400 lux, they will have to justify that choice and ensure that the building owner understands and accepts the move away from the recognised scale of illumination.

Obviously, the nature of each specific type of building influences the exact form of lighting in a particular room and each client may have a house style that will influence design. In other words, a meeting room in a merchant bank is likely to need a different style of lighting to an identical room in an advertising agency. The first may be conservative and restrained, the latter brash and exciting. Both rooms still need lighting for the participants to be able to see each other, to judge reactions of others and to read paperwork and perhaps view small-scale presentations.

These room types are grouped under two main headings: primary office spaces, which include areas such as open-plan, deep-plan and cellular offices, and secondary spaces, which include archives, refreshment areas and meeting rooms. There are also sections that cover the vital circulation spaces, such as corridors, stairs and lift lobbies, and back-of-house areas, such as plant rooms and storerooms.

The lighting levels given are for standard tasks carried out in those areas by people with normal eyesight. If the task is more complex than normal, has a lower contrast, is safety critical or is carried out by older people, then higher lighting levels may be required. If the tasks are less onerous than normal, are simpler, have a high contrast or are carried out by young people then lower lighting levels may be justified.

Cylindrical illuminance levels and recommended modelling ratios are also given.

See the *SLL Code for Lighting* for more information

The limiting glare rating shown is the maximum discomfort glare, expressed as a unified glare rating (UGR), permitted for that operation. See the *SLL Code for Lighting* for definitions and application of UGR.

12.2 Primary office spaces

The primary office space is that used for the normal office work of the company. It usually consists of a mixture of cellular offices and open-plan space. The cellular space will vary from small, single-person cellular offices to larger executive or multi-person cellular offices where groups work together.

Open-plan space will vary in size but may be categorised as normal ‘open-plan’ space, where all the working area is sufficiently close to windows to be regarded as being daylit. Where the space becomes remote from the windows it is referred to as ‘deep-plan’ space and requires special care if the users positioned further away from the windows are not to be left feeling deprived of daylight.

A very wide range of tasks may be carried out in an office. It is possible that material of poor contrast will be read, images and graphic designs prepared or amended, references researched and consulted, etc., as well as less onerous visual tasks being carried out. It is very likely that most workstations in any general office will or might be equipped with display screens for word processing, data

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manipulation, multimedia or financial use. The lighting must be suitable for these screens.

Most general office work can be lit by a well-diffused overall coverage from the lighting installation but additional lighting for visual interest may be needed. For most offices or tasks, the vertical plane illuminance should be considered as well as the more customary horizontal plane; for instance, wall charts and noticeboards.

12.3 Open-plan offices

Recommended maintained illuminance (lux)	300 for screen-based work or 500 for mainly paper-based tasks
Recommended cylindrical illuminance	150 lux at the task area with a modelling ratio of 30–60%
Limiting glare rating	19

Such space can be used for a wide variety of purposes and can be laid out with fixed desk and partition systems or have desks that are constantly being reconfigured for new projects or changing work patterns. The space planning flexibility needs to be established with the client, developer or user group. This will help to determine any special lighting needs and the likely effect of any partitions on both the illuminance levels and shadowing. The degree of flexibility may also influence the decision to use a flexible lighting system and whether a control system is justifiable or preferred.

See section 6.20 for more information

Most speculative office space is designed as totally open plan with likely partitioning plans for cellular offices indicated. Lighting designers will need to take into account these possible partition arrangements by designing any luminaire grid with gaps where walls may be located and allowing for suitable task lighting levels and uniformities in a range of cellular office modules from any fixed lighting grid. See section 6.20 for more information on cellular spaces.

The lighting needs to be controlled in such a way that distinct areas of the office can be lit only when needed and designated 'corridor' routes can be left lit when the space is occupied. Such controls can be automatic, based on presence or absence detection depending on the number of users and work patterns. Whatever the system of control, it must be of a form that relates to the layout of the luminaires and can be readily understood by the users of the space.

12.4 Deep-plan areas

Recommended maintained illuminance (lux)	500 or 750 during daytime and 300 or 500 once daylight has faded (see below)
Recommended cylindrical illuminance	150 lux at the task area with a modelling ratio of 30–60%
Limiting glare rating	19

Deep-plan areas of an office can be defined as those more than 6 m away from the window walls (Figure 12.1). It will probably be necessary for these central core areas of deep-plan offices to be lit continuously by electric lighting, as natural light will not penetrate sufficiently.

Those working in the central core areas – where the daylight factor will be significantly less than 2% – will have a lower overall lighting level as they will have little benefit from daylight. To offset this and to reduce the contrast with surfaces illuminated by natural daylight nearer the perimeter, an increased level of illumination should be provided from the electric lighting during the daytime. Generally, this should be one step higher in the normal illumination scale. Thus,

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Figure 12.1 Deep-plan office

for a general lighting level of 300 lux, the core area should be lit to 500 lux; for a 500 lux general lighting level, 750 lux should be provided in the core area.

A control system should be provided to reduce this higher light level as daylight levels fade in the perimeter zone. When daylight has faded there is no reason to provide more light in the core area than near to the windows.

Particular attention should be paid to lighting walls and other vertical surfaces adequately to minimise contrasts between them and brightly lit surfaces adjacent to windows. Variation in colour and texture in the general decor can also help here, provided that dark surfaces and high contrasts are avoided.

See section 5.7.4 for more information

Control of daylight by blinds or curtains is also helpful in reducing glare from windows. Deep-plan spaces benefit from lighting controls acting on rows of luminaires parallel to the window by improving the uniformity of light across the space. See section 5.7.4 for advice on window shading options.

12.5 Cellular offices

Recommended maintained illuminance (lux)	300 for screen-based work or 500 for mainly paper-based tasks
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

Cellular offices can be fixed office spaces or partitioned spaces (Figure 12.2). They may be for a single user or for a group of users. Usually, where there are relocatable partition walls, the lighting within the room is the same as that outside to allow the walls to be moved without having to change the luminaires. Where there are fixed walls, especially in older buildings and in senior managers' offices, there is more scope to vary or tailor the lighting to suit the specific types of task being carried out in the room, its character or the needs of the room occupant.

See section 6.3.4 and section 10 for more information

Smaller office sizes present fewer problems with potential reflections of the room lighting in any display screens, as the room is unlikely to be long enough for there to be luminaires visible in any normally orientated screen. Where there are plain glass partitions this may not be this case. See section 6.3.4 and section 10 in general for more advice.

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Figure 12.2 Glazed cellular offices

Each enclosed office needs its own means of controlling the lighting in that space. This can be by a separate controller, as part of a central automatic programmable lighting system, as a simple local light switch or, ideally, by an absence detector.

12.6 Graphics workstations

Recommended maintained illuminance (lux)	300
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

A graphics workstation can take many forms, but generally falls into one of two categories:

- those where a user is copying from an original hard copy to create a digitised version and needs good lighting on both the screen and the work area
- those where the user is creating something directly on a screen and perhaps does not need to look at the working area very often.

A copying workstation normally consists of a digitiser platen and a large high-definition colour monitor or, increasingly often, a touchscreen monitor that can be positioned at normal viewing angles or laid completely flat. Occasionally, there will be two screens – one screen to display the graphics image and the other to display text for menus and control. The digitiser, the graphics screen and/or the touchscreen monitor present the main problems for the lighting designer.

Small digitiser boards are usually located to one side of the keyboard. If large, they are often positioned at right-angles to the desk containing the screens and are used almost vertically by some operators. As drawing work itself is rarely carried out on such boards, high levels of task lighting are not normally required. The task normally performed here is to move a digitiser pen across the sketch or drawing to strategic points where a button on the mouse is pressed. This informs the drawing program where the point is located on the digitiser. For a drawing of normal clarity, 300 lux on the digitiser surface is sufficient for this task. Supplementary lighting should be provided for viewing any poor quality copy drawings. If normal drafting work is to be carried out at the same position, supplementary lighting to increase the level to 750 lux should normally be made

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available. However, care must be taken in the selection and positioning of any such task lights to avoid direct or indirect glare to adjacent workers.

The operator will normally be looking from the digitiser to the graphics screen to ensure that the graphic image being built up is correct. Reference to the keyboard and possibly to a control screen or a flat keyboard on the side of the digitiser board will also need to be made. The range of visual tasks is therefore quite wide and can involve the user in some movement and in frequent changes of view. For this reason it is advisable to keep the luminance range at the workstation and in the immediate surroundings within a range of 1:10.

With the digitiser board illuminance at about 300 lux, the luminance will be approximately 70 cd/m^2. The luminance range from background walls, to desk, to screen and to keyboard should then, ideally, all lie in the range 20–200 cd/m^2. This can be achieved by aiming for a fairly constant level of illuminance on the desk and vertically on surrounding walls. The average reflectance of these major surfaces should be kept within a 5:1 range. To achieve a constant illumination over an area both horizontally and vertically, lighting with a significant indirect lighting component is recommended. The soft, even illumination from indirect lighting also helps avoid distracting shadows being cast on the digitiser board.

Where a user is creating an image directly on a screen, the area where their hand is manipulating the digital pen might not have to be viewed very often. There may be a requirement to operate buttons on the associated digitiser or to place the pen in a specific location occasionally. In this regard, the task is similar to those of a general office workstation and therefore could be treated as such.

At some graphics workstations the user will work directly onto a touch-sensitive screen, so the digitiser and screen become one element.

Touchscreen graphics workstations present different problems, particularly those which can be laid flat. If such workstations are used to review work, a number of people could gather around one workstation, with each person likely to have a less-than-perfect view of the screen. Specular reflections from numerous directions are possible, including glare from ceiling-mounted lighting.

