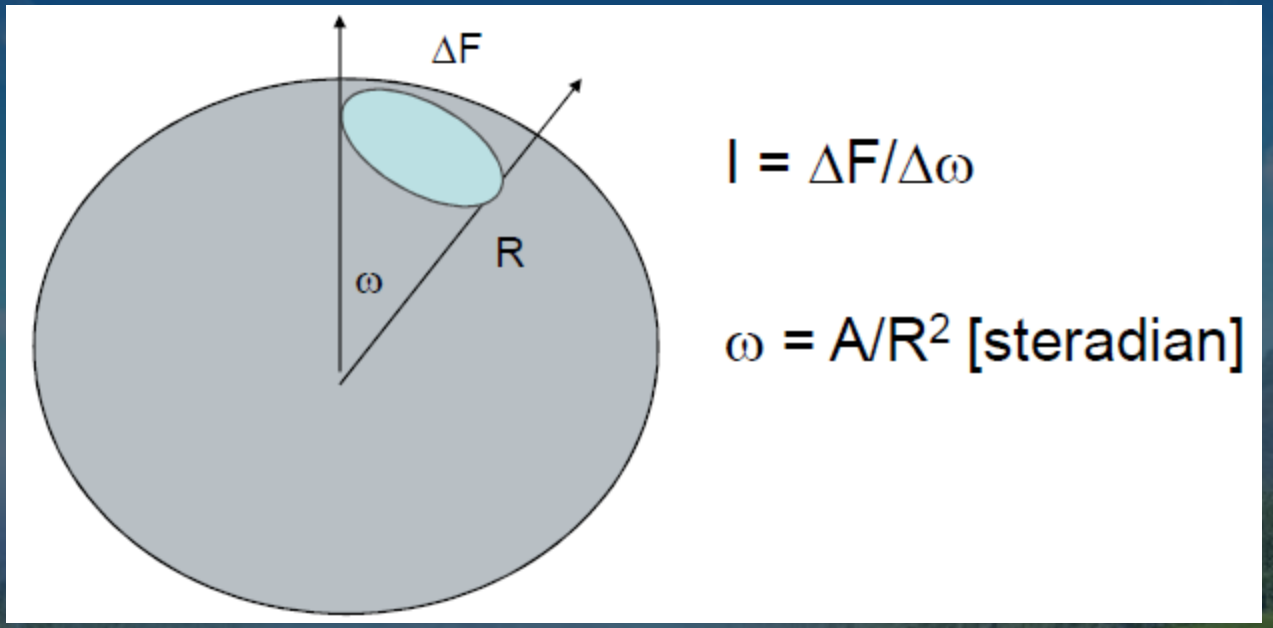
BAGIAN A : CAHAYA

BESARAN KUANTITATIF CAHAYA

Besaran Kuantitatif Cahaya

- Fluks radian (satuannya Watt, notasi P) : Energi radian yang sampai pada suatu permukaan per satuan waktu.
- Fluks Luminous (satuannya lumen, notasi F) : Fluks radian yang dinilai terhadap kemampuannya untuk menimbulkan rangsangan terang
- Intensitas Cahaya (satuannya Candela, Notasi I) : Kuat cahaya yang dikeluarkan oleh sebuah sumber cahaya ke arah tertentu. Sebuah sumber cahaya berintensitas 1 Candela (1 lilin) mengeluarkan cahaya total ke segala arah sebanyak 12,57 lumen.

- 12,57 adalah luas kulit bola berjari-jari 1 meter dengan sumber cahaya sebagai titik pusatnya. Jadi 1 Candela = 1 lumen / steradian



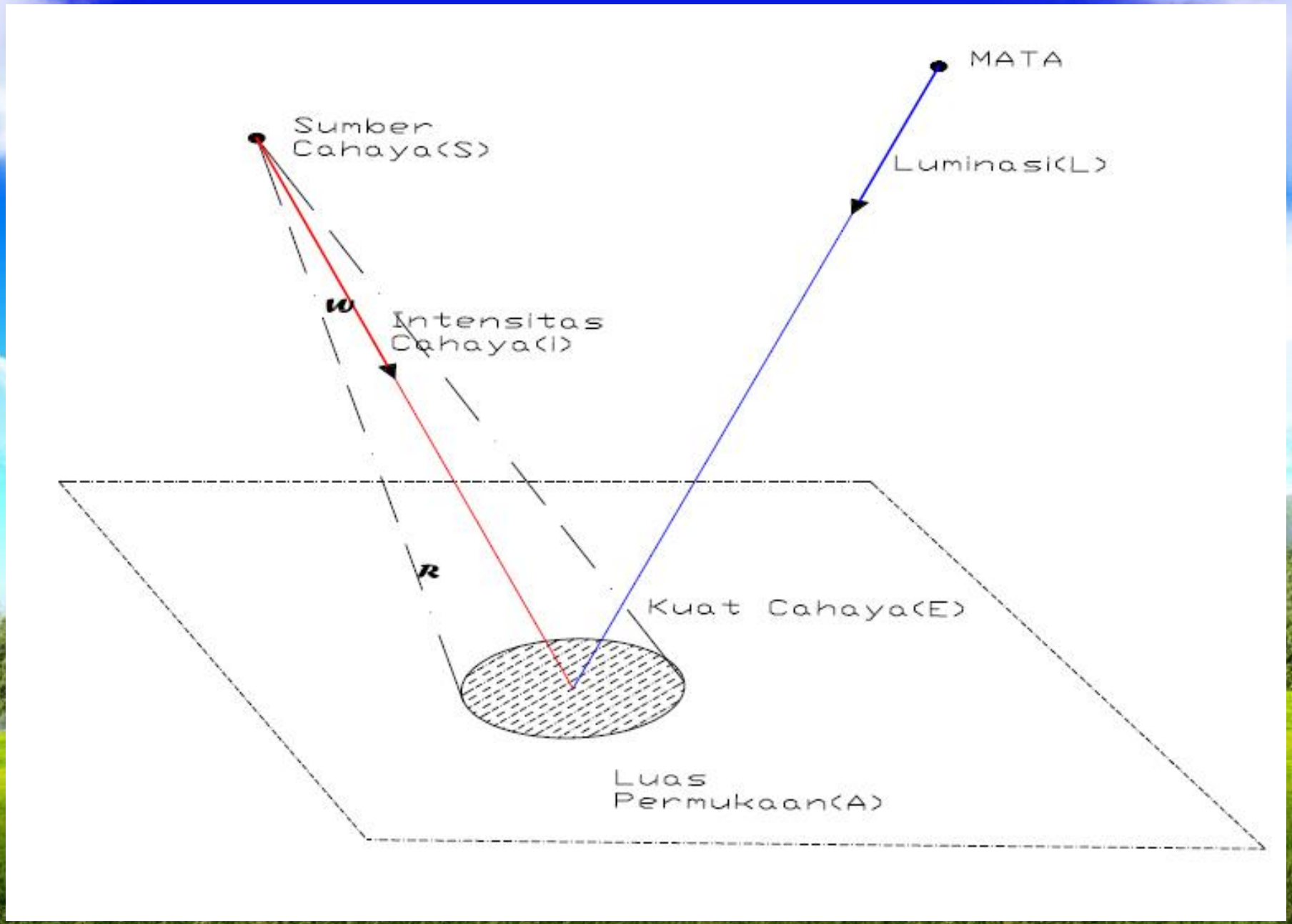
- Distribusi Intensitas : Pola Intensitas di setiap arah sudut pencahayaan (Θ) sehingga intensitas ditulis I(Θ)

