SECOND EDITION

Robert Bean

LIGHTING
INTERIOR AND EXTERIOR

ROUTLEDGE

Lighting: Interior and Exterior

This comprehensive and practical guide takes you step-by-step through the core concepts and applications of architectural lighting. Now completely revised and updated for the second edition, this book:

- Includes new information on the latest regulations and recommendations
- Extends the section on exterior lighting to deal with the subject of light pollution and stray light
- Revises the road lighting section to address the classification of roads
- Pays special attention to the rapid development of LED lighting
- Considers the new CIE colour metric system presently being developed
- Concludes most chapters with questions for the reader, together with answers
- Is published in full colour throughout, for the first time, to support the text and aid the reader

Covering a wide range of building types and external environments, this book shows how the concepts used in lighting design arise from the needs of the designer and user. These concepts are given a practical context to enable you to develop and improve your design skills, building up from the basics of how much light is needed and the role of shadows, to energy management and the calculations for daylighting. The author provides accessible, user-friendly explanations of technical information and specialist techniques intended for people who need to get to the heart of the subject as quickly as possible.

An indispensable learning tool for students, and for professionals developing their skills, this handbook provides examples and exercises to help you acquire the understanding, knowledge and skills required for examinations and professional training purposes.

Robert Bean lectures on lighting for Continuing Professional Development courses across the UK and also acts as a lighting consultant. He has previously worked as a Senior Lighting Engineer and an Academic Vice-Dean, while his wide and varied consultancy work has included the design of large-scale industrial photometers, a study of hospital lighting and a major office lighting quality study. He was also involved in the UK government's Millennium Commission project for the floodlighting of churches.

Lighting: Interior and Exterior

Second edition

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Contents

Preface to second edition

Since the first edition, there have been a number of developments which require inclusion in this book to maintain its relevance, giving the reader an up-to-date text but with the same aims as those of the first edition.

Perhaps the most significant of these developments has been the very rapid advance of the LED lamp and particularly its entry into the interior lighting sphere. The rapid increase of light output and colours available and the development of LED luminaires have made these lamps a genuine and effective alternative to other lamps in many areas.

Other developments in both interior and exterior lighting have been produced in response to the global energy crisis. The focus on task lighting of offices and work spaces rather than on unrestricted general lighting has made the lighting design of these spaces more challenging, with the aim being not to overlight these areas.

The introduction of LED street lighting has been an important development in energy efficiency, and the adoption of the European system of classifying road lighting has meant a revision of the road lighting chapters.

The above developments have given rise to the inclusion of new examples, together with additional end-of-chapter questions. The appendices now include an introduction to the European method of calculating utilisation factors.

In the introduction to the first edition of this book its stated purpose was to help the reader to get to the heart of the subject as quickly as possible. This purpose still stands and has been further developed in this new edition. The revision has concentrated on ‘explanation and illustration of the subject matter’ and this has meant that sometimes, rather than including actual tables, the purpose of the tables has been explained and illustrated and examples given.

This is particularly true in the road lighting chapters, where the number of tables would have been greatly increased by the latest classification requirements.

My career in the lighting profession has been driven by a fascination for the subject and my hope is that this book will not only give a thorough grounding in the core subjects of the discipline but will also encourage others to find that fascination for themselves.

Robert Bean

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Introduction

This book is intended for people who need to get to the heart of the subject as quickly as possible. Therefore, to suit this aim, it adopts a different style from that often found in textbooks. Nevertheless, the intention is to be rigorous in imparting the necessary information and ideas.

The early chapters are purposely kept short and in the form of questions and statements. This is to allow the reader to make early progress in understanding the basis of the subject. The length of later chapters is dictated by topic.

For the benefit of those for whom this is their first serious contact with the subject, Part One deals with lighting concepts and resources. These chapters also act as a review for those who have some knowledge of the subject. Parts Two and Three deal with applications. A wide range of situations are dealt with to give a good understanding of the techniques involved. The Appendices supply additional examples and other relevant information. It is intended that this approach will allow the reader quickly to achieve an understanding of the relationship between the various topics and their relative importance. This should enable more detailed later studies to be undertaken with confidence and an appreciation of the need for those studies.

One objective of this book is to meet the needs of those studying lighting topics as part of a wider course on the built environment. It will also meet the requirements of those who are studying with the intention of pursuing a career in lighting design.

It is the intention to use the reader's time economically whilst providing a first-class introduction to the 'lighting' aspects of lighting engineering. The questions, answers and solutions at the end of chapters are part of this process. In the later chapters the concentration is on examples rather than questions.