If only a small percentage of the workstations are touchscreens, it may be possible to move them to a location within an office that causes little or no glare. If the workstations are predominantly touchscreen and capable of being laid flat, then the lighting design will have to be one which minimises glare as a priority. An uplit scheme may be the most appropriate solution.

12.7 Dealing rooms

Recommended maintained illuminance (lux)	300–500
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

In using the term ‘dealing rooms’ we are referring to large open-plan or deep-plan areas where a large number of dealers work at multi-screen workstations. The visual task includes the recognition of data displayed on visual display terminals, input via keyboards and keypads, processing of hand- and machine-written documents and, most importantly, communication between staff. A dealer normally needs to be able to see the others in their group so that they can coordinate deals and trades, and sometimes respond rapidly to hand and facial signals to close or delay a deal.

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Thus the lighting problem is worse than for normal workstations because the multi-screen arrangements mean that some of the screens may be mounted at unfavourable angles with respect to the lighting and the need to light faces means that light has to flow across the space. The likelihood of specular reflections in some of the screens is therefore increased.

Cylindrical illuminance is a particularly important consideration in dealing rooms, given the need for quick and accurate visual communication across the space and the fact that body language can be as important as the spoken word.

It is difficult to provide satisfactory lighting using direct light alone in most dealing rooms. To minimise possible reflections in the many screens, the luminance needs to be limited at high angles from the luminaires. Unfortunately, this will then restrict the flow of light across the space that would light the faces of other dealers. Using some indirect light reintroduces some soft general light to the space without generally adding to the risk of undue screen reflections.

Great care must be taken when positioning luminaires to prevent bright images being reflected towards the viewer from display screens, keyboards, keypads, etc. As the angle at which screens are inclined away from the viewer increases, this restriction becomes increasingly onerous.

Unrestricted daylight in dealing rooms can upset the controlled environment. Patches of high luminance may result from reflected light or, worse, direct views of high-brightness cloud. Windows should therefore be considered for their visual aspect rather than as a contribution towards lighting the space. The luminances of windows and adjacent walls should be similar to those of the remaining walls.

12.8 Executive offices

Recommended maintained illuminance (lux)	300–500
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

In office buildings, what constitutes an ‘executive office’ will vary as widely as the roles of workers with the term ‘executive’ in their job title. Usually in such rooms

Figure 12.3 Executive office and secretary position

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See sections 12.5 and 12.10 for more information

there would be additional space for meetings, entertaining or for informal discussions, as well as space for standard office tasks. The lighting has to be adaptable to suit the various functions and may need to reflect a higher level of quality in the finishes to the room. This can be achieved by simple upgrading in finishes to trims on the lights or by the addition of extra lighting to artwork or furniture. See section 12.5 on cellular offices and section 12.10 on meeting rooms for general lighting advice.

12.9 Secondary office spaces

The secondary office spaces are those areas used to back up the normal office work of the company. These are found in most office building but in smaller ones the functions may be combined, such as having a small library of reference books in a meeting room.

12.10 Meeting rooms

Recommended maintained illuminance (lux)	300 for normal meetings, 500 where more intensive reading and writing is carried out
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

See section 12.12 for more information

These are small to medium-sized rooms, generally used for short or informal meetings. For larger spaces, see section 12.12 (conference rooms). Vertical illumination is important and the lighting needs to provide a flow of light across the space to light people's faces so that their reactions can be accurately judged and to aid those who may need to lip-read. However, this flow must not be so great as to cause glare. Cylindrical illuminance is a particularly important consideration in meeting rooms, given the specific purpose of such spaces, where each occupant needs to have a well-lit view of the other occupants' faces and, perhaps, body language.

Combined direct/indirect luminaires often prove ideal in this situation, as they provide good working light over any table and soft general lighting to improve modelling. Dimming is usually invaluable as various visual presentation systems may be in use in the room. Wall washing, on a separate dimmed circuit, can be useful to highlight any wall displays or presentation stands.

12.11 Training rooms

Recommended maintained illuminance (lux)	300 for mainly presentation and note-taking type training or 500 for more detailed study and writing-based training
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

These rooms normally fall between meeting rooms and conference rooms in size order, although they may be used for one of these other purposes as well. In training rooms there is usually a need to provide lighting onto areas where trainers make presentations to the audience. The lighting should also provide controllable light down onto the audience area to allow note-taking and to light the audience's faces. However, this light must not cause glare. Some training rooms are set up as miniature versions of a main office space and, as such, should be lit in a similar way.

The ability for trainer and trainees to clearly see each other's faces, perhaps over prolonged periods, is essential and therefore the cylindrical component is particularly important.

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Dimming is usually invaluable as various visual presentation systems may be in use in the room. Wall washing, on a separate dimmed circuit, can be useful to highlight any wall displays or presentation stands. Lighting controls should be simple to understand and be well labelled.

12.12 Conference rooms

Recommended maintained illuminance (lux)	300 for normal meetings, 500 where more intensive reading and writing is carried out
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

These rooms often have fixed seating and are larger than those dealt with under the meeting rooms and training rooms sections, although they may be used for one of these other purposes as well. In conference rooms, there is a need to provide adjustable lighting onto areas where lecturers or speakers make presentations to the audience. Lighting over the audience area is required to allow for note-taking and reference to notes or speakers' materials. Dimming is usually essential as various visual presentation systems may be in use in the room. Wall washing, on a separate dimmed circuit, can be useful to highlight any wall displays or presentation stands.

Cylindrical illuminance is a particularly important consideration in conference rooms, given the specific purpose of such spaces, where each occupant needs to have a well-lit view of the other occupants' faces and, perhaps, body language.

Lighting controls should be simple to understand, clearly labelled and be duplicated by the speaker's position, at the back of the room and in any projection room.

12.13 Board rooms

Recommended maintained illuminance (lux)	300 for normal meetings, 500 where more intensive reading and writing is carried out
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60%
Limiting glare rating	19

See section 12.8 for more information

These rooms may also be used as meeting rooms or training rooms. In most boardrooms the tasks are similar to those carried out in meeting rooms but there is a requirement to provide higher quality and more adaptable lighting, as the space needs to have a more 'exclusive' feel about it. See section 12.8 on executive offices for more information on this aspect. Some board rooms can also be used as executive dining rooms, either daily or just when there are formal board meetings.

Cylindrical illuminance is a particularly important consideration in board rooms, given the specific purpose of such spaces where each occupant needs to have a well-lit view of the other occupants' faces and, perhaps, body language.

Dimming is usually invaluable as various visual presentation systems may be in use in the room. Wall washing, on a separate dimmed circuit, can be useful to highlight any wall displays or presentation stands.

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12.14 Reprographics rooms

Recommended maintained illuminance (lux)	300 vertical on reprographics equipment and 300 horizontal on all collating, binding and dispatch tables
Limiting glare rating	22

A reprographics room is where large-scale copying and collation of documents takes place. Sometimes, specialists work in these rooms, processing documents and files. Tasks carried out may include scanning or copying of papers and drawings, collating, trimming and binding of documents and, possibly, labelling and dispatch back to the originating departments. The lighting therefore needs to provide good vertical illumination around printing and copying machines and good, even illumination across workbenches where detailed binding may be taking place. In some areas, task lighting may be needed.

Where colour-critical printing is being carried out, lighting (or specifically the LED arrays or lamps used) will need to have an appropriate colour rendering index (CRI) rating suitable for the task. It is a popular misconception that the colour temperature of a lamp and its CRI are directly related. Simply using lamps that mimic the colour of daylight will not necessarily provide an acceptable level of colour correctness (colour rendering). Reflected light from coloured walls, ceilings, floors, furniture and equipment will all affect the colour rendering. Refer to the *SLL Code for Lighting* and *SLL Lighting Handbook* for more information on colour rendering.

See *SLL Code for Lighting* and *SLL Lighting Handbook* for more information

12.15 Library/ information centres

Recommended maintained illuminance (lux)	200 vertical on bookcase right down to bottom shelf, 300 general, 500 on reading desks and counters
Limiting glare rating	19

The lighting needs to provide a pleasant environment in which to select books and periodicals, refer to screen-based data sources and to sit and read and make notes. These spaces in office buildings are often rearranged over time, so the lighting has to be flexible enough to cope with lighting vertical book stacks as well as horizontal desks, display screens, microfiches and seating areas.

Where tablet or smartphone use is to be encouraged, consideration must be given to minimising reflections from any direct lighting sources.

12.16 Archives/ document stores

Recommended maintained illuminance (lux)	300 for storage and selection of small items, 200 vertical on fronts of shelving
Limiting glare rating	25

These spaces can vary in size and sophistication, from simple rooms holding local department documents to central archives where documents come in from a widely dispersed set of departments or buildings and where detailed labelling, storage and retrieval systems can operate. Such rooms are often full of shelving with boxes or spaces for documents, data or samples. It is essential to ascertain from the client the type and complexity of the items being stored in each space designated as an archive, and details of the heights and locations of any shelving or wall storage units.

Where the room is to have shelving or wall storage units, the room effectively shrinks in lighting terms. If a 3×4 m room is to have 0.5 m shelving around the walls then, in lighting terms, the room becomes a 2×3 m space as the light needs

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to be within the central volume to illuminate the fronts of the shelving. There is rarely any point in having lights positioned above the storage system.

Where mobile storage shelves are in use, the lighting needs to be arranged so that, whichever aisle is open, the shelves on both sides are well lit right down to the bottom. In large areas, a control system is recommended so that the lighting is only on above the open aisles and in the access space in front of the mobile racking.

12.17 Kitchens/ rest rooms

Recommended maintained illuminance (lux)	200 general, 300 for serving and preparation areas
Limiting glare rating	22

These minor but essential spaces in offices need lighting for two purposes. The lighting around any hot drink making areas and any related sink or food preparation areas needs to provide the right quality and quantity of light. However, the lighting also needs to mark out the area as a social area rather than just part of the office space. Studies have shown that such informal areas are where a lot of office networking and information exchange takes place. Indeed, some companies, where information or ideas exchange between working groups or departments is particularly valuable, provide comfy seating and even social recreational games to facilitate such exchange.

