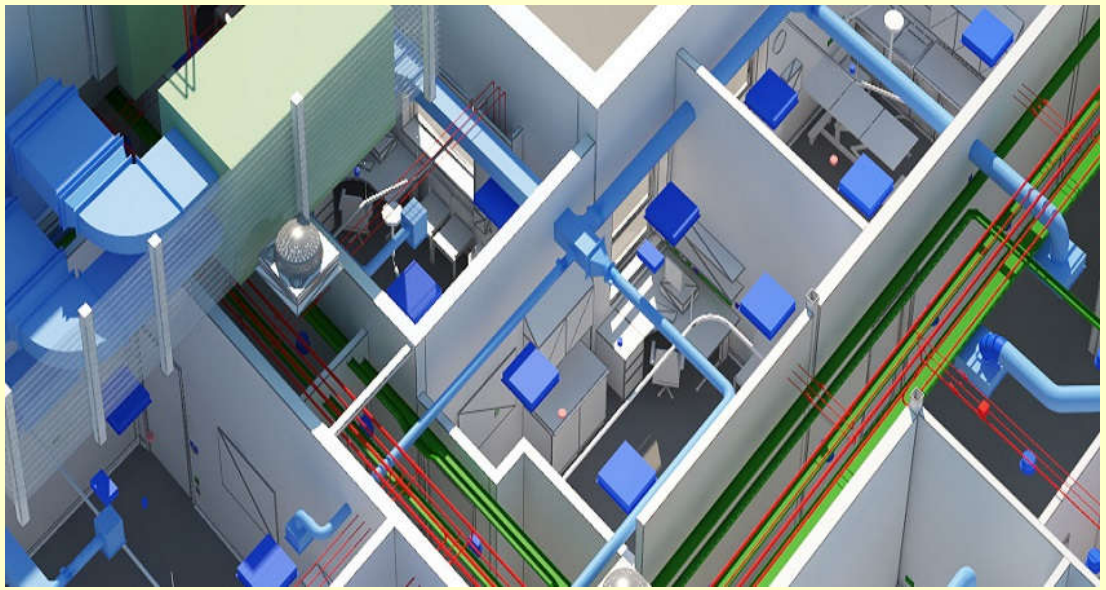

10. Electrical Services Part 3
10.1 Lighting design and equipment

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Contents 內容

- Basic concepts 基本概念
- Lighting terminology 照明術語
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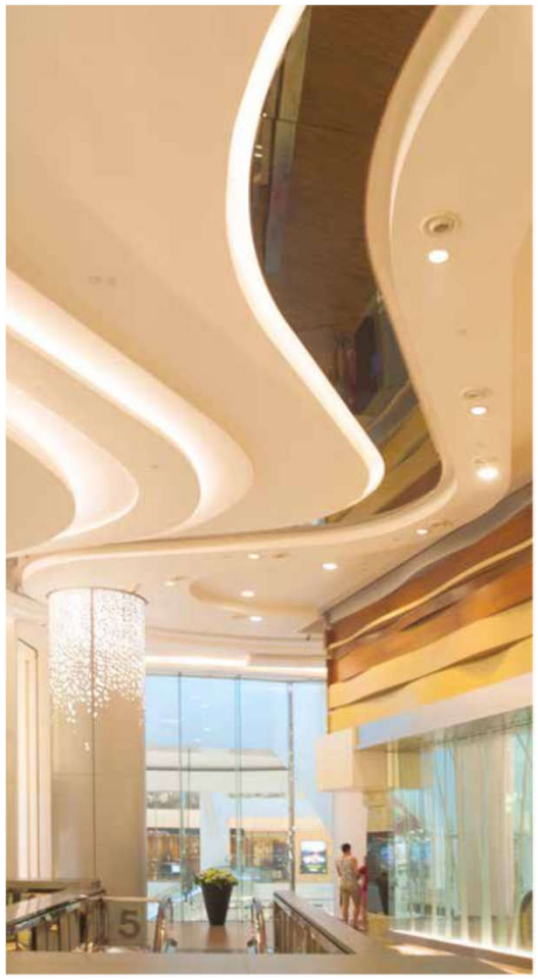