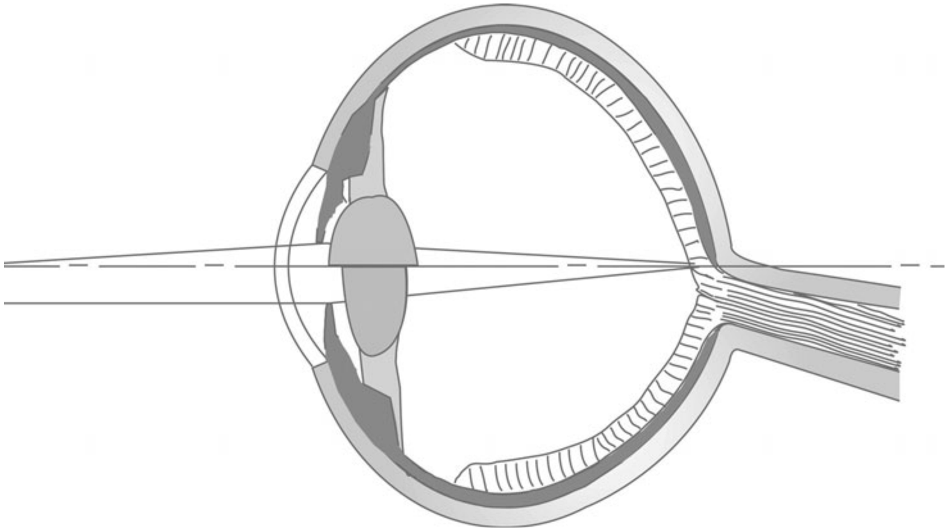
The first chapter emphasises the importance of the fact that lighting is provided in a building for the benefit of the people who inhabit or pass through that building. The needs, performance and characteristics of the people who occupy the building should be the primary concern of the lighting designer. Although energy efficiency and conservation are important considerations, they should never be allowed seriously to impede the visual performance, visual comfort or visual satisfaction of those occupying the building since, in the final analysis, it is that use that merits the building's existence.

The lighting of a building can perform a number of functions, but those functions all relate to the usefulness of the lighting to the people for whom the building was constructed, and the lighting must be such that it promotes, rather than diminishes, their well-being.

Lighting also plays its part in allowing movement between buildings, in displaying the buildings after dark and in supporting outdoor activities. Therefore, Part Three focuses on these equally important matters.

PART ONE

Lighting concepts and resources



Living in the luminous field

CHAPTER 1

We are in intimate contact with the luminous field through our eyes, except when we are asleep, just as we are in intimate contact with the atmosphere through our lungs. All the time we are absorbing electromagnetic energy which we call light and we are evaluating, consciously or subconsciously, the messages it dictates to us about the world around us.

The data we receive in this way is continually compared with previously received information to help us with this evaluation. For example, you are sitting in a room which has a wall which is brown in colour. The sun is streaming through the window and its light falls on one end of the wall. The other end of the wall is in dark shadow. Thinking about the appearance of the wall, you realise that what you see is that the end of the wall in dark shadow appears dark brown; the middle section of the wall appears light brown; and the end of the wall, where the sunlight falls, is a pale, almost luminous, brown. However, you know that the wall is painted only one colour, a particular shade of brown. You appreciate that the impression of different colours is caused by the way in which the light falls upon the wall. Such an interpretation depends upon the brain evaluating the whole scene in a routine way.

A similar thing happens when you look at a white ceiling in a daylit room. You may see various shades of grey, as well as white, but you know that the ceiling is actually painted white, not grey. It would be possible to deceive the eye/brain combination with a carefully created visual scene, but in most contexts the brain makes the correct deduction.

Appreciation of this ability of the brain to use previously absorbed information to evaluate the meaning of a visual scene is obviously important in understanding how people react to the lighting they encounter. It emphasises the point that often their feelings and opinions are related to evaluations of which they are not fully aware.

In every developed human being there is a vast store of reference data that the senses use to evaluate the present. Much of that data is shared human experience and awareness of the past. Since sight is one of the primary senses, much of that reference data is stored in visual images with associated emotional reactions. Basic to this is the experience of warm and sunny days and also of cold and dark nights, while there are others linked to private memories. Each person has a vast store of memories, many of which emerge as emotions only when particular situations are encountered. Since people vary in this way, some like certain things which others dislike. Therefore, it is not possible to arrive at a common consensus about such subjective things as art, decoration and, sometimes, lighting.

A 'natural' designer is someone who has absorbed the experiences of living in the luminous field in such a way that they find it easy to create luminous fields themselves that are appropriate for the building or space to be lit, and their creativity is rather like that of Beethoven who, when asked where his musical creativity came from, apparently replied that it came 'unbidden'.