12.18 Sick bays/ medical rooms

Recommended maintained illuminance (lux)	300 general, 500 where medical examination may be needed
Limiting glare rating	19 (16 towards practitioner for medical examination)

These rooms may vary from just a quiet space for staff to go and sit if feeling unwell to full medical rooms with beds, examination facilities and a resident nurse. The lighting generally needs to provide a quiet, attractive ambience, as occupants may be shocked or distressed. Adjustable wall or table lights may be needed for examination. Consult with company medical or human resources staff for an exact brief on the extent of medical facilities needed.

See SLL Lighting Guide 2 for more information

See SLL Lighting Guide 2: *Hospitals and health care buildings*.

12.19 Canteens/ restaurants

Recommended maintained illuminance (lux)	200 general, 300 over serveries, 500 in kitchens
Limiting glare rating	22

The lighting needs to provide an attractive ambience while providing sufficient light to eat by and to light the faces of those around each table. Lighting therefore needs to supply a good flow of light across the space from luminaires that are both functional and attractive. Dimmable lighting may be needed if the area is to be used in the evening for corporate functions or dining.

The servery area needs increased lighting to ensure safety and to allow easy identification of food. Some servery counter units have integral lighting. The client/catering suppliers/concession should be consulted to establish what is being provided.

Kitchens and areas where food is prepared should have sealed luminaires which can be easily wiped down and to ensure that any glass from broken lamps or dust/dead flies from diffusers do not fall into food below. Luminaires suitably rated for water and dust resistance as well as for heat resistance should be chosen.

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12.20 Circulation areas

These areas are the routes that link the various parts of the building. They often provide the first impression for visitors and need to be safe and pleasant to walk through (Figure 12.4).

12.21 Entrance hall/ reception

Figure 12.4 Typical office corridor

Recommended maintained illuminance (lux)	200 general, 300 over reception desks and seating areas
Recommended cylindrical illuminance	150 lux with a modelling ratio of 30–60% over the reception desk or security desk
Limiting glare rating	22

This area is normally the first to be seen by visitors to the building and, as such, should create the appropriate impression. It is likely that a leading advertising agency would require a different lighting approach to that sought by a firm of city lawyers. The lighting impression needs to work during the day, when there may be a high level of daylight flowing into and across the space, and at night, when the lighting needs to stand on its own. Where there are large street-front windows, the lighting may need to provide effectively a 'shop window' effect to project the right impression to passers-by or just to display the company's products.

Where there are large areas of windows around the entrance hall, the lighting level inside should follow the fluctuating levels outside via a suitable lighting control system. However, where there is little daylight in the space, a higher level of electric lighting may be needed to provide a transition zone for those entering from the brightly lit exterior, otherwise the space will appear dark.

Lighting over any reception or security desk needs to provide functional lighting behind the desk for handling paperwork and good multi-directional vertical illumination to provide good modelling of the faces of the receptionists and the visitors. This helps those who may need to lip-read or who need to assess visitors for security reasons. A higher level of local illumination should be provided in areas where security cards or passes are to be checked. Local lighting may be appropriate around seating areas.

12.22 Atria

Recommended maintained illuminance (lux)	50–500
Limiting glare index	Not applicable

12.22.1 General

Atria fulfil many functions – arrival points, meeting spaces, connecting spaces, work spaces, circulation, promenading, social and dining areas. They also provide a high-quality visual outlook to occupants of the abutting offices and can contribute to the environmental conditions within these offices. By providing access to daylight for those office workers on the 'inside' of the building, atria buildings can offer greater efficiency in office layout and space planning, leading to increased user satisfaction.

Planting, artwork, water features, seating and reception areas are often provided within the atrium, enhancing its social function. Similarly, they are often central to the grand circulation statement, with escalators, feature observation lifts and staircases forming major elements. Dining facilities, retail and work space may also be incorporated into the atrium design.

The atrium is therefore an extremely important area in a commercial development and will require lighting that is appropriate to these multi-functional provisions. It is essential that the designer is fully aware of all the functions that the atrium is to provide and their intended locations.

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12.22.2 Natural lighting

Natural lighting is one of the primary objectives in providing an atrium space within a building. The penetration and distribution of both daylight and sunlight at all times throughout the 'natural lighting' year should be analysed and understood. This exercise will help to determine the built form, fenestration, orientation, shading devices and fabric used in the atrium and should be undertaken jointly with the architect.

These natural lighting studies should include the way that daylight and sunlight penetrate into the abutting office spaces and workplaces around the atrium. Understanding this will allow the designer to maximise utilisation of daylight in these workspaces while providing screening to those spaces that will directly receive solar glare and gain. A knowledge of the amount and distribution of daylight from the atrium will also allow the designer to incorporate daylight linking to electric lighting where appropriate. These studies are particularly important in open-plan and deep-plan offices with fenestration both on an atrium-facing space and on an external facade.

Daylight factors within atria will depend on individual buildings, their location and the architectural intent. A daylight factor of 5% is suggested as the minimum required in atrium spaces where an impression of being reasonably well daylit is required. A norm of 10% is more usual. However, higher daylight factors are feasible but will require much greater care in terms of control and distribution.

See SLL Lighting Guide 10 for more information

See SLL Lighting Guide 10: *Daylighting – A guide for designers* for more information.

12.22.3 Planting

Where plant species are to be incorporated which have a height expectancy of over 6 m or which enjoy high illuminance levels in their natural habitat, increased daylight and sunlight penetration will be required into the atrium space. In these situations, as well as preparing natural lighting profiles at the various atrium levels and within the abutting office and workplace areas, it will also be necessary to prepare a natural and electric lighting profile at the canopy location for each plant or tree.

Profiling of natural lighting can be carried out using computer software at a relatively low cost if the plans and sections of the atrium are not too complex. Physical modelling under an artificial sky and sun are also appropriate and can be used for atria with complex shapes, provided that access to these facilities is available. Manual calculation techniques of daylight modelling are not generally appropriate, except for the simplest of atrium shapes.

Computer or physical modelling have several advantages over other techniques:

— the atrium and office interiors can be viewed from all angles at the design stage

— different fenestration and shading devices can be easily introduced into the model and the effects noted and measured

— architectural details and landscape features can be easily varied.

12.22.4 Electric lighting

Required lighting levels will vary markedly depending on the uses for which the atrium spaces are intended and their architectural design.

Those spaces used entirely for circulation and casual social meetings may have low illuminances associated with internal 'streets', i.e. 50–100 lux. Such lighting levels will create low-brightness spaces emphasising the abutting and overlooking office and workspace interiors. Enhanced lighting to building features, artwork

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and landscape in these low-brightness atria will create focal points for the users of these spaces and for the occupants of overlooking offices and workspaces.

For atria used more for reception, cafes and for informal meetings, the visual appearance of the space should be of mid-brightness with illuminance values in the 150–300 lux range. To illuminate large atrium spaces to these values will have higher energy demands and maintenance costs, particularly if high uniformity ratios are also intended. It is usually better to light just the areas that require the higher levels, i.e. where dining facilities 'break out' into the atrium or at reception and information desks, etc. Outside these localised increased illuminance areas, ambient illuminances of 50 lux may be acceptable.

General illuminance values of 300–500 lux may be required where offices and workspaces are to be carried into the atrium. In these circumstances, great care must be taken to eliminate glare from both the natural lighting of the atrium and from the electric lighting systems by the use of shading devices (static or dynamic) and luminaire design and location. Lighting to these areas could also be considered utilising ambient background levels with local lighting at the workspace.

12.22.5 Appearance of the atrium

The type, style and location of luminaires within an atrium space will depend greatly on the architecture, features and intended usage and the visual brightness patterns to be achieved in the varying operational and management modes. Liaison and coordination is therefore essential between all design disciplines to achieve these intended brightness patterns. Decisions will be needed on which surfaces are to be illuminated (e.g. horizontal, vertical or other inclined plane) and on the colour, reflectance, specularity or light-absorbing properties of these surfaces.

Manual lighting calculations will be of limited use in the prediction of brightness patterns in complex atrium spaces, and it is recommended that computer lighting program software is used that also has 'visualisation' capabilities. The lighting designer should consider the brightness patterns that will exist within the overlooking offices and workspaces, as these will form part of the overall patterns exhibited by the atrium.

Location and style of luminaires to achieve the intended brightness patterns and workspace illuminance will be dependent on the nature and design of the atrium. They may be floor-mounted 'post-top' types, wall sconces, ceiling- or soffit-mounted or local, affixed to workspace surfaces. Direct, indirect or combination techniques are all used in the lighting of atria. The criterion which will determine both the lighting technique and the type and location of luminaire will often be maintainability, i.e. safe access facilities to luminaries to ensure constancy of the lit effect.

Some atria have overhead travelling maintenance gantries. The locations of such gantries and the manner in which they traverse the space may provide guidance on where luminaires may be sited.

12.22.6 Emergency lighting

An atrium is an open space that may have escape routes crossing it, and normally needs to be lit for escape purposes across its whole length and width. This can be difficult to achieve in spaces with a complex structure or unusual layout. The lighting designer is advised to consult with Building Control and any other interested parties at an early stage to agree exit routes and lighting needs.

Emergency lighting should be considered as part of the overall lighting design and luminaire selection process. The location of the escape lighting must be considered in the light of any smoke studies to avoid their being located where smoke will collect.

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Illuminated exit signage must be considered as part of the total fire and escape strategy and the planning and location of such signage must take into account:

- legibility (signs must be large enough to be read at the likely viewing distances)
- location (signs must not be above natural sight lines or be hidden by columns, down-stand beams or smoke reservoir screens)
- architectural sensitivity.

