# Stow Lighting Advisory Subcommittee
# Terminology Guide

| ***Revision*** | ***Date*** | ***Description*** |
|---|---|---|
| 1.0 | 5 Feb 2003 | Beginning of first draft. |
| 1.1 | 5 Mar 2003 | Added *Types of Lamps* subsection. |

*Table 1Revision History*

## Introduction

This terminology guide provides the members of the Stow Lighting Advisory Subcommittee a common foundation for discussing the measurement and production of light. It also helps the members to explain these concepts to town officials and the public, and to communicate clearly with vendors and manufacturers.

# Measurement of Light

In our everyday activities, we often compare light sources or their effects, but we don't often make detailed measurements of them. Most of the time, it suffices to simply say that this lamp is brighter than that one, or that this room is too dark. In order to make economic or other quantitative choices about lighting, we need a terminology for describing the measurement of light.

## *Flow of Light*

Turn on a flashlight and shine it onto the palm of one of your hands. You see your palm become brighter, and you might feel some warmth on it. A scientist or engineer would say that there is a flow of energy from the flashlight to your palm. We're familiar with the concept of energy; it's why we pay money to the electric utility each month. The rate at which electrical energy flows into our house is called power. The more lights and appliances we have turned on, the faster our electric meter spins, and the faster we consume a given amount of energy. Power is "energy per time." Electrical power is usually measured in watts. A 100-watt lightbulb consumes electrical energy at twice the rate of a 50-watt bulb; it requires twice the power.

An electric lightbulb converts electrical power into light power. We could measure light power in watts, but for most purposes that would be unsatisfactory. The reason is that the human eye does not respond uniformly to different colors, or wavelengths, of light. In normal, daytime vision, the eye is most sensitive to green light, and its sensitivity falls off towards both the redder colors (longer wavelengths) and the bluer colors (shorter wavelengths). One watt of green light would appear much brighter than one watt of deep red light.

The flow of light is usually measured in lumens. A lumen is similar in concept to a watt, but it takes human perception into account. One lumen of deep red light appears just as bright as one lumen of green light.[1] If a light source is giving off light of multiple colors — such as a typical white light source — then the lumens of each color can be added together to arrive at a total. To get a sense of size of the lumen, consider that a 100-watt, soft white, incandescent lightbulb gives off about 1,700 lumens and a candle gives off about 12 lumens.

The technical term for the flow of light is *flux.* That's simply Latin for *flow.*

## *Intensity of Light*

Consider the flashlight again. If you shine it into your eyes, it appears dazzling, even though the flashlight's bulb is small and much less powerful than, say, a 40-watt household bulb. The flashlight has a reflector behind the bulb. The reflector redirects the light that would shine to the sides and to the rear, and it funnels all the light into a tight beam to the front. The flashlight's bulb doesn't produce much total flux, but the reflector

1 It might be difficult to imagine comparing the brightnesses of lights of different colors, but vision scientists have devised tests for doing so.

concentrates that flux into a small range of directions. The reflector gives us an intense beam. In fact, the technical term for the amount of flux in a range of directions is *intensity.*

How can we give a number to "a range of directions?" The flashlight's beam is shaped like a cone. We need to be able to describe just how narrow or broad that cone is. This is conceptually similar to an angle on a flat surface. Think of a sector in a pie chart. The sector is formed by two lines from the center of the circular pie chart to its edge. The width of that sector is described by an angle. For our flashlight beam, we need to think of a cone with its point at the center of a sphere, and its base on the surface of the sphere. Just as the two lines in the circle form an angle, the cone in the sphere forms a solid angle.

Angles are usually measured in degrees, with 360 degrees in a full circle. Solid angles are usually measured in *steradians,* with $4\pi$ ("four pi") steradians in a full sphere. $\pi$ is about 3.14, so $4\pi$ is about 12.5. There are $2\pi$, or about 6.25, steradians in a hemisphere.

Intensity is usually measured in lumens per steradians. A lumen per steradian is often referred to as a *candela.* Sometimes light sources are rated by their beam candlepower; that's just the number of candelas in a small spot at the center of the beam. For a sense of size, big flashlights produce 10,000 to 20,000 beam candlepower (candelas at the center of the beam). Remember the 12-lumen candle? It throws its light more or less into a full sphere; therefore, its intensity in most directions is about one candela.

## Luminous Surfaces

The concept of intensity is useful for describing light sources that appear small: for example, the bulb in a flashlight or even a household bulb if we're at least a few feet away from it. These are called *point sources.* Many other light sources appear to have an appreciable surface: for example, the sky, a computer display screen, or an overhead fluorescent fixture with a translucent plastic cover. We certainly could measure the intensity that the fluorescent fixture produces in a particular direction, but that would obscure a key characteristic of the fixture.

If we were to double the surface area of the fixture (double the area of its translucent cover and also double the number of fluorescent tubes above it), we'd find that the intensity produced in a particular direction has doubled.[2] We describe such an *extended source* by the intensity it produces from each portion of its surface area. We measure this in *candelas per square meter.* A meter is a unit of length that's about 3.28 feet (say three and a quarter for easy mental calculation), thus a square meter is about 10.8 square feet (say 11for easy mental calculation).

A surface such as the fluorescent fixture's cover appears luminous. The characteristic that we measure in candelas per square meter is called, quite reasonably, *luminance.* The fluorescent fixture is a *self-luminous* surface (it gives off its own light), but luminance is

2 This is not strictly true, but it's a useful approximation in many situations.

also used to describe light that's reflected from surfaces that are *indirectly lighted,* such as a billboard. Luminance corresponds to our perception of a surface's brightness.

