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Review Article

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Vital Effects of Applied Lighting Science in Road Engineering

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Introduction

At one of the many traffic nodes that lead to the Paris-Lyon highway, those concerned noticed that the rate of accidents at night is 600% higher than at other nodes whose design does not differ much from the aforementioned node.

The matter remained for years without a convincing explanation until, by chance, some of the lighting poles leading to the aforementioned node broke down.
Those concerned noticed that the accident rate had decreased significantly, then returned to its previous rate after the defect was fixed.

Here, those old studies that were conducted during World War II on the physiology of lighting color and its environmental effects came back to mind.

What is noteworthy is that the flood lighting of that traffic node was increasing by six to seven times the recommended international rate, which means that the concept of a smooth gradation of lighting intensity levels was not taken into consideration.

Optical Properties of Visible Light: [1]

It may be difficult in this paper to understand the details of the unique nature of light, in general.
Especially since the physics of light has been contained or built upon within most known forms of physics, starting from classical physics to quantum physics.
It is currently impossible to understand any form of theoretical and even applied physics without resorting to some that basic form.

To the structural concepts of light, however, we will attempt briefly to explain the theoretical concept of the ABC of light, leading to the applied calculations that are of interest to engineers concerned with lighting, especially lighting roads and public facilities (more than they may be of interest to other specialists).

The basic unit of the quanta of the light is the photon, which is a real result of the energy level of any electron in the case of eUP.

It has a fixed spin equal to one, and the effect of a beam of photons is subject to the wave physical laws, while the single photon is subject to a set of laws of renormalization and the obesity order of its electron in The probabilistic-statistical in the mechanics of quantum , and from here comes the famous saying about the lack of a separate reality for the concepts of light and color apart from the wave-particle theory in both its classical and quantum parts.

The light that the human eye can perceive has a wavelength ranging between [380 - 760] nanometers (380 nanometers for desaturated violet and 760 nanometers for desaturated red). For this reason, one can say with confidence that color is a state that does not exist outside our sensory perceptions (This literally matches the quantum mechanics vision of nature. Therefore, what we see is not the light beam or the color itself, but rather the wave effect accompanying it.

Color Temperature of the Light: [2]

Perhaps the principle of this approach originally goes back to the inimitable scientist Max Planck when he treated a phenomenon that was later known scientifically as the ultraviolet radiation disaster, which led to the derivation of one of the greatest constants in the world of theoretical physics: (Planck's constant).

The important thing is that the approach says that if we raise the temperature of a body Black to the point of glowing, it emits light radiation whose nature is proportional to its temperature, which led to the conclusion that it is possible to characterize the light source by its color temperature because the spectrum remains approximately the same every time when measuring a black body for a certain temperature.
For example, classic tungsten bulbs have a proportional color temperature. Completely with the maximum and minimum

temperature and its range.

Based on laboratory measurements, a discharged tungsten lamp with a power of 60 watts has a color temperature equivalent to 2100 degrees - Kelvin, while the same lamps in an inert gas atmosphere have a color temperature equivalent to 2500 degrees - Kelvin.
and by analogy... despite the fact that the continuous spectral structure of lighting lamps differs from the structure In the spectral spectrum of a black body, which is often accompanied by spectra with broken lines, the principle of color temperature can be applied freely even on fluorescent lamps.

That a white fluorescent lamp with a power of 60 watts is equivalent to a black body with a temperature of 3000 Kelvin, while the color temperature associated with a day-light fluorescent lamp of the same power reaches 5000. Degree - Calvin.

It remains to say that the color temperature of the direct sun is equivalent to 1850 Kelvin at the beginning of sunrise and reaches 5000 Kelvin at midday.

Light flux: Parameters and operators
((Illumination intensity coefficients)):

Lighting Flux: [3]
Let us have a light source located in the center of an uneven sphere. This source does not radiate the same amount in all directions.
Here we clearly notice that the equal surfaces S1, S2, S3... Sn receives different light fluxes that form geometric cones with equal spatial angles.
The geometric equality of the cones does not mean at all that the light flux is equal.