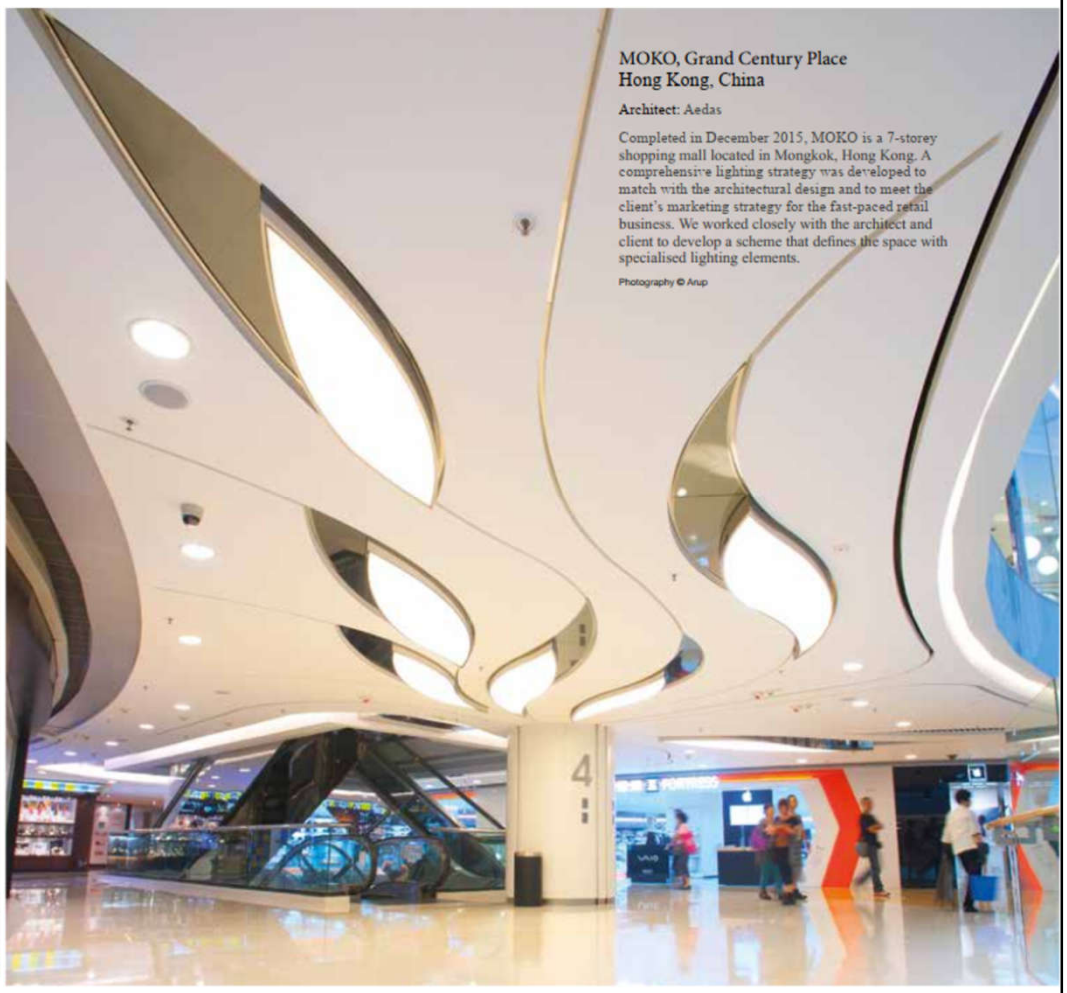
- Design & maintenance practice 設計與維護實踐
- Emergency lighting 應急照明
- Energy efficient lighting 節能照明

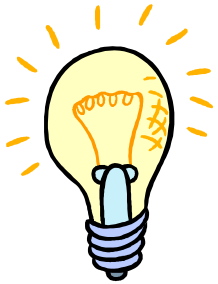
An example of lighting design for a shopping mall in Hong Kong