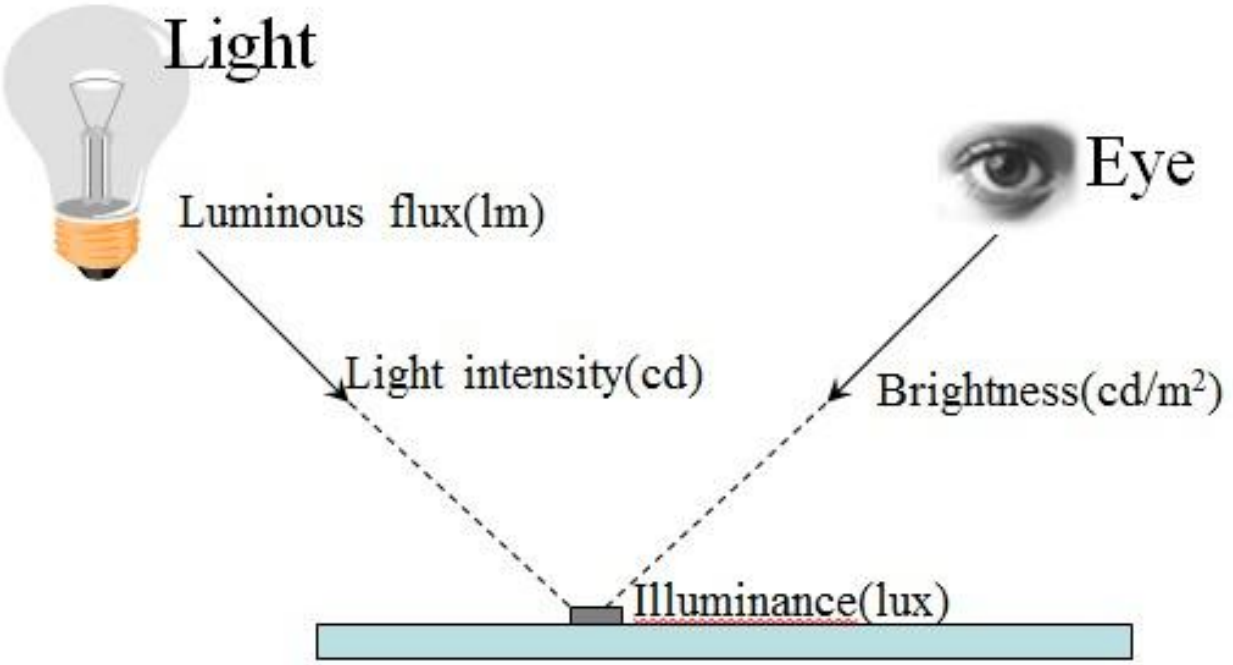
- Iluminansi (satuannya lux, lumen/m2, notasi E) Terkadang disebut tingkat penerangan merupakan banyaknya fluks luminous yang datang per satu unit bidang. 1 fc=footcandle = lumen/ft2

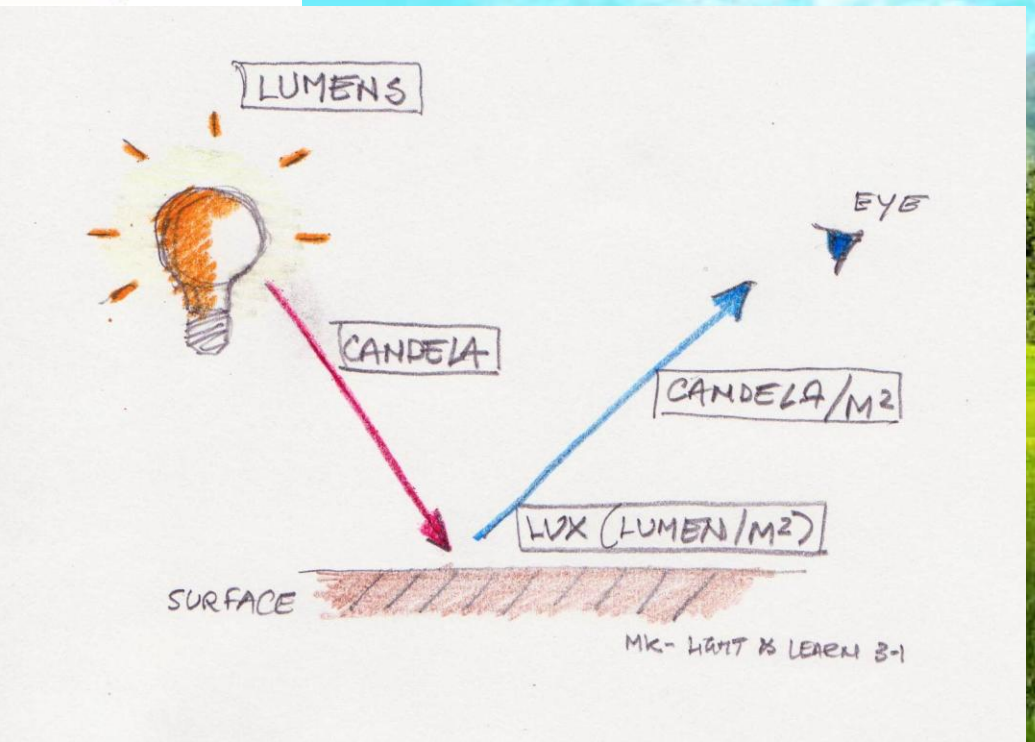
$$E = \frac{dF}{dA} = \frac{lumen}{m^2} = lux$$

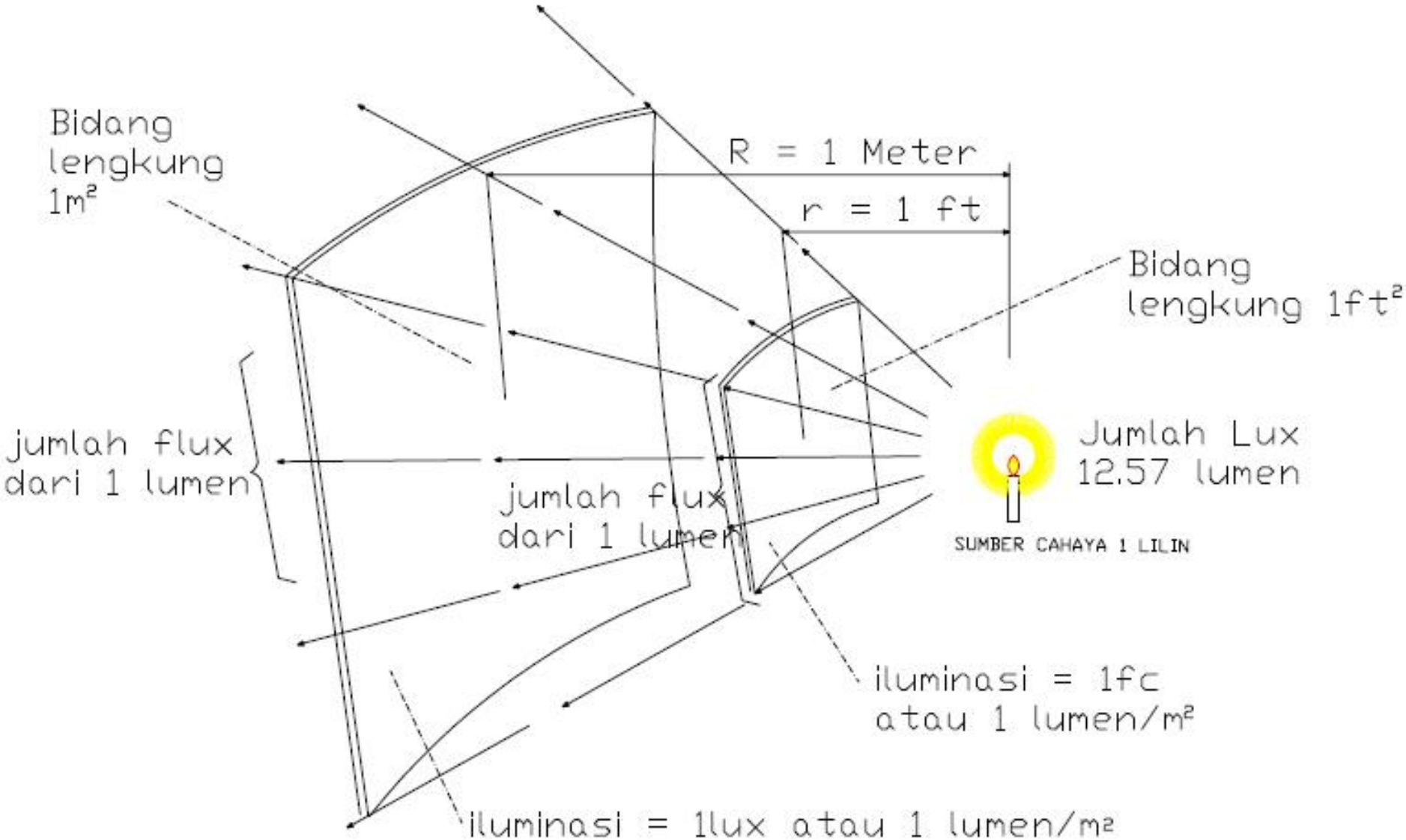
- Contoh tingkat penerangan :
  - Cahaya matahari dan cahaya langit 100.000 lux
  - Langit dengan bulan purnama : 92 lux