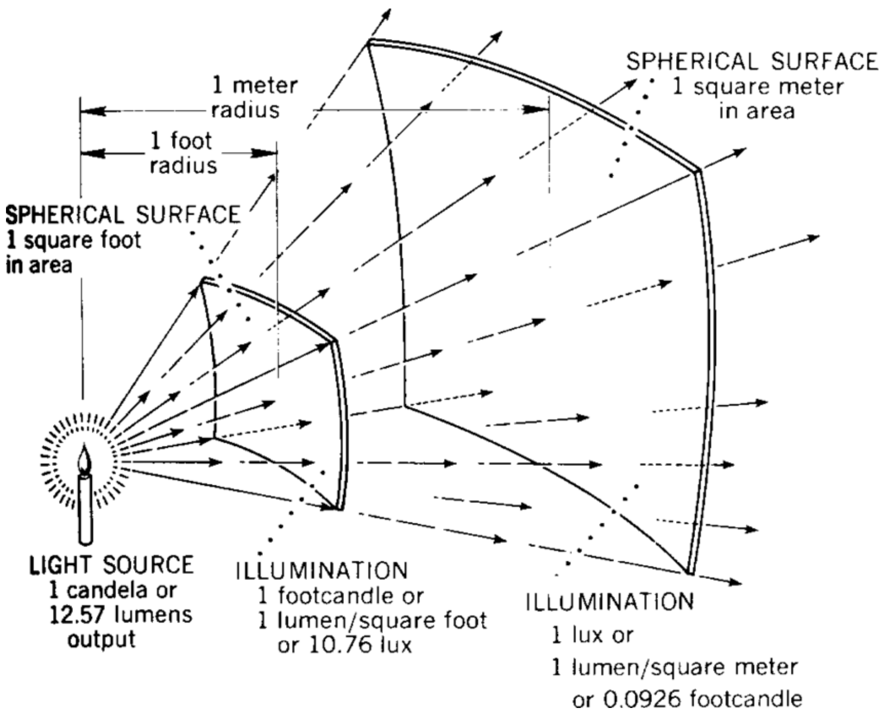

Figure 1: Relation between Luminous Flux, Intensity and Illum

Light Flux Unit (Lumen):
Let us have a light source with a value of 1 candela located in the center of a super-smooth sphere with radius r = 1M, and let us take from the inner surface of the sphere a surface S = 1M2.
The unit of luminous flux falling on this surface is called a lumen, and since the area of the sphere is equal to the luminous flux of the total surface, the ball equals 12.57 Lumen.

Lighting Intensity (Lux):
If a luminous flux of 1 Lumen falls on a surface S = 1 M2, then the luminous intensity of this surface is equal to 1 Lux.
Since the luminous intensity is the ratio of the luminous flux to the illuminated surface, and it is subject to change according to the position of the spatial angles, it is more useful to determine the illumination intensity relative to a finite angle in the smallest covers in the S area that is also infinitesimal, so that:

$$e = \frac{d\Phi}{ds}$$

Needless to say, the practical measurement of lighting intensity is done using Lux-meter devices.

Lighting Beam Intensity: [4]
Let us have two light sources of equal intensity and flux placed in the centers of two spheres with identical characteristics, the radius

of the first r1 = 10 M and the radius of the second r2 = 20 M
The sphere with radius r2 has a total area of four times that of the sphere with radius equal to r1, and therefore it shows us four times less luminosity, so the radiation intensity ratio r2 = 1/4 r1.

Industrial Production of Light Using Electricity: [5]

Incandescent Bulbs:

The first thing the world knew of incandescent lamps was a coal bulb.
The resistor (wick) was made of fibers from coal rods, and the bulb was vacuum-packed.
Coal was soon replaced by tantalum and then tungsten, which in 1905 constituted a true revolution in the world of industrial lighting.