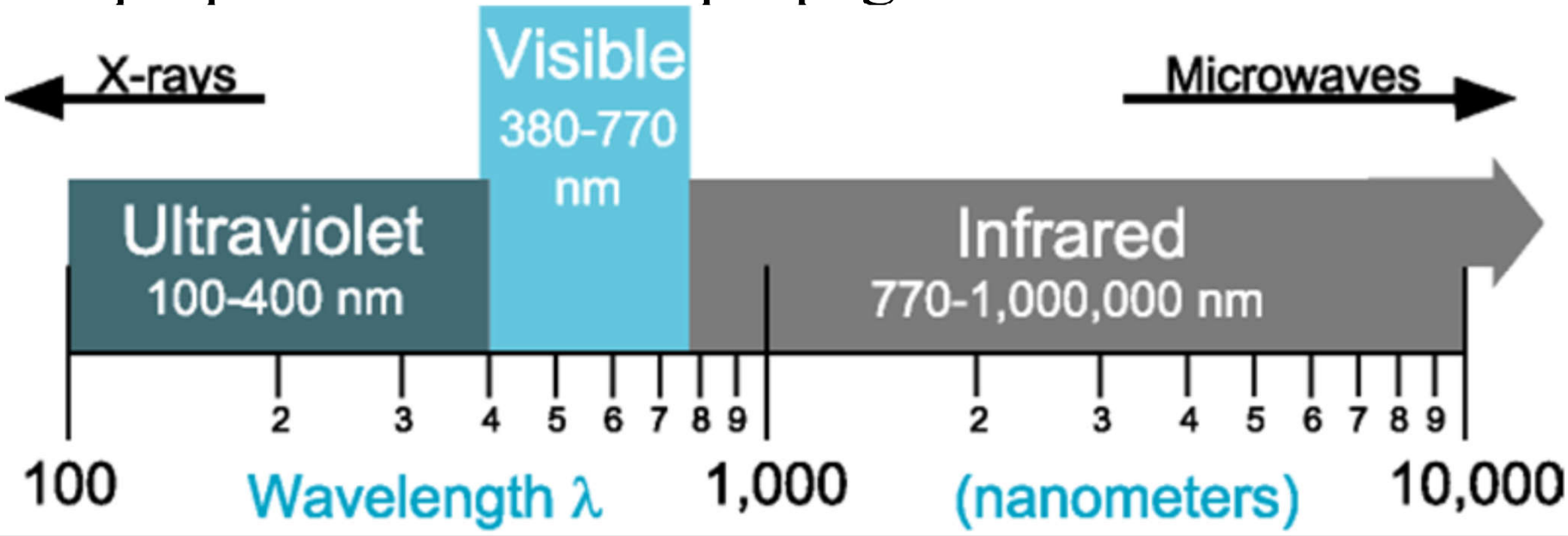


(Source: https://www.arup.com/perspectives/publications/promotional-materials/section/lighting-design)