- Luminansi (Satuannya Candela/m2, notasi L) : Intensitas cahaya yang dipancarkan, dipantulkan kembali atau diteruskan dari suatu unit bidang yang diterangi. Pada buku acuan lama sering digunakan satuan footLambert (fL) untuk membedakan Luminansi dan Iluminansi. FootLambert=Footcandle x Faktor Refleksi
- Contoh Luminansi :
  - Bulan : 2900 cd/m2
  - Lampu TL : 6000 cd/m2


MATA
Sumber
Cahaya(S)
Luminasi(L)
w
Intensitas
Cahaya(I)
R
Kuat Cahaya(E)
Luas
Permukaan(A)


Light
Eye
Luminous flux(lm)
Light intensity(cd)
Brightness(cd/m²)
Illuminance(lux)


LUMENS
EYE
CANDELA
CANDELA/M2
LUX (LUMEN/M²)
SURFACE
MK- LIGHT & LEARN 3-1



ket : 1lux = 0.0929 fc, 1fc = 10.76 lux

Candela indicates the STRENGTH of the light emission

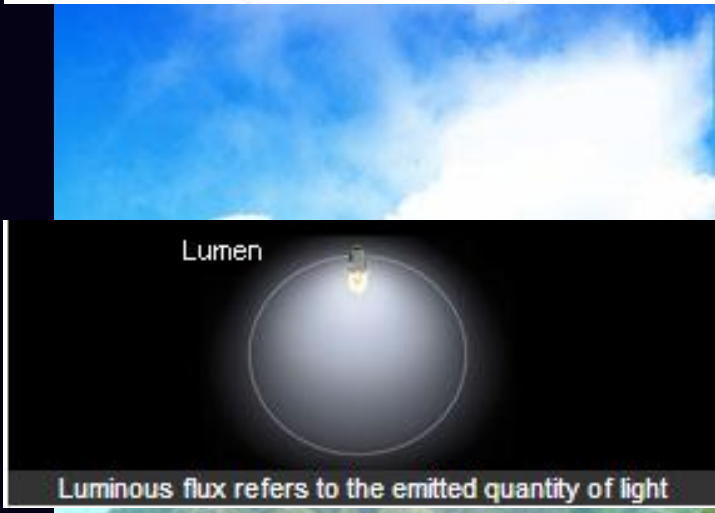
Candela

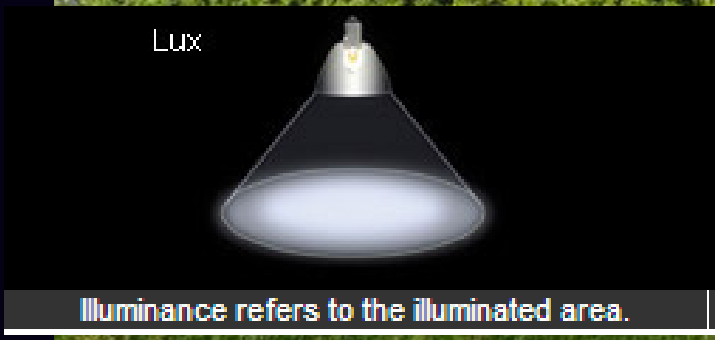
Lumen describes the amount of light that is radiated

Lumen

Lux indicated the illumination intensity of an area.

Lux





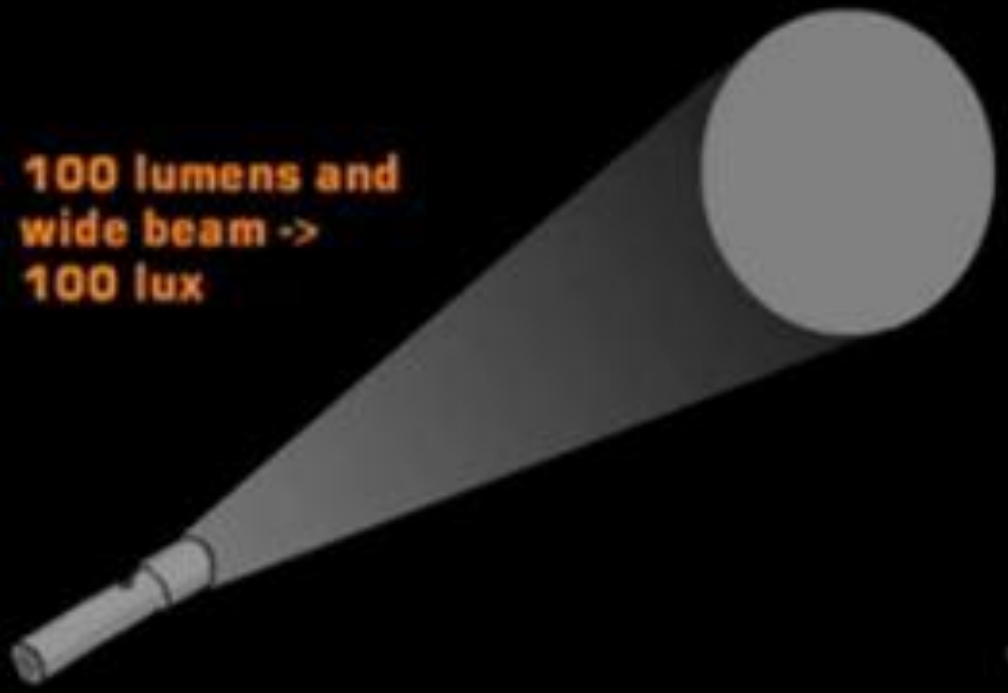
What is CANDELA, LUMEN and LUX?

... a very simple explanation!

