Units of light intensity

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THE FLUX of propagating light is known as the light field and is described in detail in the article *The underwater light field* in this series. The radiant intensity of a light field may be measured in Watts $m^{-2,}$ Einstein $s^{-1}m^{-2}$ or lux depending upon the use of the measurements. It is emphasized here that in any particular optical situation only one of these units is correct, and the appropriate metering system should be employed.

Watts m^{-2}

Light form of e-m energy (joules, J). Its flux is therefore Js^{-1} = watts, W, *i.e.* power. We usually need to measure the *intensity* of a light field, *i.e.* the energy flux per unit area. The SI unit of light intensity is therefore: Wm^{-2}**.** This measure should be employed when the absolute (SI) intensity is needed.

Photons $s^{-1}m^{-2}$ or Quanta $s^{-1}m^{-2}$

We have that the energy, *e*, in one photon is:

$$e = h.\nu = \frac{h.c}{\lambda}$$

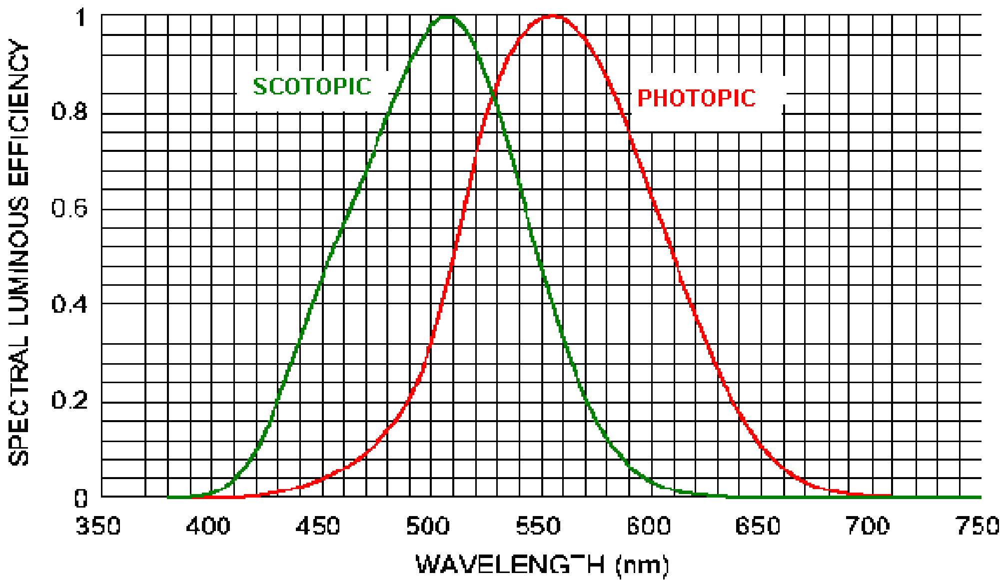
This is the smallest possible quantity of light energy and the quantum unit of light energy flux is: photons s^{-1}, and the quantum intensity: quanta $s^{-1}m^{-2}$or photons $s^{-1}m^{-2}$. Since this system of measure is appropriate to photochemical work (*e.g.* photosynthesis), then a useful unit of intensity is the Einstein $s^{-1}m^{-2}$ where the Einstein, *E*, is Avogadro's number of photons *i.e.* a *mole* of photons:

$$E = \frac{N_A.h.c}{\lambda}$$

where NA = Avagadro's number = 6.022 x 1023 *mole*$^{-1}$

Lux

We frequently need to measure light intensity in a situation which is somehow related to human vision, *e.g.* diver visibility, illumination *etc*. The sensitivity of the human eye is such that, like any sensor, it does not detect all wavelengths (colours) equally well. For example, the human eye detects green light with about twice the sensitivity of orange light of the same absolute intensity (Wm^{-2}). The unit of apparent light intensity, based upon the spectral sensitivity of the human eye, is the lux. At 555 nm (yellow-green), the peak of sensitivity of the human eye, an absolute intensity of 1 Wm^{-2} gives rise to an apparent intensity of 685 lux. The spectral sensitivity of the human eye, and hence the equivalence between lux and Wm^{-2}, is illustrated in the figure below. The *photopic curve* refers to human 'daylight' vision whereas the *scotopic curve* is for human 'night' vision. In effect, these curves define the relationship between the human sensation of light and the physical light energy giving rise to that sensation. The spectral luminous efficiency, V(l), is the sensitivity relative to the peak (= 1) at 555 nm for daylight vision.



The relative luminosity or photopic curve

Given that an intensity of 1 Wm^{-2} is equivalent to 685 lux at 555 nm, then *Fig.5* may be used to calculate the equivalence at any other wavelength. For example, at *l* = 680 nm (red) the curve gives: *V*(*l*) » 0×12, so a yellow-green light (555 nm) will appear to be 1/0×12 = 8×3 times as bright as a red light (650 nm) of the same absolute intensity (Wm^{-2}). Or, yellow-green light of 0×12 Wm^{-2} will appear to be of the same brightness as a red light of 1 Wm^{-2}; or that 1 Wm^{-2} yellow-green light will have an apparent brightness of 685 lux, whilst a red light of 1 Wm^{-2} will have an apparent brightness of 685 ´ 0×12 = 82 lux, and so on. Typical lux values, out of doors in different situations of natural illumination are presented in the table below:

Typical lux levels

Situation	*Likely light level in lux*
sunlight	100000
full daylight	10000
overcast day	1000
dark day	100
twilight	10
deep twilight	1
full moon	0.1
quarter moon	0.01
starlight	0
overcast night	0.0001

Summary

- Light may be measured in Watts m^{-2}, Einstein $s^{-1}m^{-2}$ or lux depending upon the use of the measurements. In any particular optical situation only one of these units is correct, and the appropriate metering system should be employed.

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