However, most designers need the conscious observation of the luminous field as it presents itself day by day, together with the effort of analysis, so that ideas can come to them when bidden in order that good lighting designs are achieved. Observation of the luminous field is the key to being able to create good lighting schemes; and in lighting, as with other areas of design, there is often a tension between the past and the present.

In some spaces and situations it is sequence that is important – for instance, when moving from space to space, such as passing through a museum, department store or supermarket – while in other types of building it is the need to locate a particular service or to find the means of escape in an emergency. In other spaces, such as a waiting area, a feeling of relaxation rather than stimulation is required.

The first stage in any design is simplification – finding one word or sentence to describe the aim of the space that the lighting is to assist – inspiration, stimulation, relaxation, progression, interest, awareness, performance, satisfaction, etc.

The strength of the lighting attributes to be provided will also depend upon the time spent in a space. For instance, a theatrical type of display that has some very bright lights may be ideal for short-stay stimulation but disastrous for permanent occupation.

Design means exploring the full purpose of the lighting and carefully *crafting* the solution. Start by simplifying, but end by avoiding oversimplification. Some designers would claim to have no need of calculation, measurement or the like but, in the final analysis, no design can be translated into reality without the fruits of measurement and evaluation. It is this interaction of art and science that has always been the key that has made the world function and worth living in.

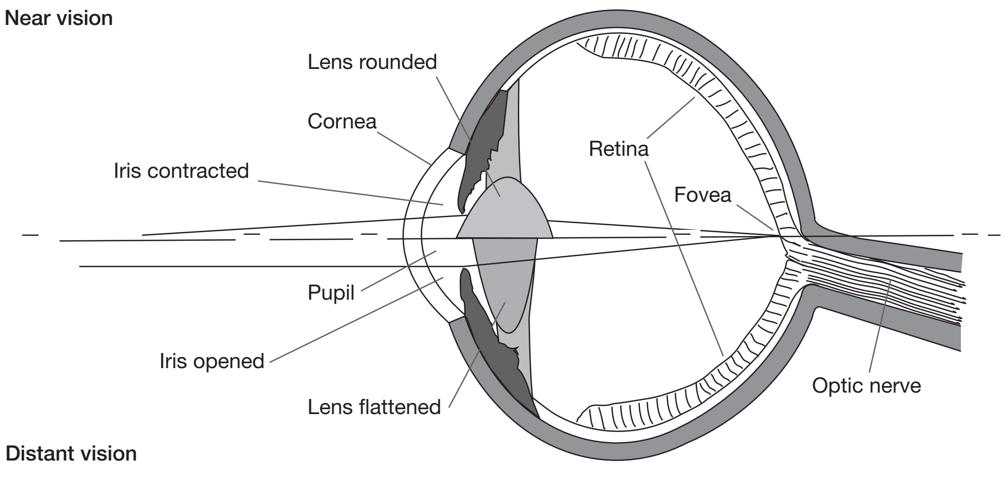
Our response to the luminous field is also affected by other factors, such as our physical state. For example, if we have a headache then our tolerance of the amount of light we can cope with is usually reduced and we reach for dark glasses. In terms of emotional state, bright sunshine stimulates us with feelings of well-being, whilst a heavily overcast sky can lower our spirits and, in more extreme cases, can result in seasonal affective disorder (SAD). SAD occurs in some people in winter when daylight periods become shorter and dark periods longer. The symptoms can be depression, an increased need for sleep and difficulty carrying out normal work.

Another area relating to visual perception is the physical behaviour of the eye itself. An example of this is that it has been found that the eye is moving *all the time*, as part of its scanning procedure. Boundaries which represent rapid or sudden change are brought to our notice so that the information implied by this change can be evaluated.

The eye itself is a most remarkable visual device worthy of a brief study.

Figure 1.1 shows a cross section of an eye. Light entering the eye is focused on the light-sensitive layer at the back (called the retina), where it produces an inverted image. The outer surface of the eye has a curved surface which provides about 70 per cent of the refraction required for focusing. The lens in the eye provides

FIGURE 1.1
The eye, showing near and distant vision



the fine adjustment and does this by changing its shape from flattened to rounded.

The sensitivity of the retina is not uniform, but rather depends on which region the light falls upon and the lighting level. The retina is a light-sensitive nervous layer containing two types of light sensor that give vision:

- cones, which operate at high lighting levels (photopic conditions); and
- rods, which operate at low lighting levels (scotopic conditions).

There are about seven million cones and about one hundred million rods (so called because of their shape) in the eye. Together, these communicate with the brain via the optic nerve. The cones are mainly concentrated on the optical axis of the eye to give sharp daytime vision, whereas the rods are spread over the rest of the retina. As the distance from the optical axis (a region called the fovea) increases, so fewer and fewer cones are found and, therefore, rods predominate.