Some typical values of luminance are:

| ***Source*** | ***candelas per square meter*** |
| --- | --- |
| Surface of fluorescent light tube | 20,000 |
| Clear daytime sky at horizon | 10,000 |
| Full moon | 6,000 |
| Fluorescent light box for film viewing | 1,400 |
| Overcast daytime sky at horizon | 1,000 |
| Fluorescent kitchen ceiling fixture | 810 |
| Floor lamp's shade, with 100-watt incandescent bulb | 320 |
| LCD computer screen, displaying white | 150 |
| Heavy daytime overcast at horizon | 100 |
| White ceiling, middle of lighted living room at night | 2.2 |
| Clear sky 15 min after sunset at horizon | 1 |
| Moonless, clear night sky at horizon | 0.001 |
| Moonless, overcast night sky at horizon | 0.0001 |

*Table 2Typical Luminances*

## *Illumination*

Flux, intensity, and luminance are all interesting characteristics of light sources, but ultimately we care about how much light is falling on some object which we care to see. Those lumens, candelas, and candelas per square meter become useful when they illuminate objects.

If you're trying to read a page of a newspaper, each portion of its surface area needs to be illuminated with some flow of light in order to be legible. This quantity of illumination is called *illuminance,* and it's usually measured in *lumens per square meter.* A common name for lumens per square meter is *lux.*

Lux actually appear in specifications for certain consumer products, namely camcorders. Some manufacturers say their camcorders need less than 1lux. They're claiming that a typical scene[3] with only 1 lumen per square meter of illuminance on all the objects in it will be recorded by the camcorder. It probably won't be recorded very well; a minimum illuminance of 100 lux is sometimes recommended for decent

3 A "typical scene" is one in which the objects aren't all very dark or all very light.

recordings. Even more illuminance is needed for high quality; that' swhy television studios are so strongly illuminated.

There are industry guidelines for how much illuminance is recommended for various locations and activities. Some examples are:

| ***Location or Activity*** | ***Recommended Illuminance, lux*** |
|---|---|
| Neighborhood shopping parking lot | 8.6 |
| Airport parking lot | 26 |
| Roadway lighting: local road | 3.2 |
| Roadway lighting: major freeway | 8.6 |
| Inactive building entrances and building surrounds | 11 |
| Active building entrances and vital areas | 54 |
| Service station approaches, with dark surroundings | 16 |
| Service station pump islands, with dark surroundings | 220 |
| Sports stadiums for televised events | 1,000 |

*Table 3Recommended Illuminances*

Some examples of illuminances produced by various sources are:

| ***Source*** | ***Illuminance, lux*** |
|---|---|
| Overhead sun | 130,000 |
| Full daylight (not direct sun) | 10,000 – 20,000 |
| Overcast day | 1,000 |
| Indirect daylight through window, room interior | 180 |
| Electric lights in a living room, nighttime | 28 |
| Twilight | 10 |
| Full moon overhead | 0.27 |
| Clear night, no moon or artificial light | 0.002 |

*Table 4Illuminances From Various Sources*

# Production of Light

In our everyday experiences, we encounter two types of artificial light sources: incandescent and fluorescent. These take care of the lighting needs in and around most of our houses and businesses. For other applications, such as roadway lighting, other types of sources are often employed. We' llexamine the variety of sources, looking at characteristics including operation, efficiency, and color effects.

## *New Names*

Before getting into the examination, we need to learn some new names for familiar devices. This is because our everyday terms are not what the lighting industry uses.

We talk about screwing a lightbulb into a lamp, say a floor lamp. However, the lighting industry uses *lamp* to refer to the actual source of light, in other words, what we call the lightbulb. Furthermore, the lighting industry uses *luminaire* to refer to what we often call a fixture. The luminaire is the device which directs, controls, or modifies the light produced by a lamp. It includes the necessary mechanical, electrical, and decorative parts. An example of a luminaire would be the housing, socket, reflector, and lens of a streetlight.

## *Types of Lamps*

Lamps can be categorized by the physical processes they use to produce light. The two most common categories of electric lamps are *incandescent* lamps and *electric-discharge* lamps.

In incandescent lamps, electricity flows through a wire filament, heating it to such a high temperature that it glows. The typical example of an incandescent lamp is the common household lightbulb.[4] There are improved versions of incandescent lamps, such as the tungsten-halogen lamp, sometimes used in torchère lighting fixtures.

In electric-discharge lamps, electricity flows through a gas or vapor, stimulating atoms to give off light. Fluorescent tubes, including compact fluorescents, are common examples. A subcategory, the *high-intensity discharge* lamps, includes the lamps commonly used for street and other outdoor lighting: mercury-vapor, metal-halide, high-pressure sodium-vapor, and low-pressure sodium-vapor lamps.

The important characteristics of different types of lamps include the following:

- Lumens produced.
- Power efficiency: how many lumens are produced for each watt of electricity.
- Initial cost of the lamp and its luminaire.

4 Non-electric incandescent light sources include candles, gas lanterns, and the sun.

- Operating lifetime.
- Efficiency reduction over time.
- Starting: suitable for frequent on/off operation or better suited for all-night operation.
- Color rendering: does the lamp' s light change the appearance of colors.
- Continuous or line spectrum (can the light be effectively filtered out during astronomical observations)

Before we get into the details, some general comparisons can be made between incandescent and electric-discharge lamps. Incandescent lamps generally have lower initial costs but are also less efficient and have shorter lifetimes. Electric-discharge lamps usually don' twork well in frequent on/off operation. Certain high-intensity discharge lamps give color rendering very different from daylight, but those are also the ones whose light is most easily filtered from astronomical observations. Incandescent light cannot be filtered at all.