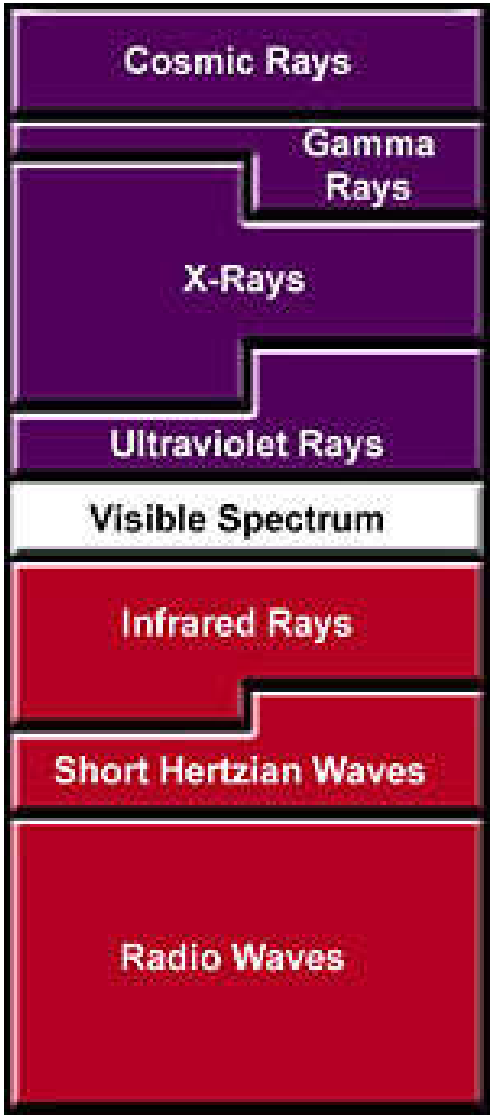
Basic concepts

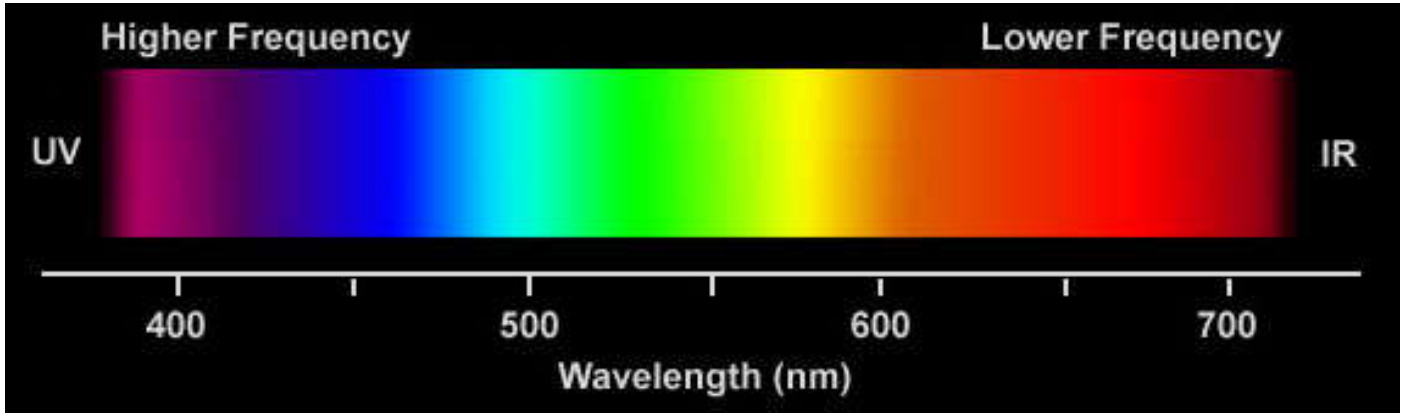


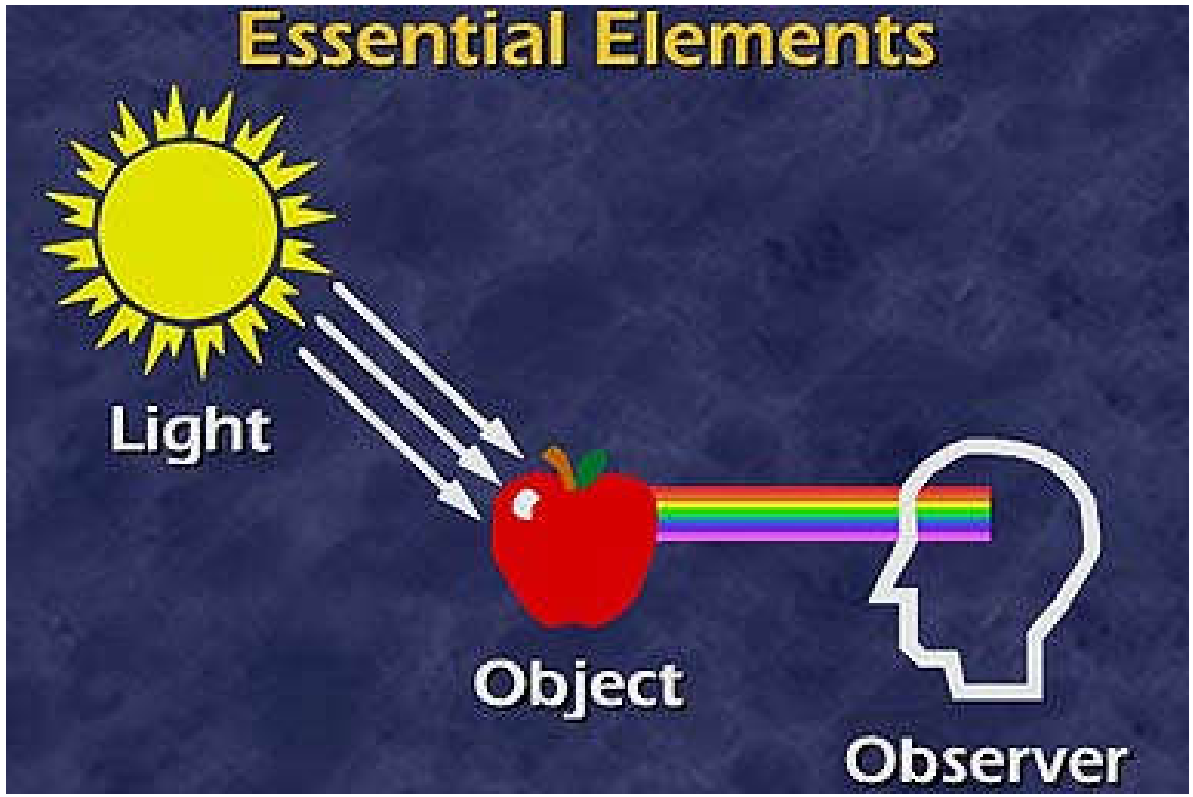
- What is *Light*? 光
  - Light is a form of electromagnetic radiation with an electric field & a magnetic field oriented at right angles and varies in magnitude in a direction perpendicular to the propagation direction