Rods are much more sensitive to light than cones, but because many more of them share the same nerve fibres they give a far less detailed image. This is why details are not very clearly seen under low lighting levels, such as moonlight. In addition, the rods do not give the sensation of colour.

A third type of receptor which does not give vision but which responds to light has been identified. It has a chemical effect on the brain which relates to the suppression of melatonin. This affects sleep patterns and produces greater alertness. This receptor is in the lower part of the retina and is most affected by light entering the eye in the downward direction. The maximum sensitivity of this receptor is in the wavelength range 430–460nm (see Figure 3.2), which is at the blue end of the spectrum. This all relates to the circadian rhythm which controls the internal human body clock.

The iris is an aperture that automatically adjusts in diameter according to the light level and state of adaptation. At high light levels the reduced size of the aperture (pupil) gives a sharper focus by reducing spherical aberration of the lens and also gives a greater depth of visual field. This also reduces chromatic aberration.

Our colour vision is produced entirely by the cones. This visual process is mainly photochemical, and cones are found with three different types of photochemicals which have three different, but overlapping, wavebands. These cover the whole visual spectrum and produce three responses that make up the colour information evaluated by the brain.

Some indication of the existence of this colour vision system is found in the after-images seen when a strongly coloured light is viewed and then followed by exposure to white light. The fatiguing of the colour receptors which responded to the strongly coloured light leaves a coloured image in the field of vision that is the complementary colour that remains after the strong colour is subtracted from white light.

The retina has a very large range of operation, as is obvious from the fact that it must operate in a wide variety of situations – from, say, Middle Eastern sunlight to starlight. However, it can only operate over part of this range at any one time. The process of changing its range is called *adaptation*.

Adaptation from dark to light is relatively rapid, since it mainly consists of contraction of the iris and bleaching of the photochemicals in the rods. Adaptation from light to dark is a much more lengthy process since it consists not only of dilation of the iris but also of the regeneration of the photochemicals in the rods. These effects have been experienced by most people, when, for example, leaving or entering a cinema.

Let us return now to the effect of lighting installations on individual impressions. It has been suggested that the effects of lighting can represent a language. For example, if you want people to look at something in particular, you light it brightly; for when someone walks into a room their attention is usually drawn first to the brightest object in that room. This is called *phototropic attraction*; moths suffer from it to a self-destructive degree. In the case of a brightly lit object the message conveyed by the lighting is simply: 'Look here!' However, if a lamp or lighting fitting (luminaire) is much too bright, so that it physically hurts the eye or makes it impossible to see past the light, then the message conveyed by the light is, in effect, 'Go away!' or, at least, 'Look away'. Considerations such as these are very important in detailed lighting design and they will play a significant part in analysing lighting requirements for particular situations.

J. A. Lynes (1996) has suggested a very useful approach to lighting design based on the idea of lighting as a language. In the same way as a verbal language differentiates active from passive, subject from object, so lighting design distinguishes the light source from the lit surface. So, in this approach, 'active' elements, such as lamps, luminaires and daylight, are considered to differ fundamentally from 'passive' elements, such as illuminated objects. The purpose of the lighting is then to reveal or modify certain perceived attributes of the passive element, such as colour, texture, modelling or sheen.

In this approach the art of lighting is to apply effectively suitable adjectives to a given noun.

QUESTIONS

1.1 Choose a word or write a sentence which describes for you an aspect of the following situations to which lighting can contribute:

(a) a primary school classroom
(b) a senior school classroom
(c) a lecture theatre
(d) a hospital waiting room
(e) a hospital ward
(f) a dental surgery

ANSWERS

1.1 The following are appropriate answers to the above questions:

(a) a bright and cheerful atmosphere
(b) a focused and stimulating atmosphere
(c) a formal focused atmosphere
(d) a comfortable and relaxing atmosphere
(e) a pleasant and restful atmosphere
(f) a sense of calm efficiency

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The importance of daylight

CHAPTER 2

The presence of windows to allow daylight to enter a space and to allow the occupants to look out is a major factor in the satisfaction or otherwise of those who use that space (see Figure 2.1).

Everyone gifted with sight can attest to this fact. However, sometimes it is necessary to exclude daylight for operational purposes, and sometimes the space is located within a building where daylighting cannot be provided. The shape, size and location of windows are really beyond the province of the ordinary lighting designer. This is because windows have such an important effect not just on the interior lighting but also on the view of the outside world and the outside appearance of the building. Additionally, they have a major effect on the energy efficiency of the building.