See SLL Lighting Guide 12 for more information

See SLL Lighting Guide 12: *Emergency lighting* for more information.

12.23 Stairs/escalators

Recommended maintained illuminance (lux)	100 on all treads, lit from two directions to avoid shadowing
Limiting glare rating	25

Stairs should be lit so that there is some contrast between the horizontal treads and the vertical risers. Lights can be wall mounted as long as they are above head height. Lights at tread level, either in the wall above each step or along the nosing, can be used to increase visibility. Increased levels of lighting should be provided at the entrances and exits to escalators and moving walkways, although many have built-in lighting below the hand-rail.

See SLL Lighting Guide 12 for more information

Emergency lighting needs to be well thought out so that all stair treads are lit in the event of failure of the main lighting. Emergency lighting is also needed in any refuge areas where disabled staff or visitors wait for evacuation, as they often need to be transferred into special stair trolleys to allow them to be taken down the stairs. See SLL Lighting Guide 12: *Emergency lighting* for more information.

12.24 Lift lobbies

Recommended maintained illuminance (lux)	200
Limiting glare rating	22

Lift lobbies are unusual spaces in a building as they are one of the few spaces where people wait with nothing to do but look around them. For this reason, the lighting needs to create a pleasant ambiance to the space, as well as providing lighting to the lift controls and doorways.

12.25 Corridors

Recommended maintained illuminance (lux)	100 at floor level with good flow of light along corridor to light faces
Limiting glare rating	25

Corridors form the arteries of most buildings: they help staff to move speedily from space to space but are rarely places to linger. The lighting needs to reflect the quality and feel of the rest of the office building without incurring unnecessary energy usage or glare. Where there is a fixed rhythm of doors, then the lighting can be designed to match or complement that rhythm. The luminaires along the corridor do not need to be centrally located or to light it completely uniformly as long as the diversity between the minimum and maximum level on the floor is not more than 1:4.

Emergency lighting and clear exit signage are needed along all corridors, especially at junctions, to aid rapid movement towards escape stairs and exits. Exit signage must be provided in front of all fire doors if the exit route passes through them. Doors which are normally held open by magnetic holders will release on loss of power or in the event of a fire alarm, closing off any view to

See SLL Lighting Guide 12 for more information

exits lying further along the corridor. It is essential that emergency lighting is provided in each compartment that lies between such doors. See SLL Lighting Guide 12: *Emergency Lighting* for more information.

12.26 Back-of-house areas

These are the areas that make the building function but may be unseen or unused by the office workers themselves.

12.27 Security/building control rooms

Recommended maintained illuminance (lux)	200 general around CCTV monitors, 300 where there is limited use of written materials
Limiting glare rating	22

The lighting needs to be positioned to light the desks, the front of any control or alarm panels and any emergency equipment kept in the room. However, panels with display screens need careful lighting to avoid any disabling reflections on them.

Where the room has a viewing window out into another space, so that the space or the people passing through it are monitored, then the lighting level within the control room should be lower than that in the space beyond the window. This will improve visibility of the space by reducing reflections back from the window. It will also reduce visibility into the control room from the space.

See SLL Lighting Guide 12 for more information

A high level of emergency lighting and, where available, standby lighting, is required to allow easy command and control of the building during any emergencies involving mains power failure to the building. See SLL Lighting Guide 12: *Emergency lighting* for more information.

12.28 Cleaners' cupboards

Recommended maintained illuminance (lux)	200
Limiting glare rating	25

These, generally small, spaces can have tricky tasks carried out in them, such as mixing cleaning solutions and pouring them into containers or cleaning machines. There is normally a sink where the rinsing out and minor maintenance of the various types of cleaning utensils and machines is carried out. Lighting should illuminate the walls where shelving may be placed, and any sink.

While there is a temptation to put just a single light in the centre of the room, in small spaces it is often better to move a single light away from the door, where few tasks are carried out. In longer rooms, two lights may provide better uniformity and avoid people working in their own shadow at sinks or benches. The lights should be switched at the door or absence detection provided.

12.29 Plant rooms

Recommended maintained illuminance (lux)	200 general for most open plant spaces; 200 vertically on front of control panels, valve sets and instruments, etc.
Limiting glare rating	25

These spaces can vary enormously in size and complexity; from simple air-handling plant spaces with a few access hatches in the sides of large pieces of air-handling equipment, to complex boiler rooms full of pumps, control panels and valves at various heights. Many plant rooms contain trip or impact hazards and need access for maintenance or supervision of plant at different heights and locations around the room.

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A larger number of lower output luminaires is usually better than trying to light the space 'economically' with a few high-output luminaires. It is often better to wall-mount lighting where there is a lot of trunking, pipework or ducting criss-crossing the ceiling. Lighting is often required to the backs of certain large items of plant.

It is essential to ascertain from the building services engineers the types and location of plant in each space designated as a 'plant room'. There is rarely any point in designing lighting for an empty plant room on an architect's layout. Many lighting positions will be obscured or even inaccessible once the plant is installed. Sometimes, if no details are known, it is better to provide a notional layout of lights on a plan for tendering purposes with the note that the final positions will be determined on site once the plant layouts have been confirmed.

In very large and complex spaces, the location of light switches needs careful thought. When the switches are located near to the access door, there may be a danger of personnel working in remote parts of the space being left in darkness when someone leaves without realising they are there. As locating switches throughout the space may result in them being overlooked or not used, it may be preferable to install emergency safety lighting which will always be on in the space. Alternately, a few safety lights could be distributed throughout the space, controlled by a key switch.

Emergency lighting is required to allow safe egress from all complex plant spaces. Particular attention should be paid to obstructions, areas with low headroom and any access ladders.

12.30 Modelling workshops

Recommended maintained illuminance (lux)	300 general for most open areas, 300 vertically on machines such as 3D printers and modelling equipment, etc., 500 on workbenches where component assembly or repair is carried out
Limiting glare rating	22/19

See *SLL Code for Lighting* for more information

See *SLL Code for Lighting* schedule sections 'Electrical industry' and 'Metal working' for more details on specialist tasks.

See SLL Lighting Guide 1 for more information

These spaces can vary enormously in size and usage: from simple spaces for minor cleaning and maintenance at the end of a plant room to fully equipped facilities where process plant or machines can be serviced, repaired or even constructed from scratch. The lighting needs to provide a good quality of light over each workbench and at each machine position. Task lighting is likely to be needed along each workbench and for each machine. Note that such lighting may be an integral part of some larger machines. See also SLL Lighting Guide 1: *The industrial environment* for advice for larger workshops.

High-frequency lighting is recommended in all areas where people work with machines with rotating parts. This is to avoid possible stroboscopic effects where the rotating parts spin at a frequency that is a multiple of the 50 Hz mains frequency, as this can make them appear stationary. High-pressure discharge lighting should therefore be avoided.

Where paint spraying is carried out, flammable liquids are used or potentially explosive dusts can collect, remote lighting or special flameproof luminaires may be needed to avoid the risk of explosion. The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2001 should be consulted.

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See SLL Lighting Guide 12 for more information

A high level of emergency lighting will be needed where moving plant is in use. In the event of power failure, the operators need to be able to move safely away from the machines and possibly to disengage or remove materials from them to render them safe. See SLL Lighting Guide 12: *Emergency lighting*.

12.31 Lift motor rooms

Recommended maintained illuminance (lux)	200 general, 200 vertically on sides of winding machines and front of control panels, etc.
Limiting glare rating	25

The lighting needs to be positioned to light the control panels and all sides of the motors, winches, winding sheaves and emergency winding equipment.

Emergency lighting is required to allow easy and safe access for manual winding to bring lift cars to a floor level in the event of mains power failure to the building.

12.32 Storerooms

Recommended maintained illuminance (lux)	100 for simple bulk storage, 300 for storage and selection of small items, 200 vertically for fronts of shelving
Limiting glare rating	25

These spaces can vary enormously in size and sophistication, from simple rooms in which to keep empty packing cases to rooms full of shelving with carefully labelled bins and spaces for components or materials. It is essential to ascertain from the client the type and complexity of the articles being stored in each space designated as a 'storeroom' and to obtain details of the heights and locations of any shelving or wall storage units.

Where the room is to have shelving or wall storage units, the room effectively shrinks in lighting terms. If a 3 × 4 m room is to have 0.5 m shelving around the walls then, in lighting terms, the room becomes a 2 × 3 m space as the light needs to be within the central volume in order to illuminate the fronts of the shelving. There is rarely any point in having lights positioned above the storage system.

Where mobile storage shelves are in use, the lighting needs to be arranged so that whichever aisle is open, the shelves on both sides are well lit right down to the bottom. In large areas, a control system is recommended so that the lighting is only on above the open aisles and in the access space in front of the mobile racking.

12.33 Standby generator/ UPS rooms

Recommended maintained illuminance (lux)	200 general, 200 vertically on sides of equipment and front of control panels, etc.
Limiting glare rating	25

The lighting needs to be positioned to light the control panels and all sides of the generator, batteries, air starters and similar support equipment.

Self-contained battery-powered emergency lighting to a good level is required to allow easy and safe access for manual starting or rapid maintenance in case of power failure and failure of the generator to start automatically.

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13 Practical examples of design approach

13.1 Introduction

This section of the guide is intended to help the reader in determining the type of lighting design most appropriate to a given situation.

The examples discussed should not be taken as exemplar designs and are not intended for use as reference points for any particular type of office.

The intention is to give an indication of how lighting could be provided in a number of scenarios, bearing in mind the fact that each office will have to be considered against specific client requirements. The advantages and disadvantages of different office plans and decor are discussed.

