Light measurement

Candelas **are a measure of Luminous intensity, which is the amount of light generated at the point of source.**
All quantitative measurements related to light are derived from the *Candela*.

The original standard light source was a candle, and the measurement unit was called *Candlepower*. This was naturally inaccurate and could not be scientifically standardised, so since the late 1940's the *Candela* has been regarded as the standard unit of measurement (**SI**) and mathematically calculated, but still equates to approximately the same intensity as the original candle.
When torches are advertised using Candlepower as a measurement of light, it is an outdated method and like the modern Candela, doesn't define how much light is actually emitted from the torch or, significantly, how useable the beam of light is for a specific task.

Lumens ***(or Luminus flux)*** **is a measurement of the total amount of light which flows away from the source in all directions, as (theoretically) seen by the human eye.**
When used for torches it is sometimes written as, *out of the front (OTF) Lumens*, this is what actually comes out of the torch as opposed to the *manufacturers ratings*, which is what the *LED (Light Emitting Diode)*, in isolation, is 'theoretically' capable of in laboratory conditions over a very short period.

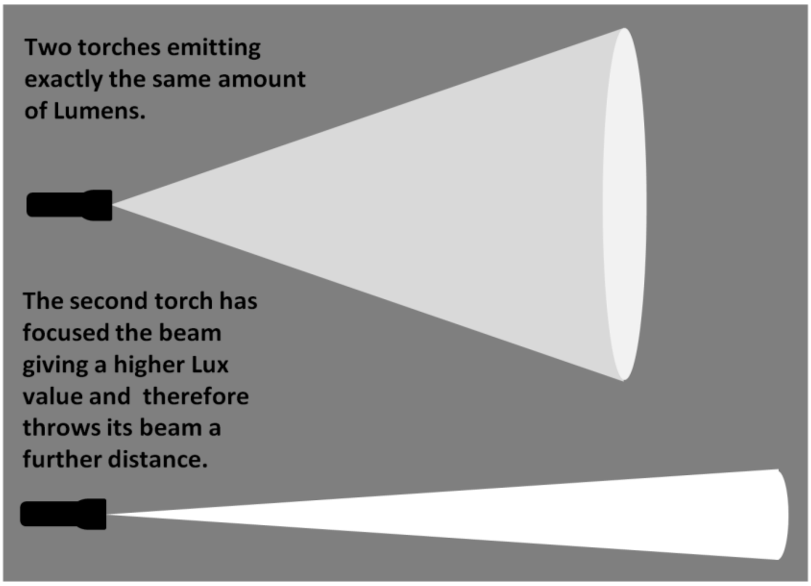
Just to make things a little more complex, *lumens* relate to the eye's sensitivity and depend on the wavelength (colour) of the light. The true point to measure *lumens* is at 555nm, (a nanometre or nm is the unit used to measure wavelengths of the electro-magnetic spectrum, of which light is a very small part) which is a yellow green colour and is where the eye, in daylight situations, is most sensitive.
This does not take into account the full spectrum of light produced by the *LED* or the fact that torches will be used in the dark, when your eyes become dark adapted (scotopic vision) and using the eyes' rod receptors in the retina which have a lower peak sensitivity of around 507nm (a blue green colour).
A traditional house 60 *watt* light bulb will give off around 900 *Lumens*, more than most high powered *LED* torches. Imagine holding that up to see something in the distance, it would only light you up and you would lose all night vision.
This just illustrates that *Lumens* alone offer very little guide to any torches potential use.
A good way to demonstrate what *Lumens* can show is to place a torch on the floor of a white room facing towards the ceiling (this is referred to as the "bounce test"). It is a good indication of how well it appears to fill the room with light.

Lux **is a measure of the intensity of illumination on a surface.**
Lux indicates how well the surface area of an object is illuminated at a given distance away from the light source. It is the intensity of the light reflecting off an object such as a wall. It could also be referred to as 'one *Lumen* per square metre'.

1000 Lumens concentrated into an area of one square metre, lights up that square metre with an illuminance of 1000 Lux.
The same 1000 lumens spread out over ten square metres, produces a dimmer illuminance of only 100 Lux.
From this measurement you can at least get an idea of how far away the torch will light an object and how brightly you will perceive the object to be. It won't however give any clues to the beam pattern or how large an area the torch will illuminate.