With the advent of the energy crisis and the greater emphasis on using daylight wherever possible, the light pipe was introduced to transmit daylight into areas where windows were not available or where it was thought that additional daylight would be worthwhile. These light pipes do introduce daylight into areas where there would otherwise be no daylight, but they do not replace one of the most important aspects of windows since they do not allow room occupants to look out. In addition, when compared with windows, they are inefficient because the area of the light pipe aperture is usually far smaller than that of a window. Light pipes have their place, but they are not a substitute for windows. Rather, they are a substitute for electric lighting during daylight hours to save energy.

Daylight is very important in buildings, but it can also cause problems. Bright sunlight shining through windows can cause disability and discomfort glare (see Chapter 15). Windows can also give unwanted thermal energy input or unwanted thermal energy losses.

The first input into the design process is quite rightly that of the architect, who has overall control of the building's design and layout. Although people prefer a well-daylit room there must also

FIGURE 2.1
A window to look through is usually an important aspect of an interior

be provision for electric lighting, since daylighting is not always available or may be inadequate. However, once the windows of a building have been designed and installed, it is seldom possible to do anything to their performance other than change the glazing or provide blinds to control the daylighting and the heating effect or heat loss. Therefore, detailed window design and calculations are beyond this book, but some indications of the sort of calculations that can be made and the thinking behind them are worthwhile and are given in Chapter 12.

The daylight available in a room varies with the time of day and the time of year, and because of this it is usual to express the daylight performance of the windows of a room by the daylight factor that they provide within the room. This daylight factor can be for a point in the room, an average for all the surfaces in a room, or, commonly, for the horizontal working plane similar to that used for electric lighting calculations. The daylight factor relates the lighting level within the room to that existing outside the building from an unobstructed sky (see Chapter 12).

There are two distinct situations for which lighting design is required. One is for a new building and the other for an existing building. Some lighting designers are fortunate in being able to specialise in lighting for new buildings where, in consultation with the architect, they can influence the daylighting design as well as the electric lighting. However, the majority of lighting design is required for existing buildings and, although the integration of the electric lighting with daylighting is equally important, the main design feature to be formulated is that of the electric lighting. For this reason much of this book attends to manipulating the electric lighting to ensure suitable visual conditions in buildings, both when daylight is available and when it is not.

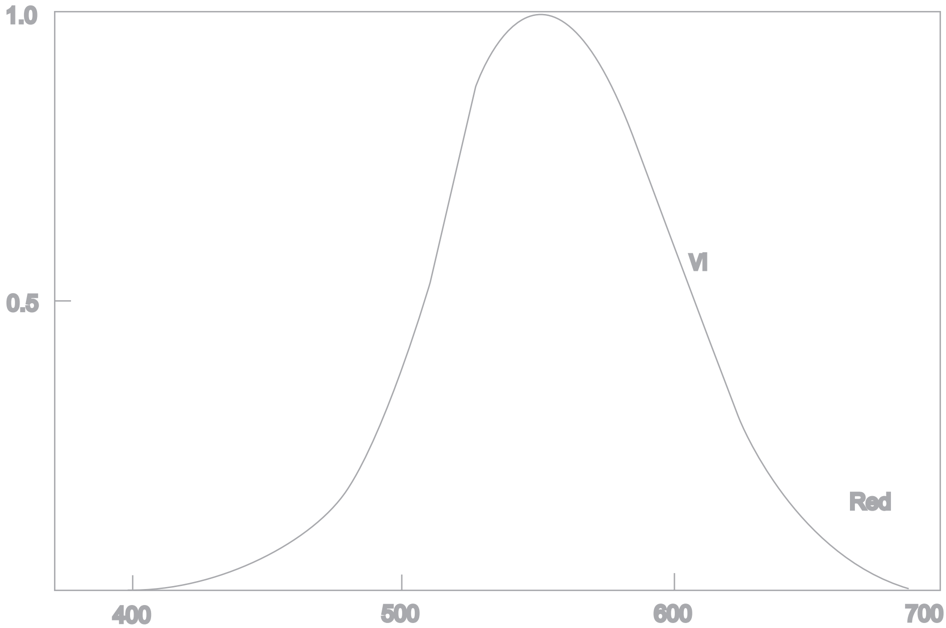
QUESTIONS

2.1 What is the most important thing that daylighting adds to a room? Place the following aspects of daylighting in what you consider to be the order of importance.

(a) saves lighting energy
(b) gives a pleasant appearance to people within the space
(c) gives light of a good colour
(d) gives the opportunity to focus on a distant scene
(e) affords variability of the light
(f) gives a sense of contact with the outside world

ANSWERS

2.1 With the advent of the energy crisis the order has changed since the first edition of this book was published. The new version is: f, a, d, b, c, e. Energy saving has therefore moved from fifth to second place.



1.0
0.5
Vl
Red
400
500
600
700

How much light is needed?