13.2 Example 1 – large open-plan office with known furniture layout

This example considers an open-plan office with full-height windows on the north and south sides (Figure 13.1). The desk layout is regular and surfaces are known to be:

- east and west walls – a pale matt-finish cream colour
- ceiling – white matt-finish ceiling tiles
- floor – light grey carpet
- blinds – a pale matt finish to match the walls
- desks – a beech-effect wood finish.

The ceiling height is typical of modern offices at around 2.8 m.

The room dimensions are approximately 16 × 22 m.

The occupants work at their desks for 8 hours a day, taking the usual breaks. They work entirely on desktop computers and telephones.

Some informal seating is provided along the centre of the room.

There are two approaches that could be applied to this office. The first is to consider a lighting design that provides a general illumination across the space, suitable for carrying out the expected tasks. As the office has a deep-plan configuration, the lighting level in the centre will need to be higher than by

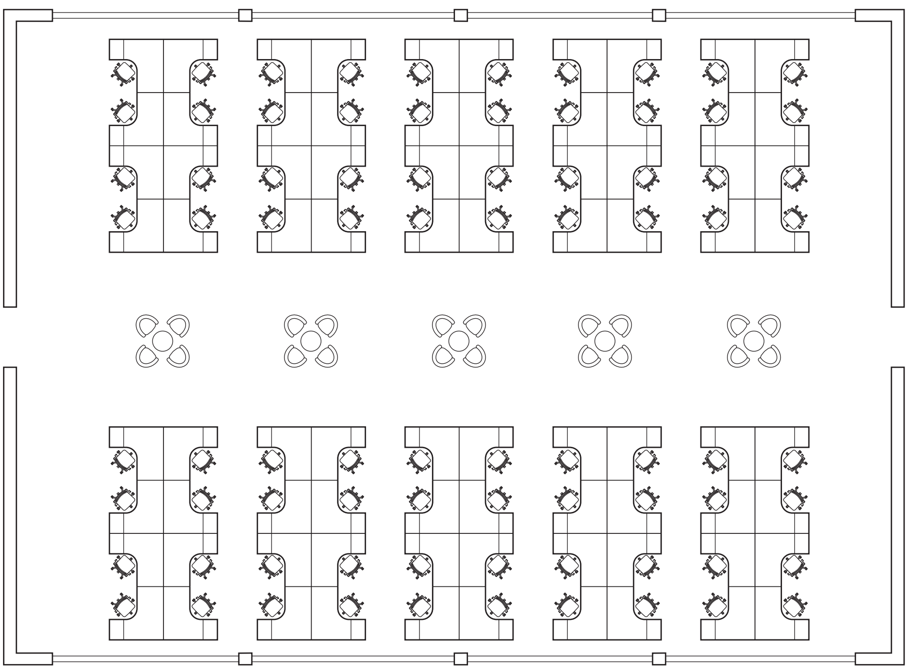

Figure 13.1 Open-plan office with windows on both north and south facades

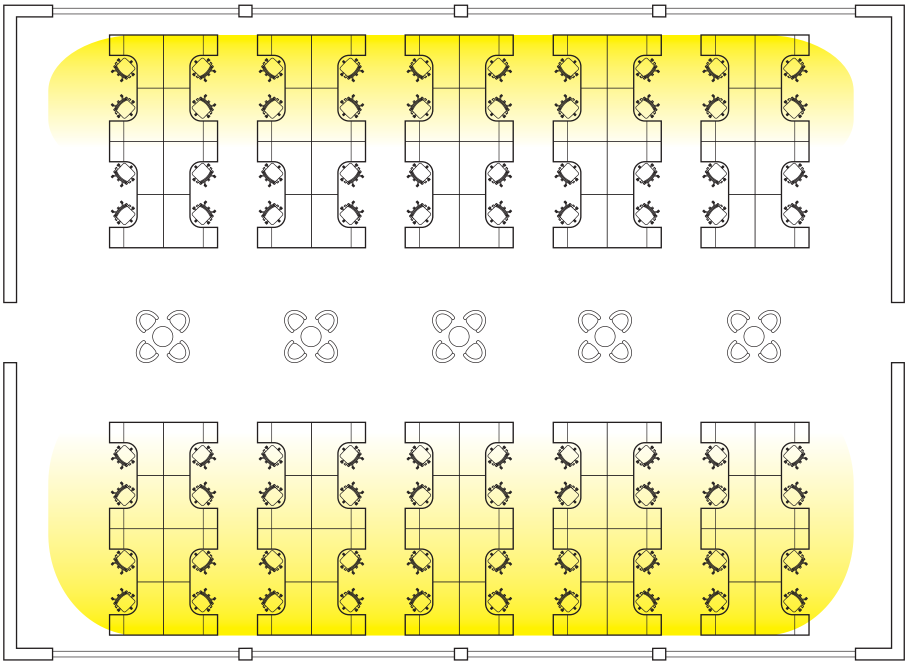

Figure 13.2 Effect of daylight on desks adjacent to windows. The south facade will be subject to a higher level, although any solar shading will have to be taken into account

the windows. In addition, and because of the fully glazed south-facing wall, the lighting will need to be carefully controlled so as to provide a reasonably uniform level across the space in response to changing levels of natural light and to make the best use of that natural light during the daytime.

Figure 13.2 shows the typical effect of daylight on the office. The desks adjacent to the south-facing window (bottom of the diagram) will gain the most benefit. The yellow-shaded areas are likely to benefit from reduced levels of artificial illumination during the day. Appropriate lighting controls will allow the luminaires adjacent to the windows to be dimmed, depending on the amount of daylighting available.

While the south facade is likely to benefit more from daylight contribution, it may need some form of permanent shading, given the extent of glazing and the glare and contrast issues this could present.

This office layout is common in the UK, particularly if the occupiers wish to maintain some flexibility over how their office is laid out. It can, however, result in the over-lighting of areas in which no tasks are being carried out.

The second approach is to consider the task areas and provide a suitable level of illumination for the specific task being carried out. The adjacent areas and circulation spaces can then be considered separately.

Figure 13.3 shows the task areas highlighted. It can be seen that the actual task area only represents around 25% of the space. Illuminating this area to the agreed level for a given task will allow a level one step lower to be provided to areas adjacent and a further step reduction for circulation areas. The central circulation area is effectively deep plan and therefore it may be worth illuminating this area to task levels during the day and allowing a control system to reduce them to the circulation level during the hours of darkness.

If the furniture layout of the office was unknown at the point when the lighting design had to be carried out, some reasonable assumptions could be made during discussions with the building owner. The north and south windows should allow a degree of daylight control to be incorporated, even if the intention was to provide some cellular offices along either facade in the future. The open-plan space is

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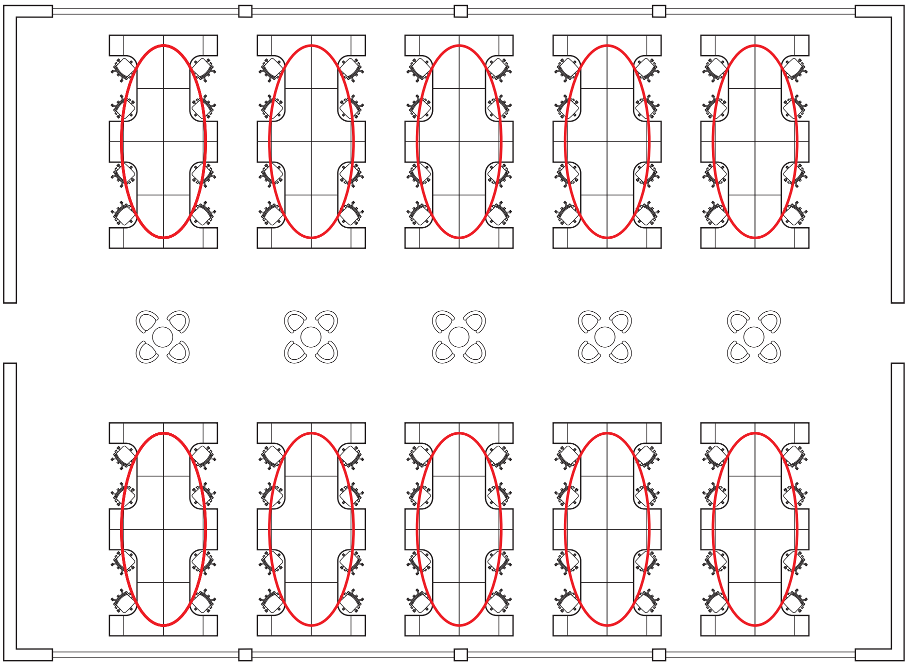

Figure 13.3 Task areas highlighted to show how little of the space requires to be illuminated to the higher level

deep plan regardless of the furniture layout and therefore the facility to provide higher levels of illumination during the daytime should still be considered.

Where a Cat A speculative office design is required with a design that includes data cabling to floor boxes, it would be worth raising with the building owner the option of installing additional data cables to each floor box to support the use of LED task lighting driven by a 'Power over Ethernet' system. Any future tenant would then have the option to install a localised lighting design – something that has previously been difficult to include in the design in speculative developments.

Both the general and localised approaches to illumination have to address the need to provide illumination of walls and ceilings. This can be done either by directly lighting the surfaces or by using spill light from the luminaires used to illuminate task and circulation areas.

As this example has a ceiling height of 2.8 m, the use of suspended luminaires with an uplight component could be considered as they would contribute to the illumination of walls and ceilings as well as helping to achieve an acceptable uniformity.

The need to provide adequate vertical illumination not only to the walls but also to the faces of people occupying the office has to be addressed. Cylindrical illuminance for this type of office should be between 30% and 60% of the lighting on the task area, depending on the specific needs of the office. There is no requirement to provide this level of cylindrical illuminance to the whole office space, however.