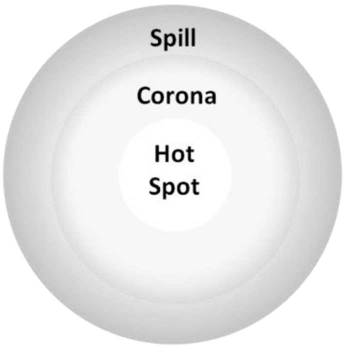
- *Sunlight on an average day ranges from 32,000 to 100,000 Lux (or Lumens per square metre) at the Earth's surface.*
- *Moonlight represents around 1 Lux at the Earth's surface. This is often used as a bench mark to indicate the maximum useable throw of a torch's beam.*
- *Work surfaces in a bright office usually reach about 400 Lux of illumination (i.e. 400 Lumens per square metre)*

An example to summarise *Candelas, Lumens and Lux*.
Take a light source of 1 *Candela*, which will also be approximately 1 C*andlepower* in intensity. If you measured the light intensity on a surface measuring 1 square metre, which was 1 metre away from the light source, it would have 1 *Lux* of illuminance. The light source is generating 1 *Lumen* in the direction of the 1 square metre that is 1 metre away. If the light source is in the middle of an 'integrating sphere' (the equipment used to measure *Lumens*), and emitting light in all directions, it would calculate that the 1 *Candela* light source is generating 12.57 *Lumens*.



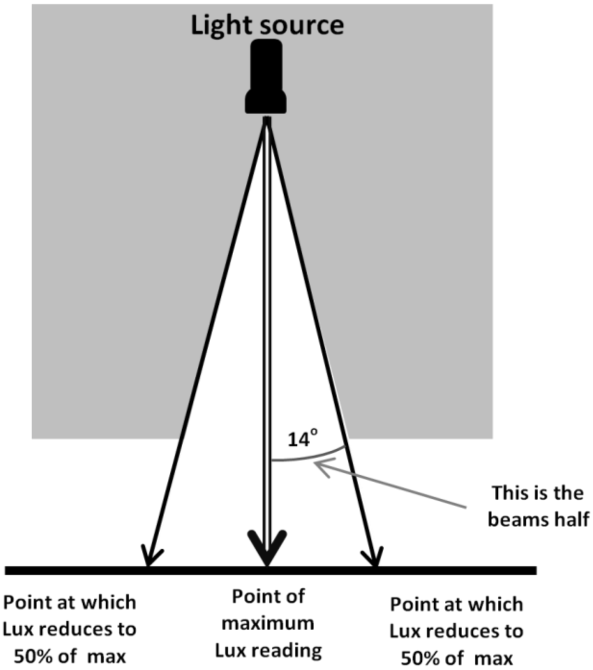
***<u>Watts</u>* refer to the amount of energy consumed to drive the light source.**
The efficiency of the bulb and optics will determine how bright the *LED* is (*Candela*s) and how much light is emitted (*Lumens*) from the torch.
An inefficient torch will emit far less light than a highly efficient torch, so this tells you very little of how the torch will actually perform. The *LED* will also produce more heat which could damage it, and will need a larger casing to conduct the heat away from the *LED*.

***<u>Beam anatomy</u>*; *Hotspot, Corona and Sidespill* are the 3 parts of a torches beam pattern.**
The *Hotspot* is the brightest, most concentrated part of the beam at the centre, and enables the torch to throw the beam a long distance.
The *Corona* surrounds the H*otspot*, although not as bright, it creates a fuller beam enabling general use of the torch.
Sidespill (or *Spill*) is the light coming directly from the *LED*, having missed the reflector, and dimly lights the surrounding area, offering the user some peripheral vision.