CHAPTER 3

In the early days of electric lighting the main requirement was to have sufficient light by which to work, so the most important consideration was the amount of light to be provided on the workbench or desk. Later, the problem of over-bright lamps and luminaires was also taken into account.

In recent years attention has been paid to providing adequate lighting on walls and vertical surfaces and to ensuring the satisfactory appearance of both the room and the people occupying it. The need to avoid reflections in display screens has also become the factor in lighting design.

Many different visual tasks have to be performed by workers in commerce, industry, etc. Although the amount of light required for a particular task may vary from individual to individual, depending upon their visual capacity – e.g. age or eyesight – it is possible to determine a lighting level that will meet the requirements of most people.

In general, the more difficult the visual task, the higher the level of lighting required. As the lighting level is raised the smaller will be the detail that can be seen. Similarly, the poorer the contrast between the task or object and its background, the greater will be the amount of light needed. Speed of vision also improves with an increased lighting level.

The law of diminishing returns

Lighting levels are measured in lux (see page 20). It has been found that although increasing lighting levels improves visual performance, after a certain level of performance has been reached further increases in the lighting level bring relatively little improvement (Figure 3.1).

In this respect sight obeys similar laws to the other senses, such as hearing. With respect to vision, some relate it to a power-type

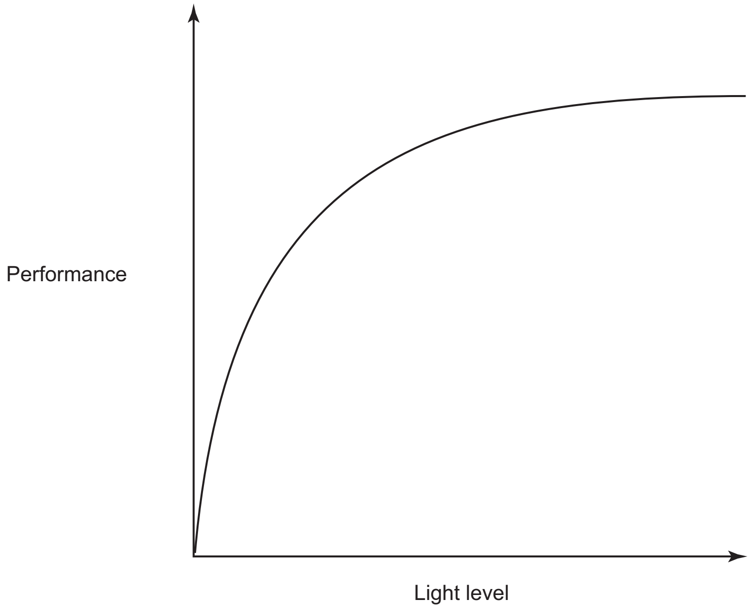


FIGURE 3.1
Typical visual performance curve

law and others to a logarithmic scale with regard to the stimulus required to produce a particular level of sensation.

We might conclude from this that very high levels of illuminance are never justified. However, this is not true. Some tasks are so important that very high levels of illuminance are provided to give the necessary accuracy of vision. The work of a surgeon at the operating table would be an example. Lighting levels up to one hundred times those recommended for a general office are often provided over small areas of an operating table. Therefore, it is important to have a schedule of recommended lighting levels for different types of work or situations. Such a set of schedules is provided by the SLL Lighting Code (CIBSE). CIBSE stands for Chartered Institution of Building Services Engineers, and the CIBSE inherited this type of code from the Illuminating Engineering Society, with which it merged in 1978; and now within CIBSE there is a Society of Light and Lighting (hence SLL).

The means of indicating what is required

The first requirement is for those who need the lighting to communicate with those who can provide it. The owner, employer or manager would ask an architect, consultant, contractor or manufacturer of lighting equipment to submit proposals. In turn, they would produce a technical specification for the suggested lighting.