It was soon followed by another development based on injecting the vacuum bulb with an inert gas whose atmospheric pressure when heated equals normal atmospheric pressure, which contributed to delaying the evaporation and corrosion of the filament, thus giving a longer life to the already short-lived tungsten bulbs.
Of course, we cannot in this hurry follow the historical development of incandescent bulbs all the way. Until now, but in general, the main characteristics of currently available incandescent lamps ((whose design principle does not differ much from their sisters that were invented at the beginning of the last century, except for the improvements that led to an increase in the actual life span of the lamp, an increase in the rate of illumination and an improvement the yield)) can be stated, including the following:

- Calculates the electric potential difference using direct volt.
- Power is calculated in watts.
- The flow rate of the luminous flux by lumens
- Optical efficiency yield in lumens-watts.

Anyway, the following table specifies the illuminance rate of some incandescent bulbs available in the global market, manufactured in accordance with the American IEEE standards that conform to the standards of the French AFE standard, amended by Bulletin 386-E of 2002.
Some types may differ from this rate slightly, and then the manufacturer often specifies the amount of flux and the rate of difference and correction (when the voltage difference or power changes associated with a sudden increase in amperage draw when the voltage drops):

Efficiency: *Lumen – Watt*		**Light flux: *Lumen* 10 X***		**Electrical Power (W)**
220 / 380 V	**127 / 220 V**	**220 / 380 V**	**127 / 220 V**	
8.8	11.2	350	450	40
10	12.4	600	750	60
14	15.5	1400	1550	100
14.7	16.3	2750	3260	200
16.7	19	8450	9500	500
18	20	13500	14800	750
18.5	20.3	18500	20300	1000
18.6	20.5	27700	31000	1500

The efficiency of light sources has risen from 10 lumens-watts in 1905 to more than 100-110 lumens-watts today, and much more than this for fluorescent and halogen or mercury, sodium, and phosphorescent bulbs (which are environmentally controversial).
While the efficiency of LED saving lamps has jumped astronomically, regardless of the problem of harmonics on capacitive loads that it causes.

Lighting calculations according to AFE and I.N.S are subject to annual adjustments, considering many concepts, the most important of which are the concepts of contrast and the mechanism of luminous flux distribution according to Isolux curves, considering Calvin's electrophysiological law with regard to the contrast factor or demand factor (usage).

A football field, for example, needs lighting intensity during matches, that is equal about three times more than what he needs during training, for example.

Lighting Levels: [6]

Naturally, the intensity of lighting in a boxing ring (2000 Lux) differs from the lighting in a football field (300-700 Lux). Likewise, lighting in swimming pools, for example, requires safety standards that exceed any other lighting, and lighting in museums and galleries requires Highlighting the item or sculpture at the expense of saturation with dark backgrounds or drop shadows to highlight the aesthetics, sometimes using the black light bulbs*.

Indeed, the lighting levels installed for the same purpose may differ from one place to another.

Wembley Stadium in London has an illumination of 350 Lux when Cup matches are played there the world in 1966, while this rate much less than the Madrid International Stadium (more than 700 Lux) for the same period.

And one of the factors influencing the choice, the lighting levels that preventing dazzlement, no matter how high the rate of illumination intensity is.

Excessive dazzlement and flood illumination in sports and Olympic stadiums may prevent players from Performing their tasks well, and this is what every engineer should keep in mind during design.

General lighting (Utilities Illumination) [7]

Road and Street Lighting:

There are many classifications of road and street lighting, however they can be divided into two levels:

A - Lighting by devices with a configuration similar to lamps operating on mercury vapor surrounded by a fluorescent crystal, and are generally used on crowded roads that do not penetrate residential areas.

B- Lighting using devices covered with transparent plastic or glass materials gives wonderful aesthetic effects at the expense of performance, which requires focusing the lighting points more closely together than others.