Clearly, the general lighting approach is easier to design and does not rely on prior knowledge about desk positions. It does, however, use energy to illuminate the areas adjacent to desks and to circulation areas, which is effectively wasted. The localised approach minimises the use of energy, which will help in meeting increasingly challenging energy targets, although it will require careful thought in order to provide a suitable level of cylindrical, wall and ceiling illuminance.

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13.3 Example 2 – open-plan space split into cellular offices with solid walls

This example considers the same space as discussed in example 1; however, in this instance, the space has been split into four equal-sized offices and a central corridor has been created (Figure 13.4). The split has had the immediate effect of reducing desk numbers from 60 to 48.

The introduction of the internal walls has taken away usable space and has provided a surface for either reflected or absorbed light.

In this example, the internal wall surface area is over 2.5 times that of example 1. As walls can act as reflectors or absorbers of light, the colour of the walls has become much more important to the illumination level calculation. Even the most reflective surface will absorb some light, so it is reasonable to conclude that the arrangement in example 2 will use more energy than example 1 to deliver the same level of illumination.

Because the space is split into cellular offices, the requirement for increased illumination levels in the central part of the space may no longer be an issue. The central corridor will have a lower level of illumination, as it does not include any tasks areas.

It will be much easier to turn off lighting that is not being used in this example since the four offices are completely independent.

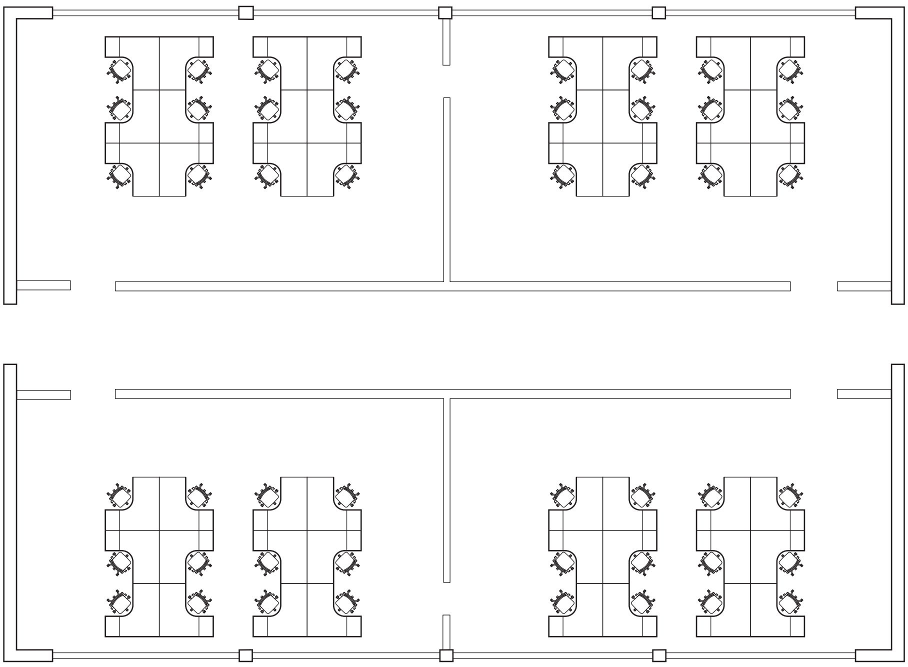

Figure 13.4 The open-plan space of example 1 split into four offices with solidly constructed walls

13.4 Example 3 – open-plan space split into cellular offices with glazed partitions

This example looks at the arrangement in example 2 but this time the walls are formed using glazed partitions (Figure 13.5). It would be easy to assume that the same lighting as used in example 1 is required, particularly if a general approach is taken, given that the walls will allow light to pass through them.

A number of issues need to be taken into account, however.

— The glazing, while allowing light to pass through, could also become a source of glare to occupants. Glazed walls adjacent to each other could result in multiple reflections and make the task of limiting glare on a display screen difficult to address.

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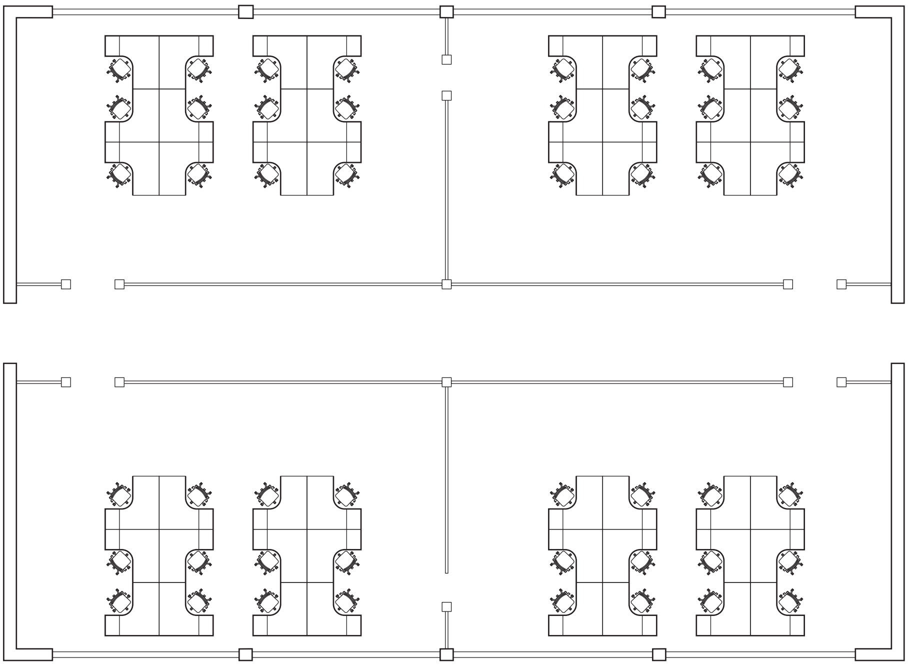

Figure 13.5 The open-plan space of example 1 split into four offices with glazed walls

- Corridor lighting will need to be considered in terms of glare, as the luminaires will be visible from the offices.
- Lighting in adjacent offices could be a source of glare and add to the issue of unwanted reflections. During hours of darkness, the interaction between offices could be more pronounced, as one unoccupied office will change the effective colour of the adjoining wall to be much darker. This may result in the need for increased illumination.
- When all offices are occupied, the uniformity across the task areas is likely to be improved but if any one office were in darkness, the other three would be affected.

Where glazing is proposed for internal partitions, it may not be possible to deal with the associated issues mentioned above. As with all design aspects of a building, the architect and interior designer may have to accept that some lighting solutions are related to the fabric of the building. In this case, it may be more beneficial to suggest that the use of glazing is limited or perhaps covered with a frosted or semi-opaque covering to reduce problems of glare.

13.5 Example 4 – conversion of a factory storeroom to an office

In this example, the room being considered was once a storeroom in a factory complex (Figure 13.6). The window wall faces east and has an unobstructed view of the sky. Apart from the door location, there are no other obstructions to the placement of the desk, and surfaces are known to be:

- walls – a pale matt-finish cream colour
- ceiling – white matt-finish ceiling tiles
- floor – dark grey vinyl covering
- blinds – a pale matt finish to match the walls
- desk – a dark oak finish.

The ceiling height is 2.3 m.

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The office occupier has chosen the desk location based on the desire to be near the window.

The lighting designer has to deal with a few major concerns. First, the window is particularly large for the space and, while it will allow the room to be illuminated without the use of electric lighting for much of the day, there is the added issue of glare.

The second concern is the desk position. While the occupier has chosen it in the belief that it is better to be close to the window, they have not considered the issue of glare and lighting placement. Any general electric lighting would probably be behind the desk, causing the occupier to cast a shadow on their own task area. Localised lighting would be required, even if the general lighting level was sufficient to illuminate the task area appropriately.

Daylight is not being utilised well in this example. Morning sunlight, particularly in winter, will result in the window having to be obscured by a blind or similar shading mechanism to avoid the issue of glare.

The dark surfaces of the floor and desk will absorb more light than brighter alternatives and may result in an increase in the amount of illumination that has to be provided electrically.

Lighting design is not simply about dealing with a predetermined situation. In this instance, a better solution can be achieved by repositioning the desk. Perhaps even a different style of desk would be appropriate, given the tight space. In situations such as that highlighted here, lighting designers should be prepared to challenge preconceptions regarding room layout and decor if by doing so the building owner or occupier can be offered a better solution. It would be worth suggesting to the building owner that replacing the floor covering could result in energy savings as it would help to make the lighting design more efficient. The desk in this scenario is not likely to have such an effect, as it would probably be covered, at least partially, in paperwork.

By repositioning the desk as shown in Figure 13.7, the occupier of the office is no longer subject to the glare from the window. The desk is lit from the side and the use of daylight is maximised. There would still be the issue of the seated person casting a shadow on their task area from any general lighting positioned behind them. There is also the problem of there being no distance view in front of them.