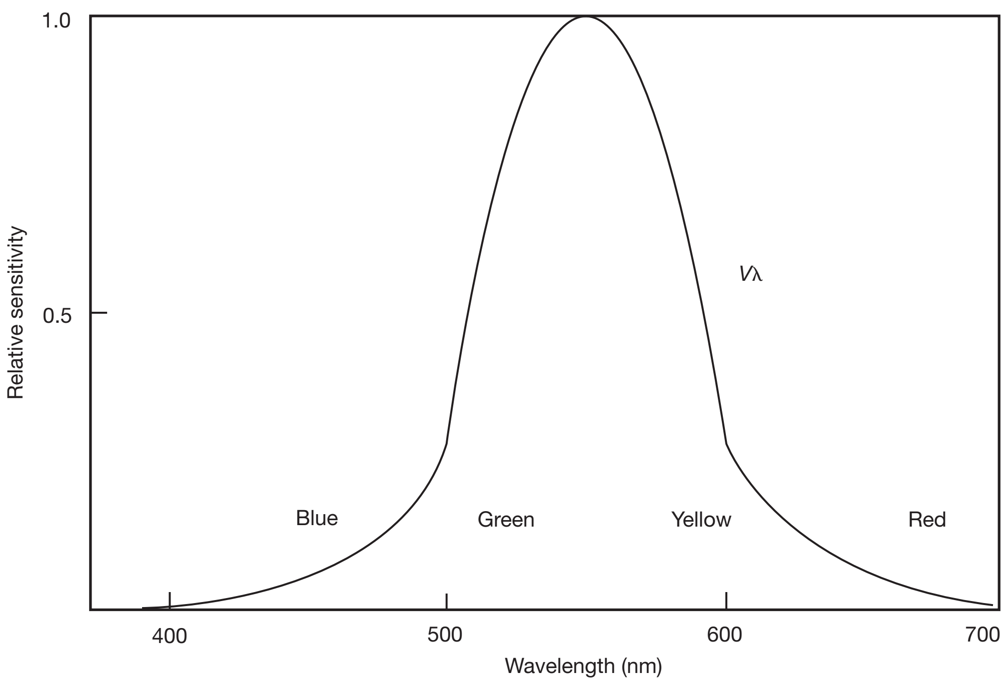
Lighting, like any commodity, needs some means of indicating its quantity. If we buy an ordinary filament lamp, often called a light bulb, we buy it in terms of wattage, e.g. 60W, 100W, etc. We know that our 100W lamp will give more light than a 60W lamp of the same type. However, when it comes to a technical specification for, say, a large office then such a simple approach in inadequate.

Offices are often lit with tubular fluorescent lamps. A typical white 100W tubular fluorescent lamp gives almost seven times as much light as a 100W domestic type of filament lamp. Therefore, watts are an inadequate measure of the amount of light provided.

Differences in light output for a given wattage of lamp can be caused by several factors. The main reason for a fluorescent lamp being far more efficient than a filament lamp lies in the fact that the atomic process for producing light is more efficient in the fluorescent lamp than in the filament lamp (see Chapter 14).

Another reason is that when the electrical power in watts is converted into light the amount of light produced depends upon its wavelength (i.e. colour). This is because the eye is more sensitive to some colours than to others. For example, under daytime or photopic conditions, the eye is far more sensitive to the yellow/green wavelengths than it is to the red or blue wavelengths. The relative magnitude of the difference is indicated in the curve shown in Figure 3.2.

FIGURE 3.2
The eye is more sensitive to yellow/green wavelengths than to red or blue wavelengths



To determine the output of a lamp, the fundamental method is to measure the power emitted in watts over a series of narrow wavebands covering the whole spectrum of the lamp and to multiply each value by the relative response of the eye (called the spectral luminous efficiency $V\lambda$). These values are then added together and multiplied by a constant (683) used to relate all light output measurements to an internationally agreed base. This quantity of light, which depends upon wavelength as well as electromagnetic power, is expressed in *lumens*.

An example of this calculation is shown below in a simplified form. In particular, the wavelength intervals are 25nm, whereas the usual interval is 1nm.

Example 3.1

A 100W tungsten filament general service lamp has a power distribution as shown in Table 3.1. Calculate the lamp output in lumens.

TABLE 3.1

Wavelength (λnm)	*Power radiated W per wavelength interval (watts)*	*Spectral luminous efficiency ($V\lambda$)*	*$683 \times W \times V\lambda$ Light output per wavelength interval (lumens)*
400	0.062	4×10^{-4}	0.017
425	0.096	7.26×10^{-3}	0.476
450	0.133	3.8×10^{-2}	3.452
475	0.176	0.1226	14.74
500	0.234	0.3230	51.62
525	0.298	0.7932	161.44
550	0.365	1.0002	249.34
575	0.433	0.9154	270.72
600	0.505	0.6310	217.64
625	0.575	0.3210	126.06
650	0.644	0.1070	47.06
675	0.712	0.0232	11.28
700	0.790	4×10^{-3}	2.21
	Total 5.023 watts		Total 1156.10 lumens