According to AFE recommendations, the ratio between each two columns relative to the height of each column for Class A devices is equivalent to:

Main roads in major cities 3 - 3.5

Secondary internal roads 3.5-4

Important methods 3 - 4.5

Secondary roads 4-5

Secondary routes and crossings 5-7

As for second-level devices (B), it is necessary to reduce the dimensions of the above percentage by at least 25%.

Naturally, the lighting intensity levels remain very small due to the very wide surfaces that must be illuminated, especially in the first level category, which is divided into six categories:

1. Major roads with heavy traffic 16 - 32 lux
2. Luxurious commercial roads and public squares 16-35 lux
3. Roads with significant traffic 8 - 16 lux
4. Roads with moderate traffic 4-8 lux
5. Roads with little traffic 2-4 lux
6. Unpaved roads and temporary stake roads 1-2 lux

In general, these levels vary from one country to another depending on the level of focus and importance (the roads leading to the main airports of the capitals are often exaggerated in lighting levels) exceeding the table above by several stages - which is the distinguishing feature.

and municipalities in small cities and towns may tend to exaggerate to the point of obsession with lighting the facility or road established for reasons that may be primarily propaganda, which may reflect negatively on the efficiency of leadership in those areas.

Basics of public lighting design: [8]

There are many things that the designing engineer must take into consideration (other than the economic return or feasibility associated with the amperage draw factor) when designing public lighting, which can be summarized as follows:

• **Clarity:** We mean relatively clear vision at dusk or the appearance of twilight, as vision is at its lowest levels at that time.

• **Preventing dazzle:** Exaggerating the intensity of light and inconsistency in the intensity of illumination between points often leads to adverse results.

• **A gentle gradient between levels:** The driver's move from a dark (black) area on the public road to an over-illuminated area at the entrances to cities may not allow the pupil to constrict appropriately, which may result in catastrophic disasters, especially for drivers who suffer from night blindness or myopia, as in the example we presented in the introduction to this topic.

• **Polarization and dispersion:** The designer often forgets the environment in which he works, literally applying global tables, intentionally or unintentionally forgetting the intrinsic nature and specificity that is unique to each region.

High-humidity areas often condense water vapor at night or at dawn, forming fog that fog is the big Enemy of the driver, which makes the saturated lighting of that area a double-edged sword, as the light is polarized around the water vapor molecules, forming billions of polarized transparent points that at the same time become tiny mirrors that scatter the light in all directions, forming a dazzling area along the areas of fog condensation that may reach The visibility rate is zero for white light and to an extent close to zero for daylight bulbs (saturated orange).

The same thing also happens in dry, dusty places, where dust particles work by the same mechanism that water vapor works in high-humidity places.

Relatively high columns and quiet, not exaggerated lighting (about 8-12 lux) may be an ideal solution for lighting these areas.

• **Ease of maintenance:** The placement of poles or lighting points to obtain the highest possible utilization rate may conflict with the ease of access to those points for the purpose of maintenance.

This typical placement, from the point of view of lighting science, may be in places that are difficult to reach easily or pose a high risk to the lives of workers.

Especially in places with high traffic density where it may not be possible - even during minimum traffic hours - to stop traffic, even temporarily, such as suspension bridges and vital tunnels, the successful design is the design that puts this issue among the priorities (even at the expense of a low partial utilization rate of up to 10 - 15 %).

It is certain that there are many other factors and variables that have been overlooked and must be considered during design, as this research does not have room for them, and here we confirm that they can be referred to in references and specialized books; that our research does not intend to compete with.

***Black Light Bulbs:**

Figure 2: Black light Bulb Work on UVA Type

They are bulbs that operate on mercury vapor under high pressure, covered with a completely opaque glass material (not permeable to visible light), but they allow UVA radiation to pass through.

If these radiations fall on light patterns formed by phosphorescent bulbs, they excite them and give them changing colors, that different every time, these bulbs are usually used in theatres, dance halls, and parties held in open archaeological and historical places such as Roman amphitheaters and ancient castles.

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