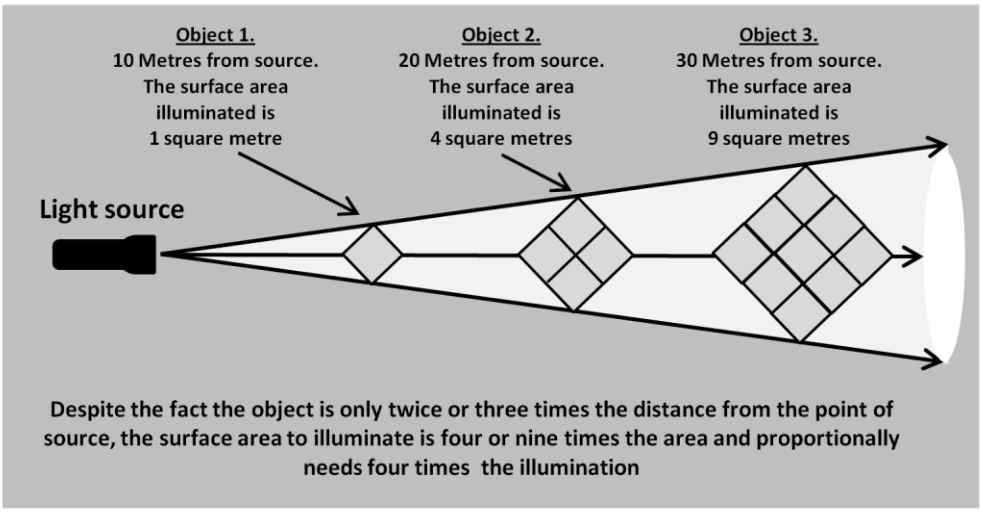


The anatomy of the beam can vary greatly depending on how the light is gathered and focused, using mirrors or lenses. If all the light being emitted is captured and manipulated into an extremely tight beam, it is possible to have little or no *Corona* and no *Spill*. This would be regarded as extremely efficient and depending on the size and intensity of the *LED's* surface, would determine exactly how tight the beam was and how far it would throw the light.
A torch with such a tight beam would only have specialist uses though, so by altering the focus some of the light can be distributed to the *Corona*, giving a wider and less intense beam of light. The *Sidespill* is the light thrown forwards by the *LED*, but at a slight angle, and completely missing the reflector, so isn't focused at all into the main beam. The more light in both the *Corona* and *Sidespill* would directly reduce the light in the *Hotspot*, therefore giving a wider beam but with less throw.
In practice this means a far lower *Lumen* rated torch, which is efficiently focused, can appear brighter and throw much further than a less efficiently focused higher *Lumen* rated torch. The higher *Lumen* rated *LED* would generate more heat, needing larger and heavier heat sinking to dissipate the heat away from the *LED* to protect it, and would also consume more battery power.
This is critical knowledge when buying an appropriate torch and not just one displaying the highest *Lumens* rating.

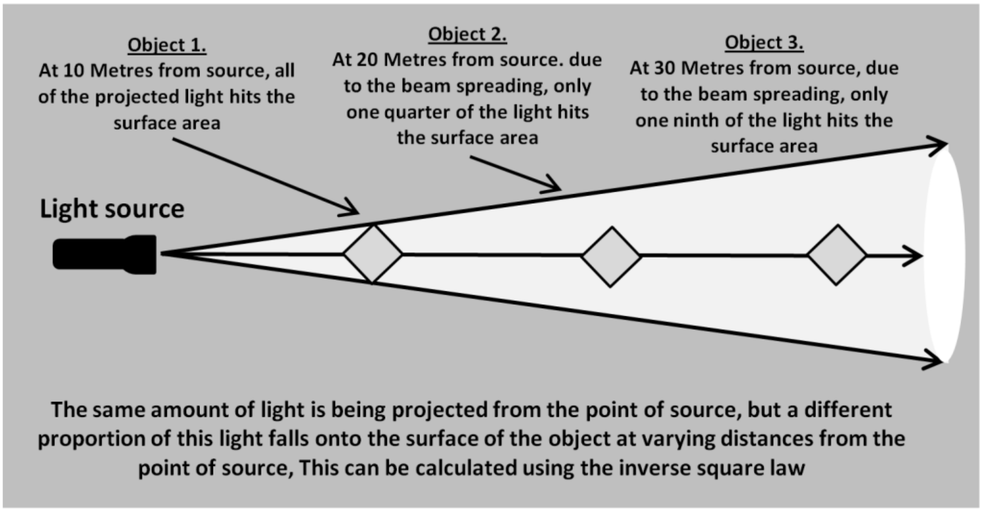
The Beam's *<u>Half angle</u>* shows the point at which the beam of light's luminous intensity drops to half that of the maximum luminous intensity, in the Hotspot, which is the most concentrated area of the beam at the centre.
Although this does not completely explain the whole of beam pattern, it can be used to clearly show whether it's a tight or a wide spread (floody) beam.



How the inverse-square law applies to a beam of light.
To equally illuminate an object twice the distance from the point of source, the beam requires four times the amount of light**.**



Equally an object two times the distance away will receive quarter the amount of light and record one quarter the *Lux* reading. The light appears dimmer on the surface due to the beam of light spreading, and a smaller proportion of the light hitting the object.



The alternatives to increasing the *Lux* reading and improving a torches ability to throw light further, are to increase the *Lumen* output or to focus the *Lumens* being emitted more efficiently.
Using a more powerful *LED* or driving an *LED* harder will increase the *Lumen* output but could shorten its life span due to the extra heat generated, so a solution needs to be found to conduct the heat away from the *LED* (an efficient thermal path), this though will add bulk and weight to the torch which is undesirable. The extra energy required to drive the *LED* harder will also require more energy, which equates to a shorter battery life or more batteries, bulk and weight.

The other, more suitable, solution would be to use the most appropriate *LED*, which is the CREE 7090 XR-E (EZ900), as it possesses the smallest and most intense surface area, and throws the light forwards at a tight angle of 90 degrees, and combine it with the most suitable optic, which would be an *Aspherical lens*. It would produce less than 200 (OTF) Lumens, but would maximize the light emitted.

Gathering and focusing the light emitted more efficiently using Lenses and mirrors, creates an intense *Hotspot* with less *Corona* and *Sidespill*. Although reducing the flood lighting and peripheral vision, all the light emitted would be channelled into throwing the beam as far as possible.

An interesting analogy to demonstrate the effect of focusing light is the garden hose pipe.
Attach a shower head to the end of a hose pipe and the water would spray fine droplets over a large area but not shoot out very far, attach a jet nozzle to the pipe and it would cover a very narrow area but would shoot out a long way. With the jet nozzle attached the water supply could be turned down and still shoot out a greater distance than with the shower head.

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