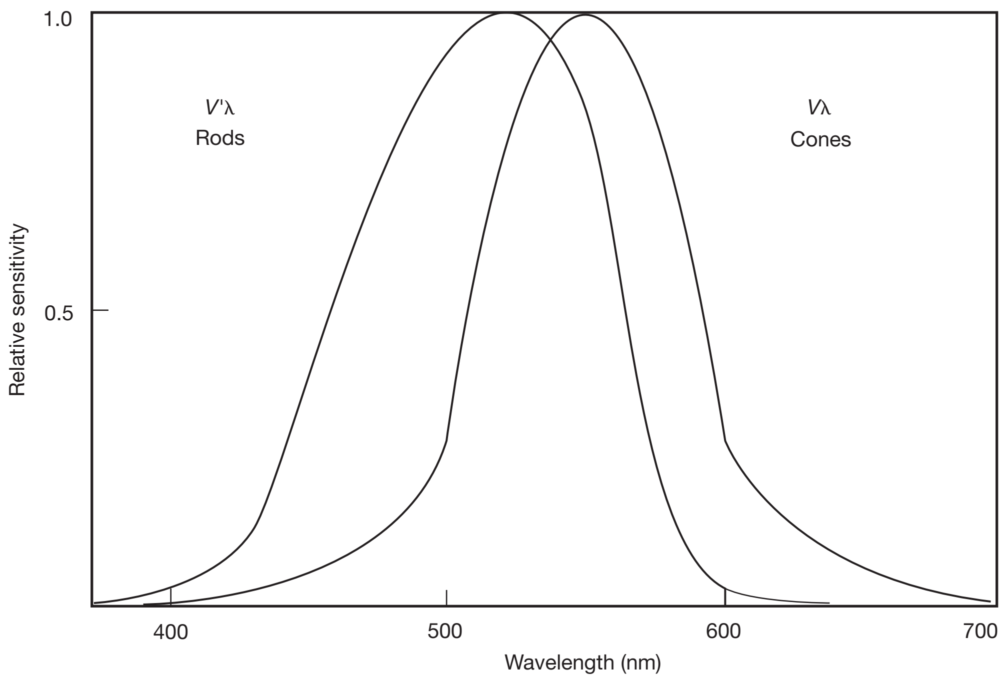
From such a process it is found that a 100W general service filament lamp typically produces 1200 lumens, a 2400mm 100W tubular fluorescent lamp about 8000 lumens and a 100W high-pressure sodium lamp about 10,000 lumens (see Chapter 14).

Dividing the lumen output by the wattage gives a useful indication of the relative efficiencies with which light is produced. The results for the lamps mentioned above are: filament lamp –12 lm/W; fluorescent tube – 80 lm/W; high-pressure sodium lamp – 100 lm/W. LEDs are still developing, but typically they are 50–70 lm/W.

These are not ratios of like quantities so they are not termed efficiencies, but since they do indicate the 'efficiency' with which light is produced from the electrical power supplied to the lamp, the term *efficacy* is used.

In the above calculation the Vλ data was used in the formula to convert watts into lumens. This Vλ function related to cone vision or photopic vision and not rod or scotopic vision. There is another spectral luminous efficiency function V′λ which relates to rod vision, but this is not used in calculating the light output of light sources in lumens. The two spectral luminous efficiency functions are shown together in Figure 3.3.

FIGURE 3.3
The two spectral luminous efficiency functions



During adaptation from a very high level to a very low level of lighting the sensitivity curve of the eye moves from the photopic curve towards the scotopic curve and in doing so passes through the mesopic region of adaptation. In this condition both rods and cones are operative.

Road lighting often operates under lighting levels where some mesopic conditions are encountered. This process shows an increasing maximum response as the response curve moves from photopic to scotopic vision. The peak of photopic curve is at 683 lumens per watt. The peak of the scotopic curve is at 1700 lumens per watt. Some lamp manufacturers calculate the luminous output of the lamp using the photopic curve and then again using the scotopic curve and publish the scotopic ratio, which is the scotopic output divided by the photopic output. A typical value of this ratio would be 1.38. The suggestion is that this ratio distinguishes which lamps are best suited to mesopic conditions encountered in road lighting.

A simple but inadequate specification

The simplest form of lighting specification might require 100,000 lumens to be fed into the room via the lamps and luminaires. The problem with such a simple specification is that it does not ensure that the light is received where it is needed most. So, although the outcome of the lighting designer's calculations may be to conclude that 100,000 lumens are required in that room, it is not the starting point. The starting point is to specify the required density of light (light flux) required at various points in the room.

This density of the light flux is specified in terms of lumens per square metre and given the name *lux*. This is a measure of the illuminance received by the surface or point in space. For example, the SLL Code calls for 500 lux at desk height in a generally lit office.

Now that there is a concerted attempt to save energy, where the position of the task areas are known in detail, the SLL Lighting Code gives advice on the relationship of the surrounding area to the task area and the background area. As an example, if the task area illuminance is 500 lux, the surrounding area should be at least 300 lux and the background area should have a maintained illuminance of not less than one-third of the value of the surrounding area – in this case not less than 100 lux.

Where the work stations are not known or are frequently moved, the uniform illuminance over the whole working area may be required