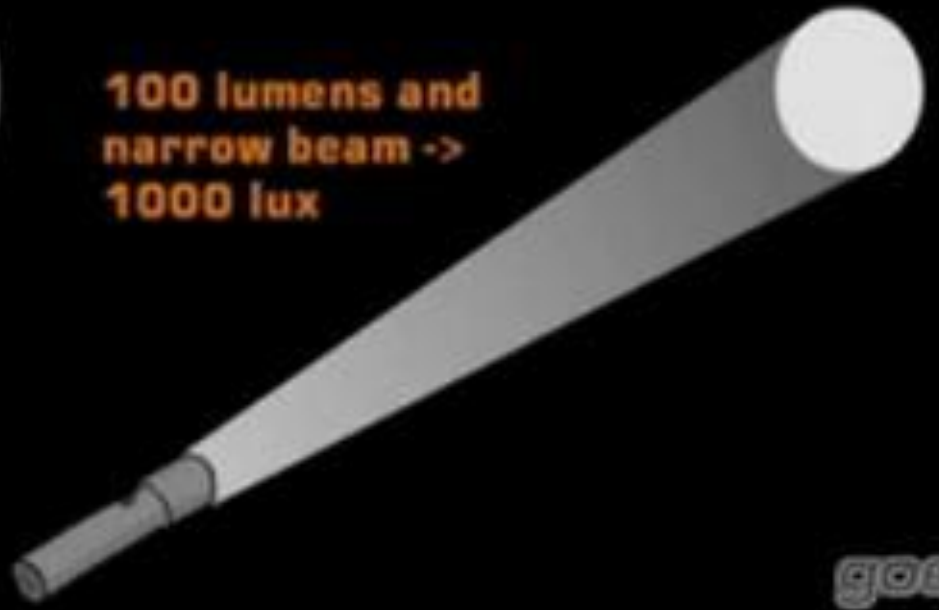
Let's say this flashlight produces 100 lumens and illuminates the spot on the wall at 100 lux. Yes, there IS a wall - you just can't see it!

If we narrow the beam so that the illuminated spot on the wall is reduced to 1/10, the number of lumens is still the same, 100 lumens, but now all these 100 lumens are 10 times as "concentrated", making the spot on the wall 10 times brighter; 1000 lux!

100 lumens and wide beam -> 100 lux



100 lumens and narrow beam -> 1000 lux

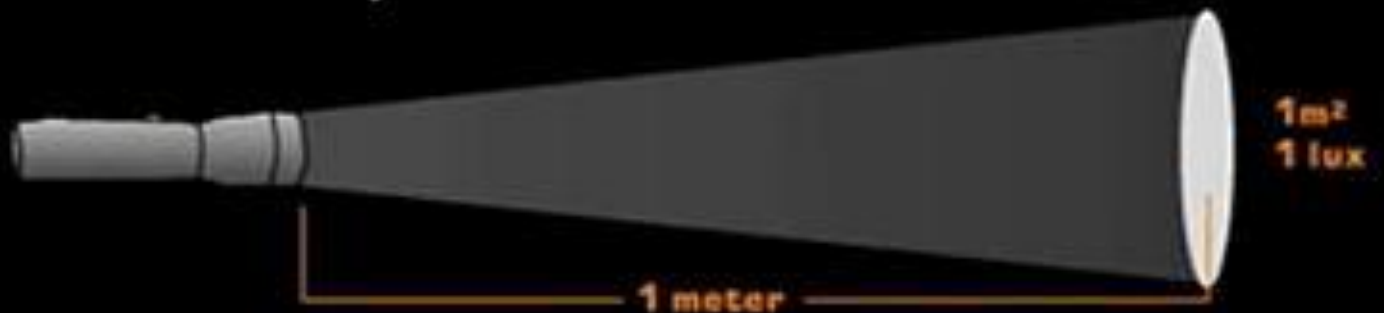


What is CANDELA, LUMEN and LUX?

... a very simple explanation!

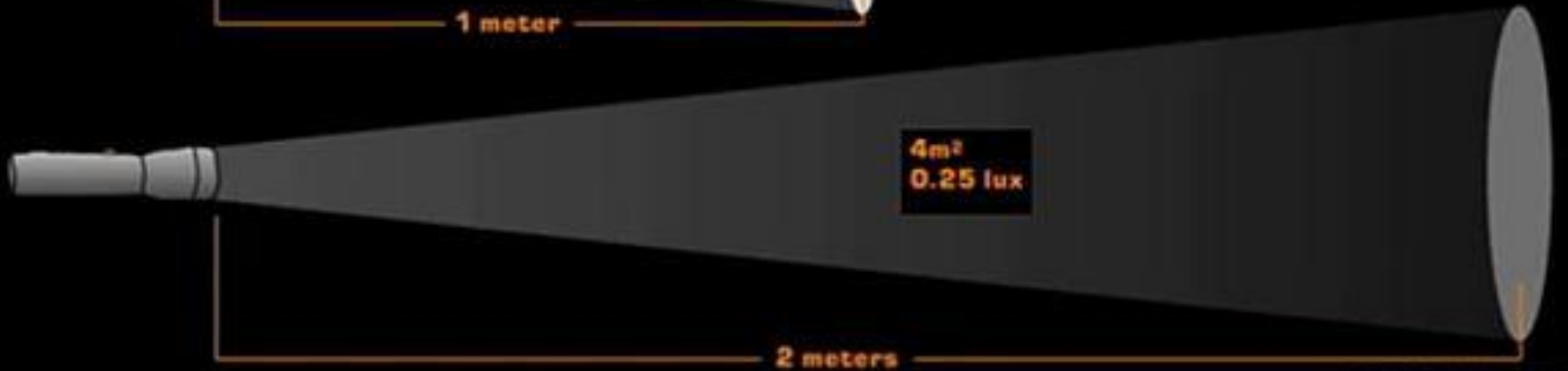
And another example:

This little flashlight illuminates a 1m² spot on the wall - 1 meter away - at 10 lux



Then we move the wall 1 meter further away from the flashlight ... Yes, I know it would be easier to move the flashlight, but then the illustration would be confusing!

Anyway, now the spot on the wall is 4 times as big *), making it 4m². So instead of concentrating the lumens (as we did before), we are SPREADING THEM OUT, giving us a lux value of 1/4 = 0.25 lux!



*) It's called the "inverse-square law" - and you can read aaaaaaaaall about it on the internet :)

What is CANDELA, LUMEN and LUX?

... a very simple explanation!

CANDELA is a measure of light intensity - measured at the light source. 1 candela is close to the light intensity of one ordinary candle! Like, "how BRIGHT is this light"!

LUMEN measures the total amount of light, independent of distribution, emitted from a light source, like for example a flashlight. Like, "how MUCH light is coming from this flashlight"!

LUX is a measure of illumination of a surface at distance. Like, "how well is this object ILLUMINATED at this distance from the light!"

Trouble reading? Professor Wise's book suffers from "lux-deficiency"!

Oh yeah, much better. 300-500 lux is fine for reading.