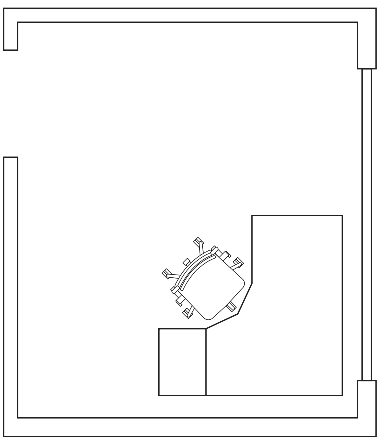

Figure 13.6 A small storeroom with a window along one wall and a door on the opposite wall could be converted into an office for one person

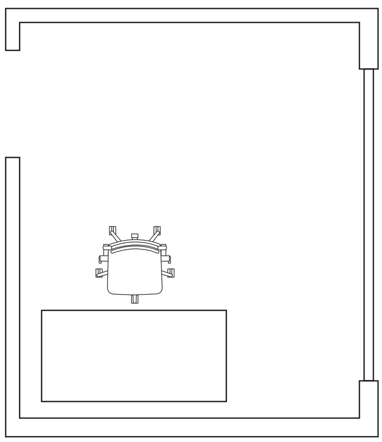

Figure 13.7 Desk repositioned to avoid direct glare

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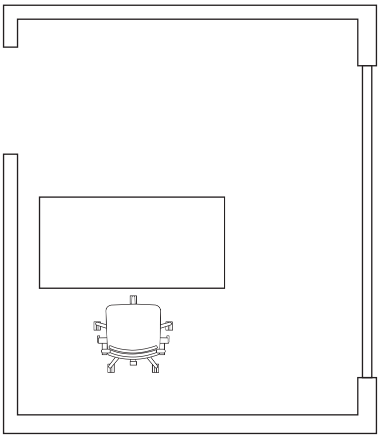


Figure 13.8 Desk repositioned to make better use of electric lighting

It is likely that a two-luminaire solution would be chosen for such a space. By increasing this to four luminaires of a lower output, the uniformity would be improved and a luminaire could be placed above the desk, reducing the shadowing effect of the occupant on the task area of the desk.

However, if the desk is rotated 180°, the optimum use of daylight is maintained and, with the desk positioned more centrally within the room, the electric lighting can be more effectively utilised without the expense of having to install a greater number of luminaires or provide lighting local to the task area (Figure 13.8).

Figure 13.9 shows the position of the task area in each of the three scenarios. By centralising the task area in the third scenario, the electric lighting design can more easily provide task lighting and background lighting for the minimum amount of energy.

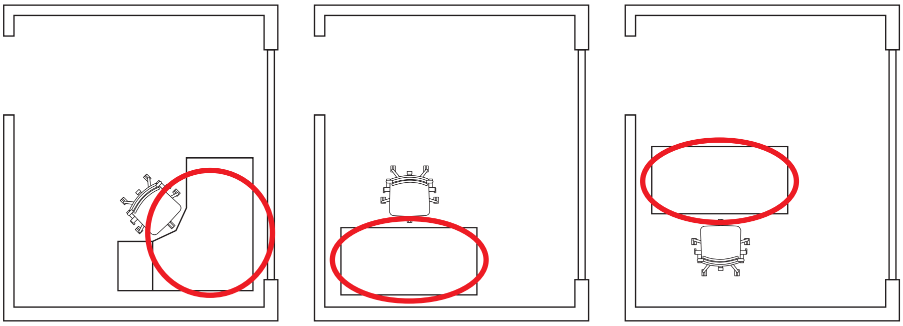


Figure 13.9 Diagram highlighting the task areas of the three possible room layouts discussed in this example

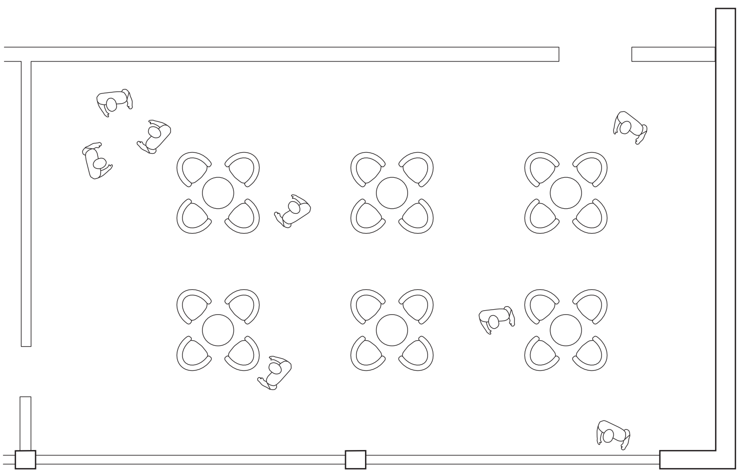
13.6 Example 5 – change of use from general office to informal breakout space

This example takes the cellular office approach of example 2 and replaces the formal desk layout with low-level tables and easy chairs (Figure 13.10). The space is intended to be used by people working on tablets and touchscreen laptops during a mix of informal meetings and coffee breaks.

The layout of such a space could vary significantly over time. Even during the course of a working day the occupants may move furniture to permit a more comfortable style of working. It is therefore impractical to define task areas within the space as the users may choose to sit, stand or even walk in any part of the room.

As the original use of the space was as a general office, the electric lighting would have been designed to illuminate specific task areas, most likely from above using direct lighting.

Figure 13.10 Former office area used as breakout space



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The versatile nature of tablets means that the screen could be in any orientation or position within the room and subject to reflections from both daylight and electric lighting, sometimes simultaneously. In such a situation, it is not possible to provide a lighting design which will control glare from all illumination sources. Occupiers of the room will inevitably find themselves in a position where they experience reflections on their screens and the simplest solution will be to move position. That said, the lighting design for this space should still seek to minimise the risk of unwanted reflections from both daylight and electric lighting.

The windows would need to have blinds installed; however, the occupants could choose to have them closed or open. Breakout space will benefit from external views, so the option should be provided. If occupants choose to open the blinds, they will need to position their tablets or touchscreens accordingly.

As the space is not used significantly for paper-based tasks, and tablets and touchscreen computers have self-illuminated task areas, the level of illumination required can be lower than that expected in a conventional office space. Good uniformity and low contrast are particularly important, especially where occupants of the room may use some form of personal video conferencing from the tablet. An uplit lighting design is therefore the most appropriate, as this will remove any direct glare source from above. This could be provided by freestanding uplighters, which would add visual interest and differentiate the space from the adjacent offices.

13.7 Example 6 – meeting rooms

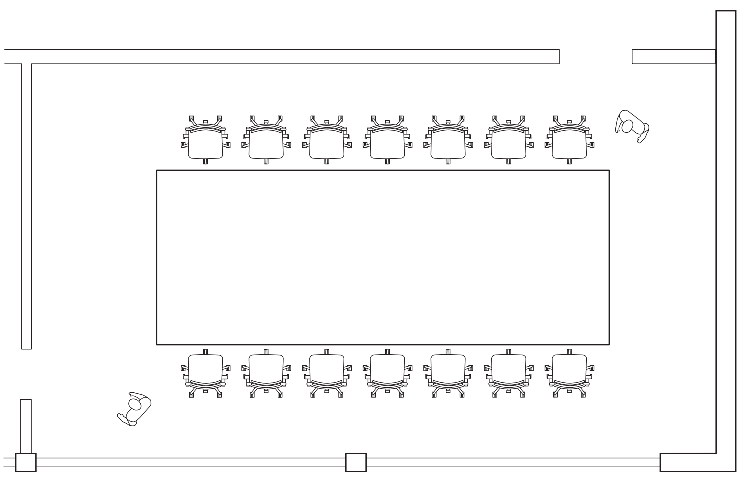
This example takes the cellular office approach discussed in example 2 but this time considers the space in use as a meeting room (Figure 13.11). Meeting rooms can vary considerably, from small spaces such as interview rooms, to large function rooms for team meetings and executive meeting rooms.

Meeting rooms, regardless of size, will need to consider the fact that interaction between people is the key driver for the lighting design. This can sometimes be coupled with the need to provide adequate task area lighting as well and, depending on the room's use and status, some decorative lighting.

Controls can be used to create different 'scenes' for a meeting space, and this is particularly useful in multifunctional rooms.

The example considered here is a relatively large meeting space for up to 14 people and, as part of an office complex, is most likely to be used for general team meetings and presentations. There will probably be a projector and screen or flat-screen display mounted on one wall. Video conferencing facilities may also be present.

Figure 13.11 Space in use as a meeting room



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It is tempting to treat a meeting room such as this as another office space and provide lighting for the task areas only; however, good illumination of faces is essential in meeting rooms. The cylindrical illuminance is therefore an important factor when considering the design of the lighting.

As a projector or flat-screen display is expected to be required, reflections must be avoided from any of the 14 viewing positions and, possibly, from a temporary lectern position. General dimming may be required if a projector is used, whereas it may not be needed if a flat-screen display is used due to the higher brightness of self-illuminating displays.

Direct lighting alone is therefore the least suitable solution as it is likely to give a less than adequate uniformity of illumination across the space and reflections on the display screen will be difficult to control without further compromising the uniformity or efficiency of the design.

An uplit lighting design or a suspended uplit/downlit design would allow an acceptable uniformity and cylindrical illuminance to be achieved much more easily. A suspended uplit/downlit design may be more energy efficient than a fully uplit design but, again, care would have to be taken over the issue of controlling reflections, particularly if a high mounting position is envisaged.

Decorative lighting in this type of meeting room is not likely to be required, given its functionality.

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Glossary

Average illuminance	Illuminance averaged over the specified area. *Note*: In practice this may be derived either from the total luminous flux failing on the surface divided by the total area of the surface, or alternatively from an average of the illuminances at a representative number of points on the surface. *Unit*: lux (lx)
Average luminance (L_{av})	Luminance averaged over the specified area or solid angle. *Unit*: candela per square metre (cd/m^2)
Ballast	A device connected between the supply and one or more discharge lamps which serves mainly to limit the current of the lamp(s) to the required value. *Note*: A ballast may also include means of transforming the supply voltage, correcting the power factor and, either alone or in combination with a starting device, provide the necessary conditions for starting the lamp(s).
Brightness contrast	Subjective assessment of the difference in brightness between two or more surfaces seen simultaneously or successively.
Brightness	Attribute of the visual sensation associated with the amount of light emitted from a given area. It is the subjective correlate of luminance. Technically defined: brightness, luminosity (obsolete): Attribute of a visual sensation according to which an area appears to emit more or less light.
Colour contrast	Subjective assessment of the difference in colour between two or more surfaces seen simultaneously or successively.
Colour rendering (of a light source)	Effect of a light source on the colour appearance of objects compared with their colour appearance under a reference light source. The definition is more formally expressed as: Effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant.
Colour rendering index (of a light source) (R_a)	Value intended to specify the degree to which objects illuminated by a light source have an expected colour relative to their colour under a reference light source. *Note*: R_a is derived from the colour rendering indices for a specified set of eight test colour samples. R_a has a maximum of 100, which generally occurs when the spectral distributions of the light source and the reference light source are substantially identical.
Colour temperature (T_C)	The temperature of a Planckian (black body) radiator whose radiation has the same chromaticity as that of a given stimulus. Used to describe how ‘warm’ or ‘cool’ the light from a lamp appears. *Unit*: kelvin (K) *Note*: The reciprocal colour temperature is also used, unit K^{-1}.

