

Lux

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The **lux** (symbol: **lx**) is the SI unit of illuminance and luminous emittance, measuring luminous flux per unit area.^[1] It is equal to one lumen per square metre. In photometry, this is used as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface. It is analogous to the radiometric unit watts per square metre, but with the power at each wavelength weighted according to the luminosity function, a standardized model of human visual brightness perception. In English, "lux" is used in both singular and plural form.^[2]

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A lux meter for measuring illuminances in work places.

Explanation

Illuminance

Illuminance is a measure of how much luminous flux is spread over a given area. One can think of luminous flux (measured in lumens) as a measure of the total "amount" of visible light present, and the illuminance as a measure of the intensity of illumination on a surface. A given amount of light will illuminate a surface more dimly if it is spread over a larger area, so illuminance (lux) is inversely proportional to area when the luminous flux (lumens) is held constant.

One lux is equal to one lumen per square metre:

$$1 \text{ lx} = 1 \text{ lm/m}^2 = 1 \text{ cd}\cdot\text{sr/m}^2$$

A flux of 1000 lumens, concentrated into an area of one square metre, lights up that square metre with an illuminance of 1000 lux. However, the same 1000 lumens, spread out over ten square metres, produces a dimmer illuminance of only 100 lux.

Achieving an illuminance of 500 lux might be possible in a home kitchen with a single fluorescent light fixture with an output of 12 000 lumens. To light a factory floor with dozens of times the area of the kitchen would require dozens of such fixtures. Thus, lighting a larger area to the same level of lux requires a greater number of lumens.

As with other SI units, SI prefixes can be used, for example a kilolux (klx) is 1000 lux.

Here are some examples of the illuminance provided under various conditions:

Illuminance (lux)	Surfaces illuminated by
0.0001	Moonless, overcast night sky (starlight) ^[3]
0.002	Moonless clear night sky with airglow ^[3]
0.27–1.0	Full moon on a clear night ^{[3][4]}
3.4	Dark limit of civil twilight under a clear sky ^[5]
20–50	Public areas with dark surroundings ^[6]
50	Family living room lights (Australia, 1998) ^[7]
80	Office building hallway/toilet lighting ^{[8][9]}
100	Very dark overcast day ^[3]
320–500	Office lighting ^{[7][10][11][12]}
400	Sunrise or sunset on a clear day.
1000	Overcast day, ^[3] typical TV studio lighting
10,000–25,000	Full daylight (not direct sun) ^[3]
32,000–100,000	Direct sunlight

The illuminance provided by a light source, on a surface perpendicular to the direction to the source, is a measure of the strength of that source as perceived from that location. For instance, a star of apparent magnitude 0 provides 2.08 microlux at the earth's surface.^[13] A barely perceptible magnitude 6 star provides 8 nanolux.^[14] The unobscured sun provides an illumination of up to 100 kilolux on the Earth's surface, the exact value depending on time of year and atmospheric conditions. This direct normal illuminance is related to the solar illuminance constant E_{sc} , equal to 128 000 lux (see Sunlight).

The illumination provided on a surface by a point source equals the number of lux just described times the cosine of the angle between a ray coming from the source and a normal to the surface. The illumination provided by a light source that covers a large solid angle is proportional to the cosine of the angle between the surface normal and a sort of barycentre of the light source, so long as all of the source is above the plane of the surface. The number of lux falling on the surface equals this cosine times a number (in lux) that characterizes the source from the point of view in question.

Luminous emittance

The lux is also a measure of luminous emittance, the number of lumens given off by a surface per square metre, regardless of how that light is distributed in terms of the directions in which it is emitted. It differs from the luminance (measured in candela per square metre or "nits"), which does depend on the angular distribution of the emission. A perfectly white surface with one lux falling on it will emit one lux.

Relationship between illuminance and irradiance

Like all photometric units, the lux has a corresponding "radiometric" unit. The difference between any photometric unit and its corresponding radiometric unit is that radiometric units are based on physical power, with all wavelengths being weighted equally, while photometric units take into account the fact that the human eye's image-forming visual system is more sensitive to some wavelengths than others, and accordingly every wavelength is given a different weight. The weighting factor is known as the luminosity function.

The lux is one lumen per square metre (lm/m^2), and the corresponding radiometric unit, which measures irradiance, is the watt per square metre (W/m^2). There is no single conversion factor between lx and W/m^2 ; there is a different conversion factor for every wavelength, and it is not possible to make a conversion unless one knows the spectral composition of the light.

The peak of the luminosity function is at 555 nm (green); the eye's image-forming visual system is more sensitive to light of this wavelength than any other. For monochromatic light *of this wavelength*, the amount of illuminance for a given amount of irradiance is maximum: 683.002 lux per W/m^2 ; the irradiance needed to make one lux at this wavelength is about $1.464 \text{ mW}/\text{m}^2$. Other wavelengths of visible light produce fewer lux per watt-per-meter-squared. The luminosity function falls to zero for wavelengths outside the visible spectrum.