One candela = the light intensity
from a candle (more or less)

... a very simple explana

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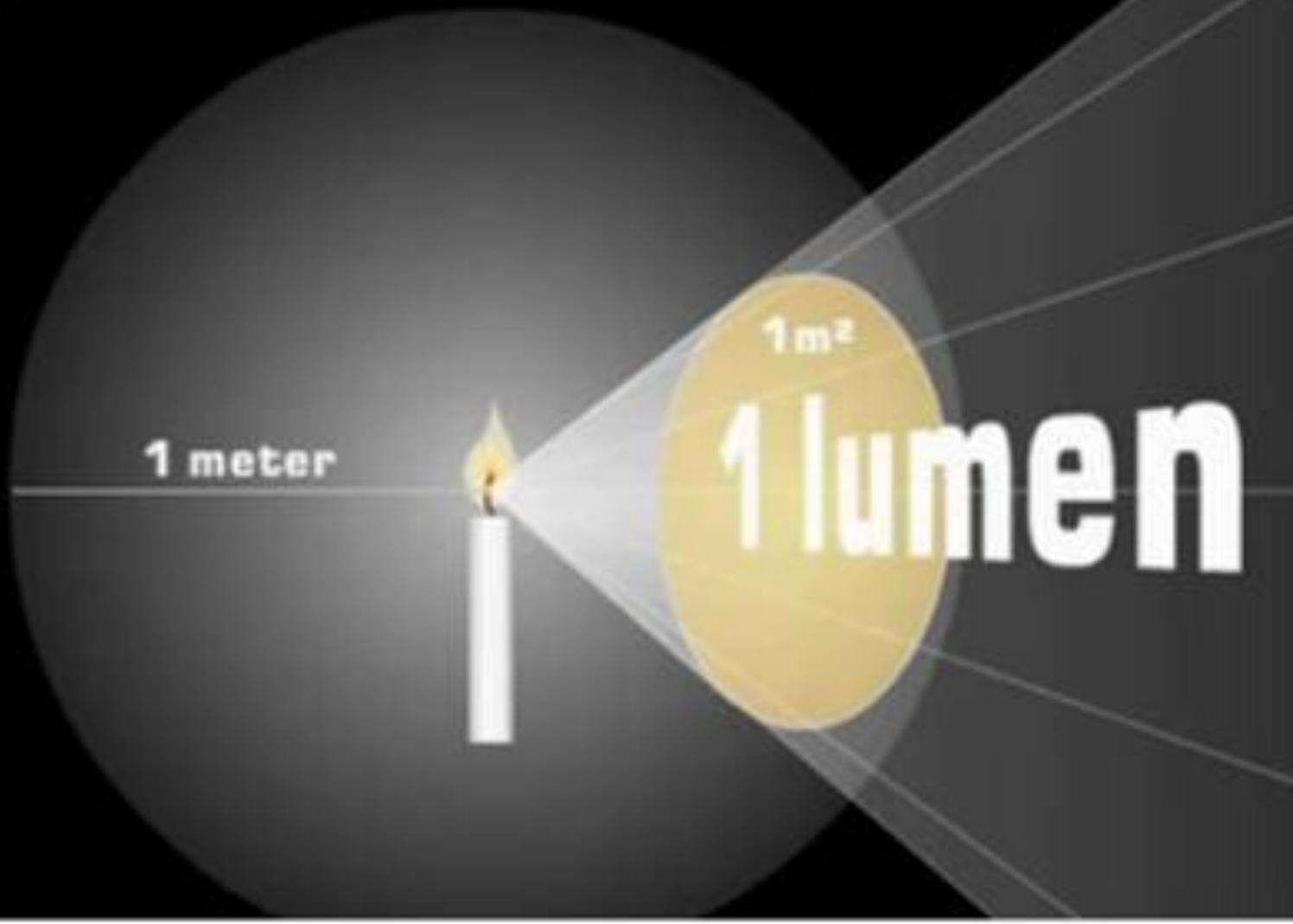
One lumen = the amount of light produced by a 1 candela source radiating out through 1 steradian (one steradian is about 1/12.57 of a sphere) - in this case 1m² of this sphere



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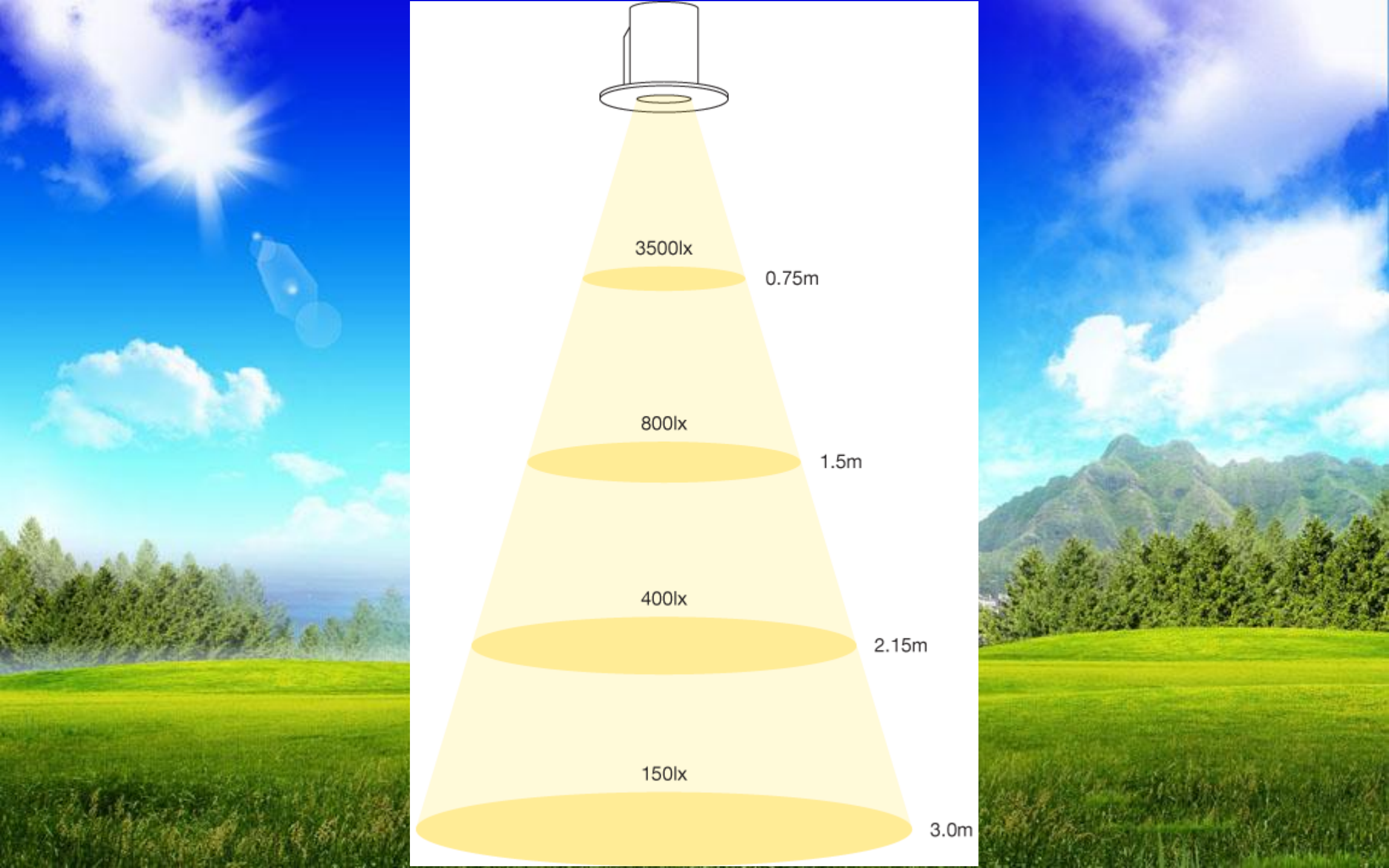
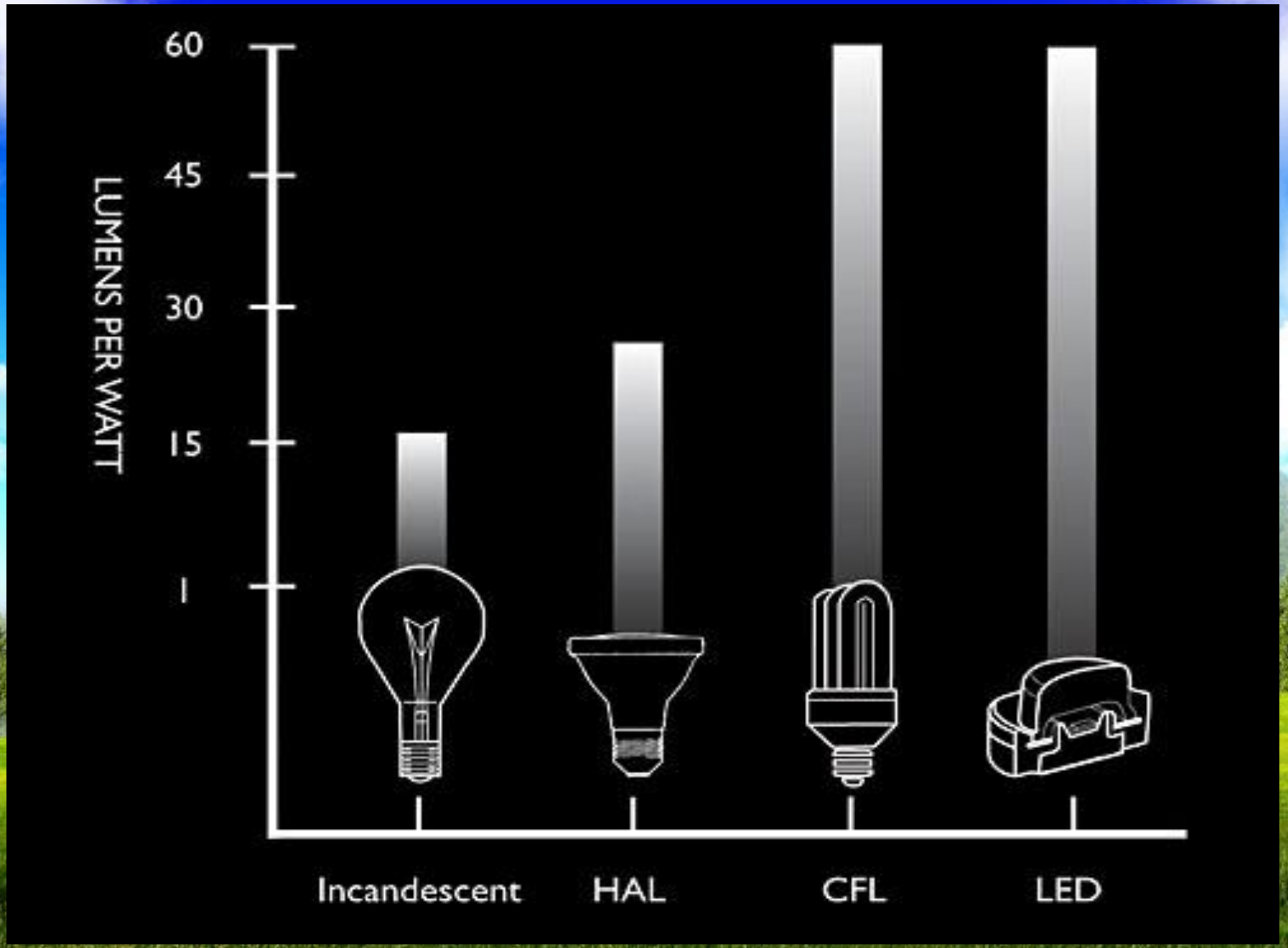
One lumen = the amount of light produced by a 1 candela source radiating out through 1 steradian (one steradian is about 1/12.57 of a sphere) - in this case $1m^2$ of this sphere

