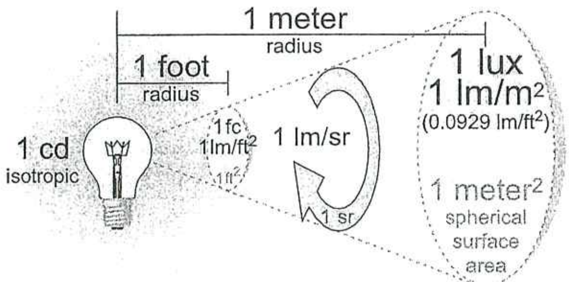
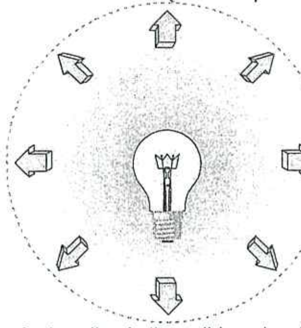
IRRADIANCE & ILLUMINANCE
(Flux per unit area, or flux density)



Inverse Square Law: Irradiance varies in inverse proportion to the square of the distance. $E=I/d^2$. If you measure 16 lm/m^2 at 1 meter from a point source, you will measure 4 lm/m^2 at 2 m, etc. Point source approx.(±1%): [distance : lamp diameter] > [5 : 1].

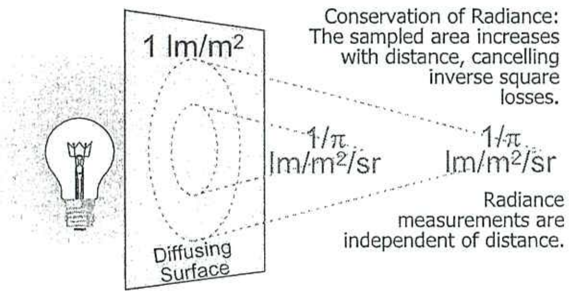
RADIANT & LUMINOUS FLUX
(Total optical power, or flux)



Flux is the basic unit of optical power, expressed in watts or lumens. An integrating sphere is often used to collect the light emitted in all directions (4π sr). Light in a narrow collimated beam can be measured directly with a planar receiver, provided the source underfills the receiver. Dose energy can be measured by integrating the optical power over time.

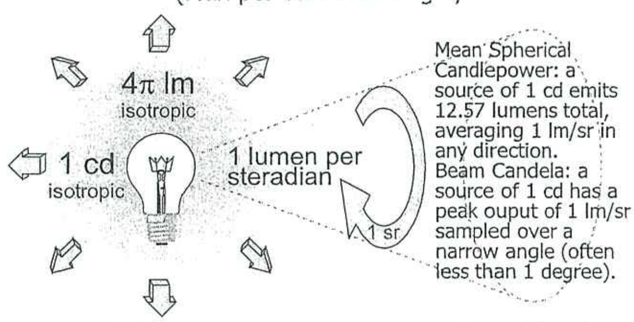
A steradian is the solid angle whose projected spherical surface area is equal to the square of its radius. A sphere contains 4π sr.

RADIANCE & LUMINANCE
(Flux density per unit solid angle)



1 lux (1 lm/m^2) of illuminance on a perfectly diffusing surface produces 1 apostilb ($1/\pi$ $lm/m^2/sr$) of luminance. Similarly, 1 foot-candle (1 lm/ft^2) will result in 1 foot-lambert ($1/\pi$ $lm/ft^2/sr$).

RADIANT & LUMINOUS INTENSITY
(Flux per unit solid angle)



1 cd (MSC) = 1 cd (Beam) for an isotropic source. A 1 cd (MSC) laser beam may have 1,000,000 cd (Beam) output.

Power:

1 watt (W)
- = 0.27 lm @ 400nm
- = 25.9 lm @450 nm
- = 220.0 lm @ 500 nm
- = 679.0 lm @ 550 nm
- = 683.0 lm @ 555 nm
- = 430.0 lm @ 600 nm
- = 73.0 lm @ 650 nm
- = 2.78 lm @ 700 nm

1 lumen (lm)
- = 1.464×10^{-3} W @ 555 nm
- = 7.958×10^{-2} candela (4π sr)

1 joule (J)
- = 1 watt∗second
- = 1×10^{7} erg
- = 0.2388 gram∗calories

1 lm∗second
- = 1 talbot (T)
- = 1.464×10^{-3} joules @ 555 nm

Irradiance:

1 W/cm^2
- = 1×10^{4} W/m^2
- = 6.83×10^{6} lux @ 555 nm
- = 14.33 g∗cal/cm^2/min

1 lm/m^2
- = 1 lux
- = 1×10^{-4} lm/cm^2
- = 1×10^{-4} phot (ph)
- = 9.290×10^{-2} lm/ft^2
- = 9.290×10^{-2} foot-candles (fc)

Intensity:

1 watt/steradian (W/sr)
- = 12.566 watts (isotropic)
- = 683 candela @ 555 nm

1 lumen/steradian (lm/sr)
- = 1 candela (cd)
- = 12.566 lumens (isotropic)
- = 1.464×10^{-3} W/sr @ 555 nm

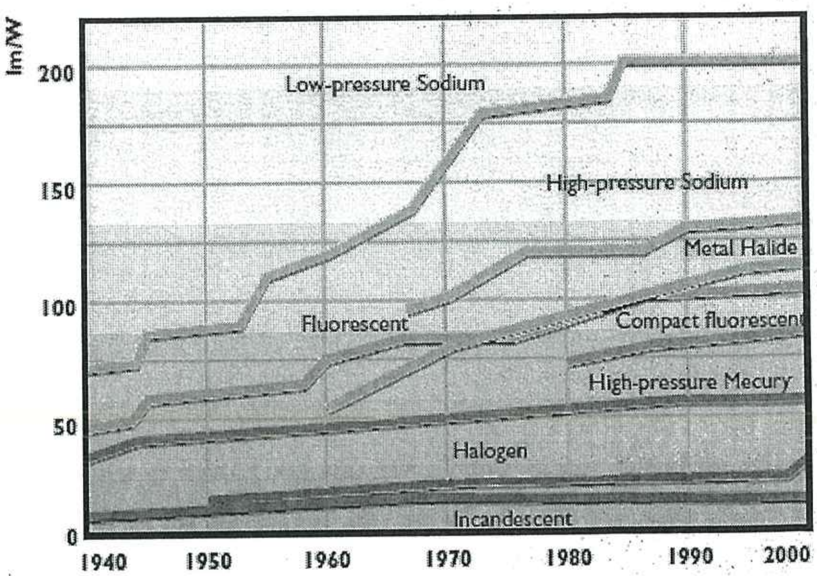
Radiance:

1 $W/cm^2/sr$
- = 6.83×10^{6} $lm/m^2/sr$ @ 555 nm
- = 683 cd/cm^2 @ 555 nm

1 $lm/m^2/sr$
- = 1 candela/m^2 (cd/m^2)
- = 1 nit
- = 1×10^{-4} $lm/cm^2/sr$
- = 1×10^{-4} cd/cm^2
- = 1×10^{-4} stilb (sb)
- = 9.290×10^{-2} cd/ft^2
- = 9.290×10^{-2} $lm/ft^2/sr$
- = 3.142 apostilbs (asb)
- = 3.142×10^{-4} lamberts (L)
- = 2.919×10^{-1} foot-lamberts (fL)

Overview of some typical lighting sources

Lamp type	Luminous flux (lm)	Luminous (lm) efficacy (lm/W)	Colour temperature (K)	Colour rendering index (R_a)	Power (W)
Incandescent/halogen	60 – 48400	5 – 27	2700 – 3200	100	5 – 2000
Low-pressure sodium	1800 – 32500	100 – 203	1700		18 – 180
High-pressure sodium	1300 – 90000	50 – 130	2000, 2200, 2500	10 – 80	35 – 1000
High-pressure mercury	1700 – 59000	35 – 60	3400, 4000, 4200	40 – 60	50 – 1000
Fluorescent	200 – 8000	60 – 105	2700, 3000, 4000, 6500	60 – 95	5 - 80
Compact fluorescent	200 – 12000	50 – 85	2700, 3000, 4000, 6500	80	5 – 165
Metal halide	5300 – 220000	75 – 140	3000, 4000, 5600	65 – 95	70 – 2000
Ceramic metal halide	1500 – 23000	68 – 95	3000 – 4200	80 – 95	20, 35, 70, 150, 250
LED	10 – 170	Up to 50	3000 – 8000	up to 90	0,1 – (x)3W



Development of luminous efficacy from 1970 onwards

$$\text{Efficacy (lm/W)} = \frac{\text{Luminous flux (lm)}}{\text{Power input (W)}}$$