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Contrast	In the perceptual sense: Assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence: brightness contrast, lightness contrast, colour contrast, simultaneous contrast, successive contrast, etc.) In the physical sense: Quantity intended to correlate with the perceived brightness contrast, usually defined by one of a number of formulae which involve the luminances of the stimuli considered, for example: $\Delta L/L$ near the luminance threshold, or L_1/L_2 for much higher luminances.
Cylindrical illuminance	The illumination on a vertical object (or person) averaged to take account of light falling on the surface of an imaginary cylinder surrounding that object or person.
Daylight	Visible part of global solar radiation.
Daylight factor (D)	Ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded. *Note 1*: Glazing, dirt effects etc. are included. *Note 2*: When calculating the lighting of interiors, the contribution of direct sunlight must be considered separately.
Diffuse sky radiation	That part of solar radiation which reaches the Earth as a result of being scattered by the air molecules, aerosol particles, cloud particles or other particles.
Direct lighting	Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 90% to 100%
Direct solar radiation	That part of the extraterrestrial solar radiation which as a collimated beam reaches the Earth's surface after selective attenuation by the atmosphere.
Directional lighting	Lighting in which the light on the working plane or on an object is incident predominantly from a particular direction.
Disability glare	Glare that impairs the vision of objects without necessarily causing discomfort. *Note*: Disability glare may be produced directly or by reflection.
Discomfort glare	Glare that causes discomfort without necessarily impairing the vision of objects. *Note*: Discomfort glare may be produced directly or by reflection.
Emergency lighting	Lighting provided for use when the supply to the normal lighting fails.
Escape lighting	That part of the emergency lighting which is provided to ensure that the escape route is illuminated at all material times.
Floodlighting	Lighting of a scene or object, usually by projectors, in order to increase considerably its illuminance relative to its surroundings.
General lighting	Substantially uniform lighting of an area without provision for special local requirements.

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Glare	Condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or to extreme contrasts. See also: *Disability glare* and *Discomfort glare*
Global solar radiation	Combined direct solar radiation and diffuse sky radiation.
Illuminance (at a point of a surface) (E)	Quotient of the luminous flux $d\Phi$ incident on an element of the surface containing the point, by the area dA of that element. *Unit*: lux (lx) = lumens per square metre *Note 1*: Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L \cdot \cos\theta \cdot d\Omega$, where L is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point. $$E = \frac{d\Omega}{dA} = \int_{2\pi sr} L \cos\theta \, d\Omega$$ where E is the illuminace at a point on a surface, L is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, θ is the angle between an incident beam and the normal to the surface at the given point, and $d\Omega$ is the solid angle. *Note 2*: The orientation of the surface may be defined, e.g. horizontal, vertical hence horizontal illuminance, vertical illuminance.
Indirect lighting	Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 0% to 10%.
Lamp	Source made in order to produce an optical radiation, usually visible. *Note*: This term is also sometimes used for certain types of luminaires.
Light output ratio (of a luminaire)	Ratio of the total flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions.
Limiting glare rating	The upper limit of glare for a particular task as derived from the unified glare rating (UGR).
Localised lighting	Lighting designed to illuminate an area with a higher illuminance at certain specified positions, for instance those at which work is carried out.
Local lighting	Lighting for a specific visual task, additional to and controlled separately from the general lighting.
Luminaire	Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.
Luminance (L)	Luminous flux per unit solid angle transmitted by an elementary beam passing through the given point and propagating in the given direction, divided by the

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	area of a section of that beam normal to the direction of the beam and containing the given. It can also be defined as: The luminous intensity of the light emitted or reflected in a given direction from an element of the surface, divided by the area of the element projected in the same direction. It is the physical measurement of the stimulus which produces the sensation of brightness. *Unit*: candela per square metre (cd/m^2)
Luminous efficacy of a source (*h*)	Quotient of the luminous flux emitted by the power consumed by the source. *Unit*: lumens per watt (lm/W) *Note 1*: It must be specified whether or not the power dissipated by auxiliary equipment such as ballasts etc., if any, is included in the power consumed by the source. *Note 2*: If not otherwise specified, the measurement conditions should be the reference conditions specified in relevant IEC standard; see *Rated luminous flux*.
Luminous environment	Lighting considered in relation to its physiological and psychological effects.
Luminous flux	Quantity derived from radiant flux (radiant power) by evaluating the radiation according to the spectral sensitivity of the human eye (as defined by the CIE standard photometric observer). It is the light power emitted by a source or received by a surface. *Unit*: lumen (lm)
Luminous intensity (of a point source in a given direction) (*I*)	Luminous flux per unit solid angle in the direction in question, i.e. the luminous flux on a small surface, divided by the solid angle that the surface subtends at the source. *Unit*: candela = lumen per steradian (lm/sr)
Maintained illuminance	Value below which the average illuminance on the specified area should not fall. It is the average illuminance at the time maintenance should be carried out. *Unit*: lux (lx)
Maintenance cycle	Repetition of lamp replacement, lamp/luminaire cleaning and room surface cleaning intervals.
Maximum luminance (L_{max})	Highest luminance of any relevant point on the specified surface. *Note*: The relevant points at which the luminances are determined shall be specified in the appropriate application standard. *Unit*: candela per square metre (cd/m^2).
Modelling ratio (cylindrical illuminance)	The relationship between the illumination of the horizontal plane (task area) with the illumination of the vertical plane (face of person either standing or sitting).

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Power over Ethernet (PoE) — A method of delivering power to devices along cabling which also carries data via Ethernet.

Rated luminous flux (of a type of lamp) — The value of the initial luminous flux of a given type of lamp declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions.

Unit: lumens

Note 1: For most lamps, in reference conditions the lamp is usually operating at an ambient temperature of 25 °C in air, freely suspended in a defined burning position and with a reference ballast, but see the relevant IEC standard for the particular lamp.

Note 2: The initial luminous flux is the luminous flux of a lamp after a short ageing period as specified in the relevant lamp standard.

Note 3: The rated luminous flux is sometimes marked on the lamp.

Reflectance (r) — Ratio of luminous flux reflected from a surface to the luminous flux incident on it.

Note: The reflectance generally depends on the spectral distribution and polarisation of the incident light, the surface finish and the geometry of the incident and reflected light relative to the surface.

Room index — An index related to the dimensions of a room and used when calculating the utilisation factor and other characteristics of the lighting installations:

$$\text{Room index} = \frac{L \times W}{h_m(L + W)}$$

where L is the length of the room, W the width and h_m the height of the luminaires above the working plane.

Safety lighting — That part of emergency escape lighting that provides illumination for the safety of people involved in a potentially dangerous process or situation and to enable proper shut down procedures for the safety of the operator and other occupants of the premises (known as 'high risk task area lighting' in BS 5266-1: 2011).

Solar radiation — Electromagnetic radiation from the Sun.

Spacing (in an installation) — Distance between the light centres of adjacent luminaires of the installation.

(Spatial) distribution of luminous intensity (of a lamp or luminaire) — Display, by means of curves or tables, of the value of the luminous intensity of the source as a function of direction in space.

Standby lighting — That part of the emergency lighting which may be provided to enable normal activities to continue.

Stroboscopic effect — Apparent change of motion and/or appearance of a moving object when the object is illuminated by a light of varying intensity.

Note: To obtain apparent immobilisation or constant change of movement, it is necessary that both the object movement and the light intensity variation are periodic, and some specific relation between the object movement and light variation frequencies exists. The effect is only observable if the amplitude of the light variation is above certain limits. The motion of the object may be rotational or translational.

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Sunlight	Visible part of direct solar radiation. *Note*: When dealing with actinic effects of optical radiations, this term is commonly used for radiations extending beyond the visible region of the spectrum.
Task area	The horizontal or vertical area in which a task is undertaken. In general offices this can be taken to be at a horizontal height of 0.8 m above the floor level.
Task lighting	Lighting provided for the specific purpose of highlighting or increasing the amount of illumination on a particular task or task area.
Transmittance (t)	Ratio of the luminous flux transmitted through a body to the luminous flux incident on it. *Note*: The transmittance generally depends on the direction, polarisation and spectral distribution of the incident light and on the surface finish.
Uniformity (luminance, illuminance) (U_o)	Ratio of minimum illuminance (luminance) to average illuminance (luminance) on (of) a surface.
Unified glare rating (UGR)	A method of determining the discomfort glare from a luminaire within a lighting installation.
Utilisation factor	Ratio of the luminous flux received by the reference surface to the sum of the rated lamp luminous fluxes of the lamps in the installation.
Veiling reflections	Specular reflections that appear on the object viewed and partially or wholly obscure details by reducing contrast.
Visual comfort	Subjective condition of visual well-being induced by the visual environment.
Visual field	Area or extent of physical space visible to an eye at a given position and direction of view. *Note*: The visual field may be either monocular or binocular.

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