Appliances & Lighting
Article
www.leonardo-energy.org
July 2007

Lighting & Human Life

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1 Introduction

This is the first article in a series of three in which we will focus on the relationship between lighting and human life. This topic is much broader than merely 'ensuring vision'. After defining some important terms and measurement units, we will discuss how the quality of lighting interacts with and effects human behaviour.

This will set the background for the forthcoming articles, where lighting design and lighting technologies will be discussed.

2 Light and human life

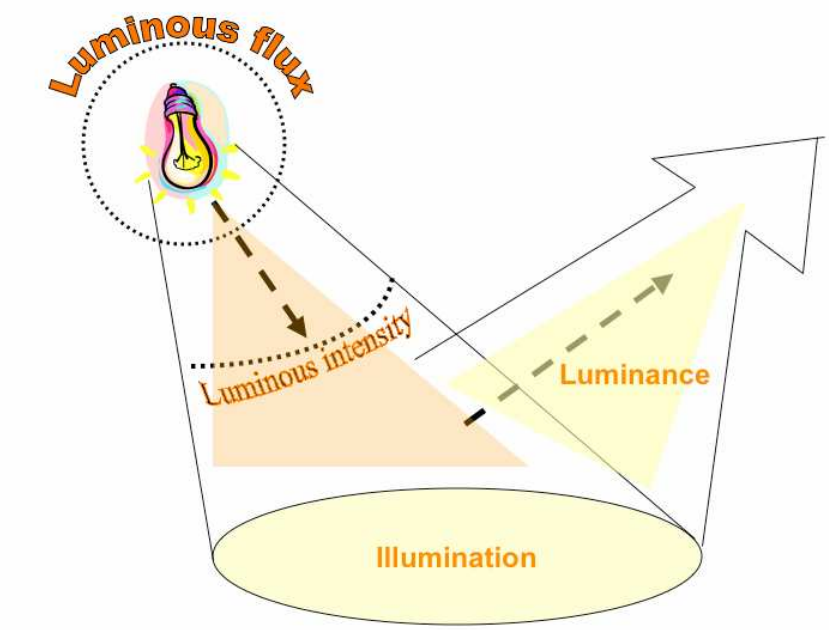
2.1 What is light?

Light is usually defined as an 'electromagnetic radiation that has a wavelength in the range from about 4,000 (violet) to about 7,700 (red) angstroms and may be perceived by the normal unaided human eye' (www.answers.com). Various physical units are used in photometry, the science of the measurement of light in terms of its apparent brightness to the human eye.

The most useful terms are listed below:

Quantity	Symbol	SI Unit	Comments
Luminous energy	lm.s	Lumen second	The amount of energy emitted as light in a second
Luminous flux	lm	Lumen	The luminous power emitted by a given source on 4π steradian
Luminous intensity	Cd=lm/sr	Candela	Luminous power in a given solid angle
Illumination	Lx=lm/m²	Lux	Amount of light received on a given surface
Luminance	L=Cd/m^2	Candela/m^2	Amount of light of a given source sent by a lighted surface and perceived by eye
Luminous efficacy	lm/W	Lumen /watt	Ratio between emitted light and input energy

The main characteristics are presented below.



From a **lighting design point of view**, illumination is most important, because it measures the fulfilment of a need.

From an **energy point of view**, luminous efficacy is critical. It links the fulfilment of need to energy input.

From the **building design point of view**, lumens are also often used to define the lighting requirement and the number of lamps to be installed.

These units will help to define the quantity of emitted or received light. Other units or indicators will be mentioned below where they define a particular quality of light. The perceived reception (perception) of light also depends on the quality of the light, as defined by the colour rendering index and the colour temperature. The colour rendering index measures the ability of a light source to reproduce colours, on a 0 to 100 scale. The colour temperature defines the cold or warm aspect of a light source. It is expressed in Kelvin.

2.2 Interactions with human life

2.2.1 VISION

Light and lighting's primary function is, of course, vision. While much is known about the physics of vision (the path of the light in the eye), little is known about the feeling and perception of light. Some of the elements of vision relevant to lighting design are reviewed below.



- Illumination range

The eye can see things over a very large range of illumination conditions; roughly between 1 lux to over 100 000 lux. That is anything between a clear night without a moon to a bright sunny day. Nevertheless, at a given moment, the human eye can only process information in a range of about three orders of magnitude (1 – 1 000 lx, or 100 – 100 000 lx). It is therefore quite common to consider the eye as a logarithmic sensor, not appropriate to judge absolute illumination levels. Moreover, characteristics of eye and vision evolve throughout life. Slower scanning function, a more rigid lens, and loss of visual acuity and contrast sensitivity cause older people to need more light for the same purpose.