For a light source with mixed wavelengths, the number of lumens per watt can be calculated by means of the luminosity function. In order to appear reasonably "white," a light source cannot consist solely of the green light to which the eye's image-forming visual photoreceptors are most sensitive, but must include a generous mixture of red and blue wavelengths to which they are much less sensitive.

This means that white (or whitish) light sources produce far fewer lumens per watt than the theoretical maximum of 683.002 lm/W. The ratio between the actual number of lumens per watt and the theoretical maximum is expressed as a percentage known as the luminous efficiency. For example, a typical incandescent light bulb has a luminous efficiency of only about 2%.

In reality, individual eyes vary slightly in their luminosity functions. However, photometric units are precisely defined and precisely measurable. They are based on an agreed-upon standard luminosity function which is based on measurements of the spectral characteristics of image-forming *visual photoreception* in many individual human eyes.

Use in video camera specifications

Specifications for video cameras such as camcorders and surveillance cameras often include a minimum illuminance level in lux at which the camera will record a satisfactory image. A camera with good low-light capability will have a lower lux rating. Still cameras do not use such a specification, since longer exposure times can generally be used to make pictures at very low illuminance levels, as opposed to the case in video cameras where a maximum exposure time is generally set by the frame rate.

Non-SI units of illuminance

The corresponding unit in English and American traditional units is the foot-candle. One foot candle is about 10.764 lux. Since one foot-candle is the illuminance cast on a surface by a one-candela source one foot away, a lux could be thought of as a "metre-candle", although this term is discouraged because it does not conform to SI standards for unit names.

One phot (ph) equals 10 kilolux.

One nox (nx) equals 1 millilux.

In astronomy, apparent magnitude is a measure of the illuminance of a star on the Earth's atmosphere. A star with apparent magnitude 0 is 2.54 microlux outside the earth's atmosphere, and 82% of that (2.08 microlux) under clear skies.^[13] A magnitude 6 star (just barely visible under good conditions) would be 8.3 nanolux. A standard candle (one candela) a kilometre away would provide an illuminance of 1 microlux—about the same as a magnitude 1 star.

Legacy Unicode symbol

Unicode has a symbol for "lx": (l×). It is a legacy code to accommodate old code pages in some Asian languages. Use of this code is not recommended.

SI photometry units

SI photometry quantities

Quantity		Unit		Dimension	Notes
Name	Symbol ^[nb 1]	Name	Symbol	Symbol	
Luminous energy	Q_v ^[nb 2]	lumen second	lm·s	T·J ^[nb 3]	Units are sometimes called <i>talbots</i> .
Luminous flux / luminous power	Φ_v ^[nb 2]	lumen (= cd·sr)	lm	J ^[nb 3]	Luminous energy per unit time.
Luminous intensity	I_v	candela (= lm/sr)	cd	J ^[nb 3]	Luminous power per unit solid angle.
Luminance	L_v	candela per square metre	cd/m ²	L⁻²·J	Luminous power per unit solid angle per unit <i>projected</i> source area. Units are sometimes called <i>nits</i> .
Illuminance	E_v	lux (= lm/m ²)	lx	L⁻²·J	Luminous power <i>incident</i> on a surface.
Luminous exitance / luminous emittance	M_v	lux	lx	L⁻²·J	Luminous power <i>emitted</i> from a surface.
Luminous exposure	H_v	lux second	lx·s	L⁻²·T·J	
Luminous energy density	ω_v	lumen second per cubic metre	lm·s·m ⁻³	L⁻³·T·J	
Luminous efficacy	η ^[nb 2]	lumen per watt	lm/W	M⁻¹·L⁻²·T³·J	Ratio of luminous flux to radiant flux or power consumption, depending on context.
Luminous efficiency / luminous coefficient	V			1	
See also: SI · Photometry · Radiometry					

- Standards organizations recommend that photometric quantities be denoted with a suffix "v" (for "visual") to avoid confusion with radiometric or photon quantities. For example: *USA Standard Letter Symbols for Illuminating Engineering* USAS Z7.1-1967, Y10.18-1967
- Alternative symbols sometimes seen: *W* for luminous energy, *P* or *F* for luminous flux, and *ρ* or *K* for luminous efficacy.
- "**J**" here is the symbol for the dimension of luminous intensity, not the symbol for the unit joules.

See also

- Exposure value

Notes and references

1. SI Derived Units (<http://physics.nist.gov/cuu/Units/units.html>), National Institute of Standards and Technology
2. NIST Guide to SI Units - 9 Rules and Style Conventions for Spelling Unit Names (<http://physics.nist.gov/Pubs/SP811/sec09.html>), National Institute of Standards and Technology
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14. Schlyter, Section 14. (<http://stjarnhimlen.se/comp/radfaq.html#14>)

External links

- Radiometry and photometry FAQ (<http://fp.optics.arizona.edu/Palmer/rpfaq/rpfaq.htm>) Professor Jim Palmer's Radiometry FAQ page (University of Arizona).

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Categories: SI derived units | Units of illuminance | Photometry

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