One lux = the illumination produced when there is one lumen falling on one square meter


3500lx
0.75m
800lx
1.5m
400lx
2.15m
150lx
3.0m


LUMENS PER WATT
60
45
30
15
1
Incandescent
HAL
CFL
LED

No	Aktifitas atau Area	Lux (Rata -rata)
1	Penerangan Umum	100
2	**Ruang Operasi**	
	Penerangan Umum	500
	Kantor Dokter	300
	Meja Operasi	20000
3	**Kamar Perawatan**	
	Penerangan Umum	100
	Baca	300
	Kamar Mandi/WC	200
4	**Perpustakaan/ Ruang Tunggu**	
	Penerangan Umum	200
	Baca	300
	Pemantauan	700
5	Kantor Pengawas	200
6	Daerah komersil	200
7	Ruang merokok	150
8	Tangga dan selasar	200

Standar kebutuhan pencahayaan

Environment	Required Light Level
Storage Area / Plant Room (minimal movement of people)	150 – 200 Lux
Construction Areas & Loading Bays (minimal perception of detail)	300 – 500 Lux
Factories & Kitchens (higher perception of detail)	500 – 750 Lux
Inspection, Welding & Machinery (demanding work)	750 – 1000 Lux
Electronics & Textile Production (repetitive work)	1000 – 1500 Lux
Technical Offices (accurate detail)	1500 – 3000 Lux
Jewellers & Goldsmiths (precision detail)	3000+ Lux

Environment	Light / Lux Level
Very Bright Summer Day	Up to 100,000 Lux
Overcast Summer Day	30,000 – 40,000 Lux
Floodlit Football Match	700 – 16,000 Lux
Shady Room in Daylight	250 – 300 Lux
Night Light on a Building	60 Lux
Nighttime Urban Street	10 Lux
Nighttime Car Park	1 Lux

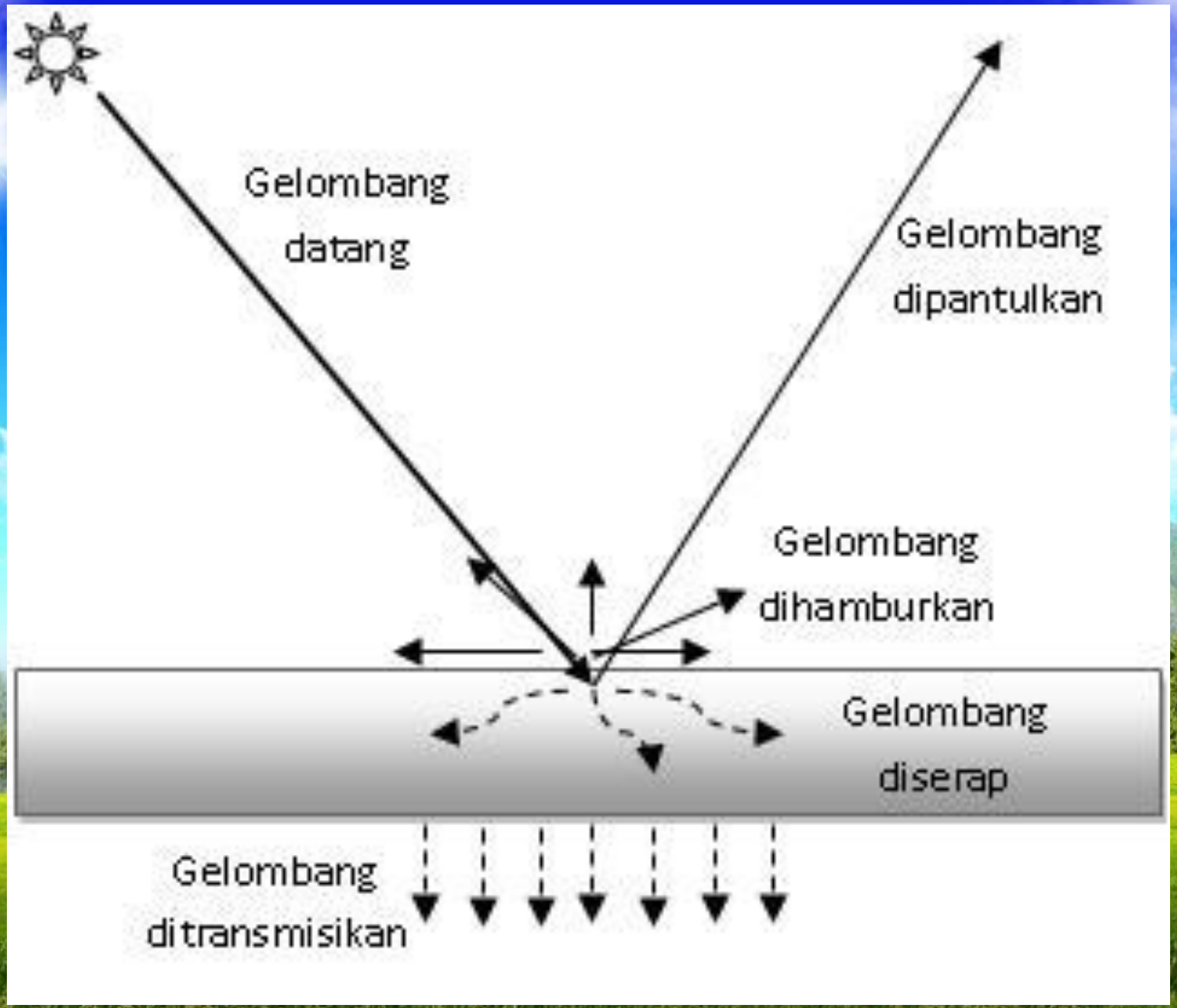
BESARAN KUANTITATIF CAHAYA (LANJUTAN)