- Colour

Being able to see colours accurately is especially important in certain situations as varied as art museums, health care facilities, or the fashion industry. The sensitivity of the human eye does not cover the whole spectrum; it peaks at around 550 nm (green-yellow).

The colour perception depends on the brain's interpretation, using a complex process of comparison and referencing. Moreover, colours surrounding a given object influence the perception of its colour by modifying the reflected light. This is why colours intensify as the surface area increases. In addition, the colour spectrum of natural light varies widely during the day.

The lighting designer must always keep in mind the anatomy and the process of vision in order to create an appropriate and satisfying colour spectrum.

The quality of colour rendering is usually expressed through two parameters: chromaticity (or colour index) and colour rendering index. They respectively express the colour appearance of the light source and the colour appearance of the objects being lighted. Both are defined according to the International Commission on Illumination and are applied by manufacturers to light sources worldwide.

These two indexes play a leading role in the way we feel and perceive colours and in how we experience thermal comfort. This also has a strong relationship with energy management.

- Photopic and scotopic vision

Humans actually have two distinct visual systems that function differently, but work together to provide our vision: rods and cones.

- *Rods* are distributed relatively uniformly across the retina. They contribute to peripheral vision and are particularly effective at modest and low light. They are most sensitive to shades of grey and motion.
- *Cones* are concentrated most strongly in the small central area of the retina called the fovea and allow us to see colours.

These visual systems function seamlessly together, in three different modes:

- *Photocopic vision* functions at relatively high light levels where cones are active. This is commonly referred to as our *day vision* and is the basis for most research, particularly in the area of the indoor work environment.
- *Scotopic* vision occurs below the level of illumination where cones are active. This is our so-called *night vision*. It is marked by low perception of colour and poor central vision.
- *Mesopic* vision is the state between the two others. This is our *dusk vision*, with a shift in spectral sensitivity from yellow-green (typical of cones) to blue-green (typical of rods).

Knowing the vision mode in use in a particular situation is important in improving efficiency in lighting.

One conclusion that can be drawn regarding human vision is that human eyes are very well adapted to natural light. To perform the same task, an individual needs less natural light than artificial light. Reading, for instance, requires 35% less natural light than artificial light.

- Medical influences

We have all experienced the effects of UV light exposure through its contribution to tanning (melanin synthesis within the skin). This is positive proof that our luminous environment is much more than merely a visual issue.

In fact, a whole branch of medicine (photo immunology) investigates these side-effects. As an example, some drugs have their effects amplified or decreased with exposure to certain wavelengths of visible and invisible electromagnetic radiation. There is still much to be discovered in this area connecting our exposure to both natural and artificial lighting to health.

- Circadian rhythms

Light is one of the cues that our biological system uses to set our internal clock. A well-known example is the treatment of seasonal affective disorder. This condition can occur in some individuals as the days shorten in the fall and winter causing depression. It has been found that certain patterns of lighting (especially bright light around 10 AM) can reduce this effect.

Light exposure for travellers experiencing jet-lag, control of melatonin production, and possible interactions between cancer risks and light exposure are just a few of the areas under investigation.

- Other health aspects

Research abounds regarding the influence of virtually any given parameter of light quality on human health. Several are listed below:

- Relation between light exposure and infant eye development
- Possible effects of the natural spectrum on people
- Relation between lighting quality, mood, and emotions
- Influence of flickering light (including nausea or epileptic seizures)
- Specific ultraviolet light effects

2.2.2 PRODUCTIVITY

The relationship between lighting and productivity of workers has been extensively studied in recent years. Findings have led to lighting retrofits and upgrades that meet energy efficiency requirements as well as health and safety considerations.

The influence of both artificial and natural lighting has been intensively studied, especially in the USA. In has been shown, for example, that exposure to daylight and productivity are strongly related. The influence of daylight has been extensively studied in offices, retail stores and schools, independent of the other qualities typically associated with daylight (glare, view, psychological status, etc.). Retails stores have higher sales, children learn mathematics and reading significantly faster, and workers have higher productivity when exposed to full spectrum (daylight equivalent) light.

Green construction tends to confirm these results, as it leads to intriguing similarities. Both higher productivity and greater profitability is achieved with a more appropriately lit environment.

3 Conclusion

We have briefly covered several key aspects of lighting, from energy production system to biosphere impact. It has been confirmed that lighting has a great interaction with human life. This background, used with due consideration for and knowledge of our vision system, will help in analyzing and evaluating lighting technologies and technical solutions using relevant criteria.

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