- Faktor refleksi ρ : rasio fluks luminus yang dipantulkan suatu permukaan Φ_ρ terhadap fluks luminus yang datang; $\rho = \Phi_\rho / \Phi$

- Faktor transmisi τ : rasio fluks luminus yang diteruskan suatu permukaan Φ_τ terhadap fluks luminus yang datang; $\tau = \Phi_\tau / \Phi$

- Faktor absorpsi α :
  rasio fluks luminus yang diserap suatu permukaan Φ_α terhadap fluks luminus yang datang; $\alpha = \Phi_\alpha / \Phi$

- Eksitansi luminus M [lumen/m^2] :
  fluks luminus yang dipancarkan atau dipantul-kan per satuan luas permukaan A;
  $M = \Phi_\rho / A = \rho E$ atau $\Phi_\tau / A = \tau E$


Gelombang
datang
Gelombang
dipantulkan
Gelombang
dihamburkan
Gelombang
diserap
Gelombang
ditransmisikan

- DF (Daylight Factor) : Perbandingan antara iluminansi di satu titik di dalam ruangan dengan titik di luar ruangan. Semakin tinggi nilai DF maka semakin banyak pencahayaan alami dalam ruangan tersebut.

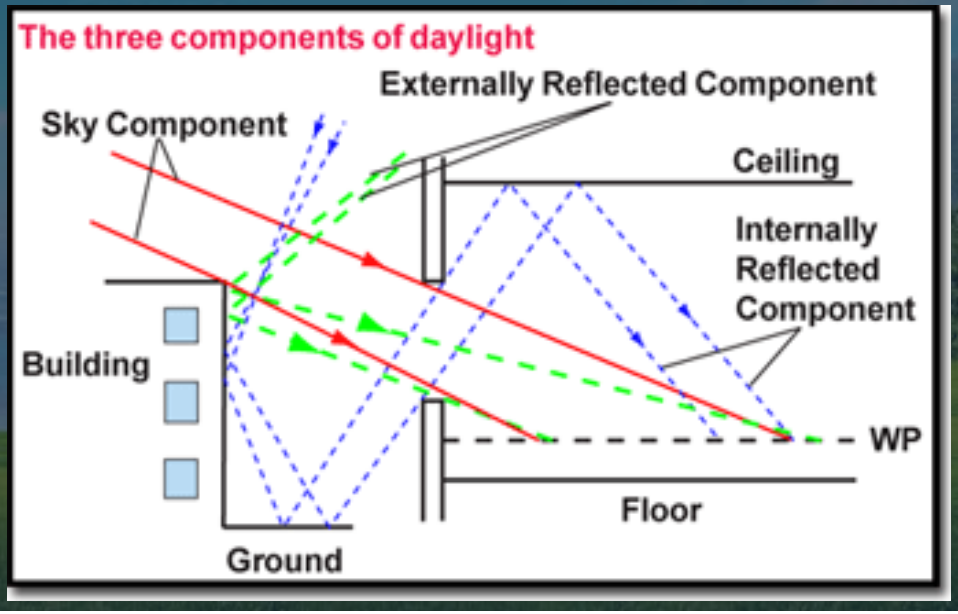
$$DF = 100 * E_{in} / E_{ext}$$

E_{in}
inside illuminance at a fixed point

E_{ext}
outside horizontal illuminance under an overcast (CIE sky) or uniform sky.

Nilai Iluminansi E_{in} bersumber dari :

- The Sky Component (SC), this is the light reaching the point directly from the sky.
- The Externally Reflected Component (ERC), this is the light that reaches the point after being reflected from surfaces outside the room such as buildings or roads.
- The Internally Reflected Component (IRC), this is the amount of light that reaches the point after being reflected from other surfaces in the room.



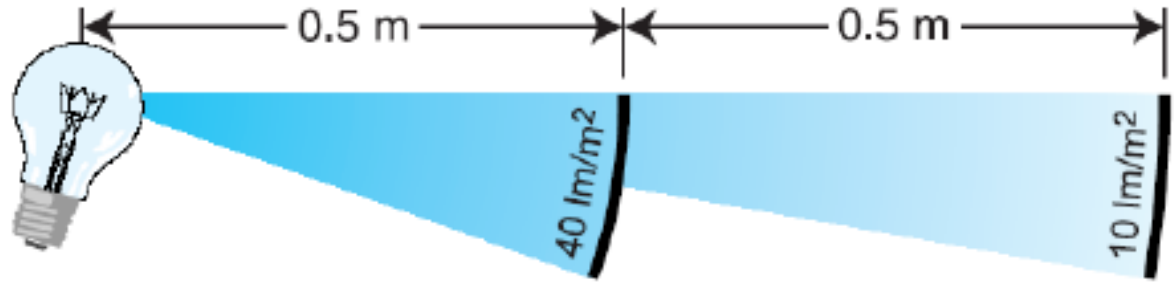
- Langit rancangan (Design Sky Light), luminan langit yang digunakan sebagai patokan perancangan yaitu kondisi langit yang terjadi sebanyak 90%. Untuk Indonesia dipakai 10.000 lux. Ruangan diterangi oleh cahaya langit (sky light) bukan oleh daylight

Hukum Kuadrat Terbalik

- Hukum Kuadrat terbalik adalah hukum yang mengatakan bahwa intensitas cahaya akan menjadi seperempat setiap kali jarak digandakan

- Hubungan antara iluminansi terhadap jarak: $E = I/d^2$
- Untuk intensitas luminus yang sama:

  $E_1 d_1^2 = E_2 d_2^2$

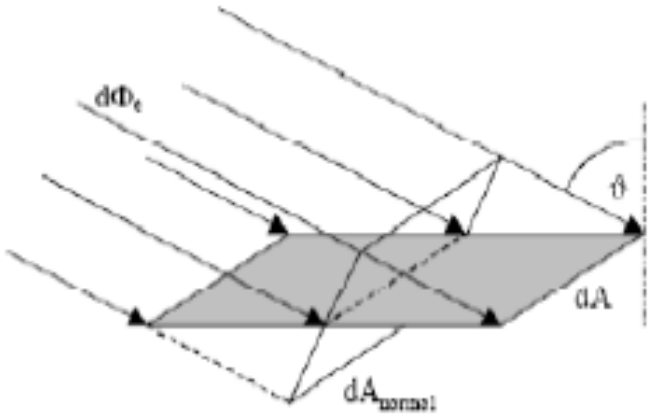


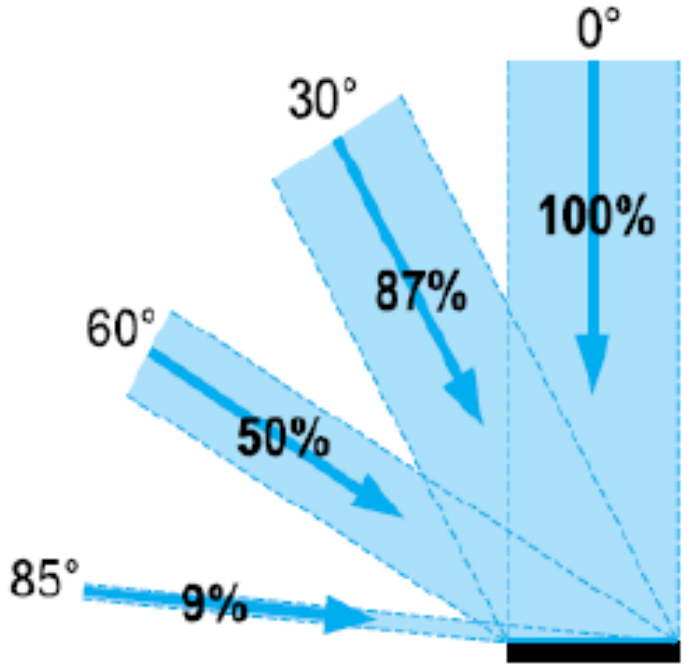
- Berlaku untuk sumber titik: jarak titik ke sumber sekurang-kurangnya lima kali dimensi terbesar sumber cahaya

Hukum Cosinus Lambert

- Iluminansi yang diterima suatu permukaan bervariasi terhadap sudut datang θ (diukur terhadap normal bidang permukaan):

$$E_\theta = E\cos\theta$$
$$= (I/d^2)\cos\theta$$

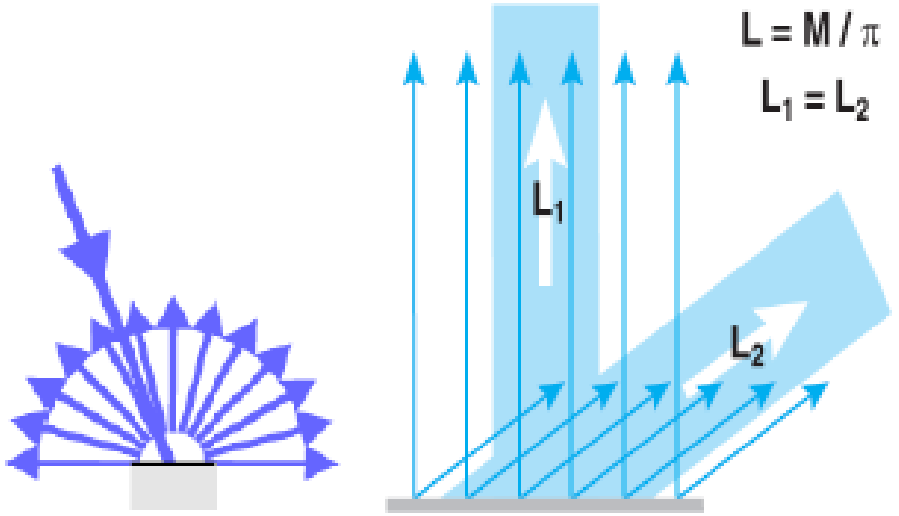




Permukaan Lambertian

- Permukaan yang luminansinya sama jika dilihat dari segala arah; sebagian besar permukaan difus adalah Lambertian

- Permukaan Lambertian dengan luminansi 1 cd/m^2 akan meradiasikan πA lumen (A luas permukaan) ke arah 2π steradian, dengan eksitansi luminus π (= $\pi A/A$) lumen/m^2



Konversi Satuan Cahaya

- 1 lumen = $1{,}464 \times 10^{-3}$ watt (pada 555 nm)
  = $(1/4\pi)$ candela (jika isotropik)
- 1 lux (=lm/m^2) = 0,093 footcandle (=lm/ft^2)
  = 10^{-4} phot (=lm/cm^2)
- 1 cd/m^2 = π apostilb (=cd/π/m^2)
  = 0,0929 cd/ft^2
  = 0,2919 footlambert (=cd/π/ft^2)

Standard unit of luminance is **candela per square meter (cd/m^2)**. (also called **Nits** in the USA, from latin "nitere" = "to shine").

There are several older units of luminance:

Apostilb (deprecated)	1 asb	=	1/pi cd/m^2
Blondel (deprecated)	1 blondel	=	1/pi cd/m^2
Candela per square foot	1 cd/ft^2	=	10.764 cd/m^2
Candela per square inch	1 cd/in^2	=	1550 cd/m^2
Footlambert (deprecated)	1 fL	=	3.426 cd/m^2
Lambert (deprecated)	1 L	=	10^4/pi cd/m^2
Nit	1 nit	=	1 cd/m^2
Skot (deprecated)	1 skot	=	10^{-3}/pi cd/m^2
Stilb (deprecated)	1 sb	=	10'000 cd/m^2

Typical luminance values are:

$1.6 * 10^9$ cd/m^2	Solar disk at noon (don't look!)
600'000 cd/m^2	Solar disk at horizon
120'000 cd/m^2	Frosted bulb 60 W
11'000 cd/m^2	T8 cool white fluorescent
8'000 cd/m^2	Average clear sky
2'500 cd/m^2	Moon surface
2'000 cd/m^2	Average cloudy sky
30 cd/m^2	Green electroluminescent source
0.0004 cd/m^2	Darkest sky

Contoh Soal

Misalkan sebuah permukaan difus berbentuk lingkaran dengan jari-jari 1 meter dan faktor refleksi 85% menerima fluks cahaya sebesar 100π lumen pada bidang permukaannya. Berapakah luminansi, L, pada permukaan tersebut?

Solusi

Luas permukaan $A = \pi r^2 = \pi(1\ \text{m})^2 = \pi\ \text{m}^2$

Iluminansi pada permukaan:

$E = \Phi/A$

$= (100\pi\ \text{lm})/(\pi\ \text{m}^2) = 100\ \text{lm/m}^2\ (=100\ \text{lux})$

Eksitansi luminus pada permukaan:

$M = \rho E$

$= (0{,}85)(100\ \text{lm/m}^2) = 85\ \text{lm/m}^2$

Luminansi pada permukaan:

$L = M/\pi$

$= (85\ \text{lm/m}^2)/\pi = 27{,}1\ \text{cd/m}^2$

SI photometry units

Quantity	Symbol	SI unit	Abbr.	Notes
Luminous energy	Q_v	lumen second	lm·s	units are sometimes called talbots
Luminous flux	F	lumen (= **cd**·sr)	lm	also called *luminous power*
Luminous intensity	I_v	**candela** (= lm/sr)	**cd**	an SI base unit
Luminance	L_v	**candela** per square metre	$\mathbf{cd}\cdot m^{-2}$	units are sometimes called nits
Illuminance	E_v	lux (= $lm\cdot m^{-2}$)	lx	Used for light incident on a surface
Luminous emittance	M_v	lux (= $lm\cdot m^{-2}$)	lx	Used for light emitted from a surface
Luminous efficacy		lumen per watt	lm/W	ratio of luminous flux to radiant flux; maximum possible is 683.002