Essential elements of light and human vision 光和人類視覺的基本要素

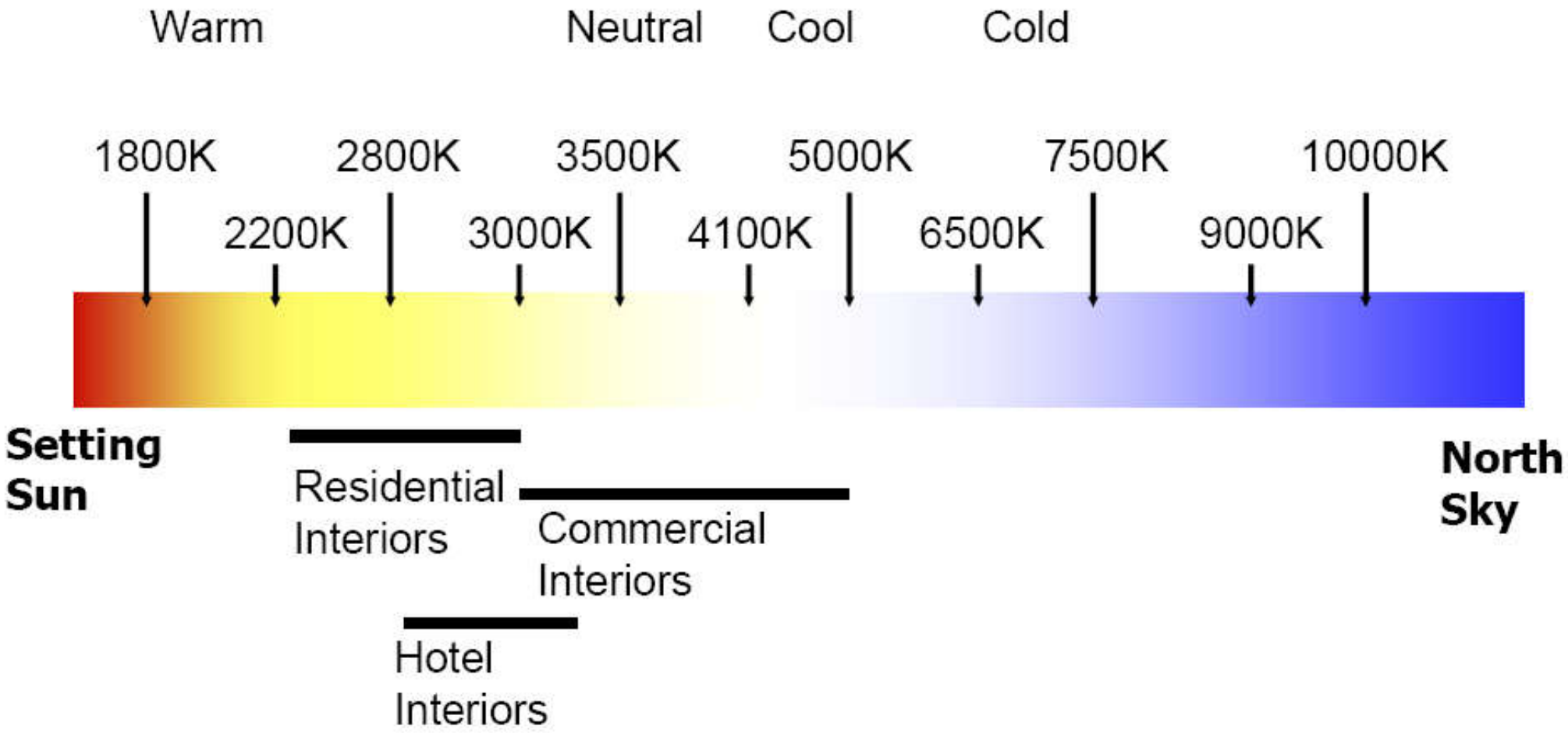






[Color Science, Texas A&M University http://www.isc.tamu.edu/%7Eastro/color.html]

Correlated colour temperature (CCT) of lamps 燈的相關色溫



[Source: www.benyalighting.com]

Lighting terminology

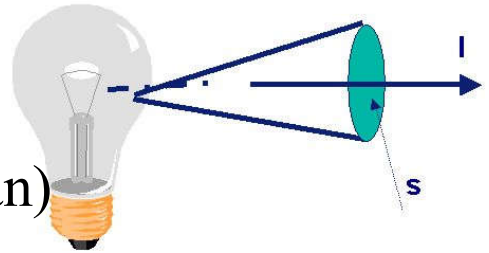
- Important terms
  - Luminous flux 光通量 (lumen, lm), Φ

Radiation value

  - Light power emitted by a source or received by a surface (radiant flux according to the spectral sensitivity of the human eye)
  - A candle flame generates about 12 lumens
  - Fluorescent lamp 32W = 3,300 lumens

Sender-side value

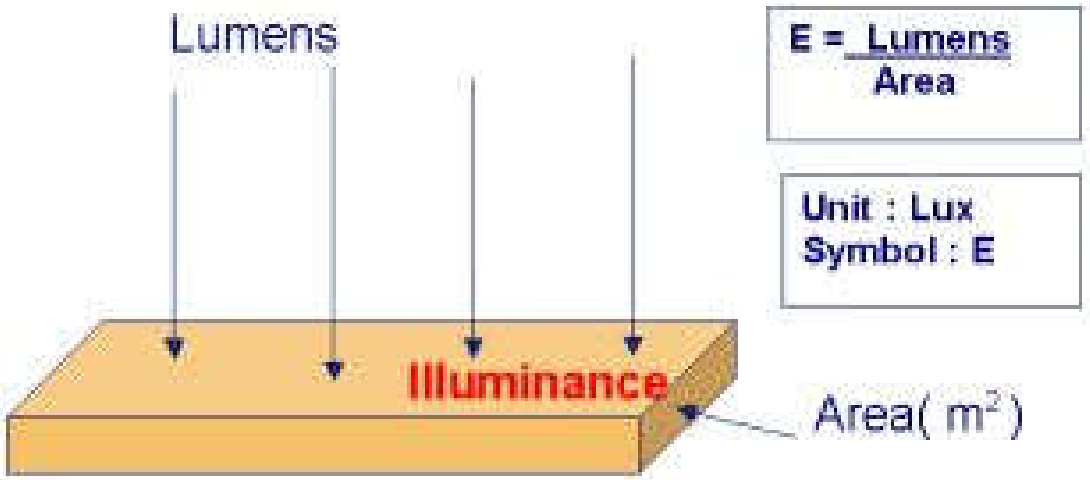
  - Luminous intensity 光強 (candela, cd), *I*
    - Luminous flux per unit solid angle in the direction in question, $I = d\Phi / d\omega$ (ω = solid angle, in steradian)



Recipient-side value

  - Illuminance 照明度 (lm/m^2, or lux), *E*
    - Light energy arriving at a real surface, $E = d\Phi / dA$ (*A* = receiving surface area) (“lumen per unit area”)

Practical examples of illuminance 照明度



Summer, at noon, under a cloudiness sky	100 000 lux
Ditto, but in the shade	10 000 lux
In the open under a heavily-overcast sky	5000 lux
Artificial light, in a well-lit office	1000 lux
Artificial light, average living-room	100lux
Street lighting	5-30 lux
Full moon, on a clear night	0,25 lux

(Source: Philips Lighting, http://www.lighting.philips.co.in)

Lighting terminology

- Important terms
  - Luminance 亮度 (cd/m^2), L

Sender-side value

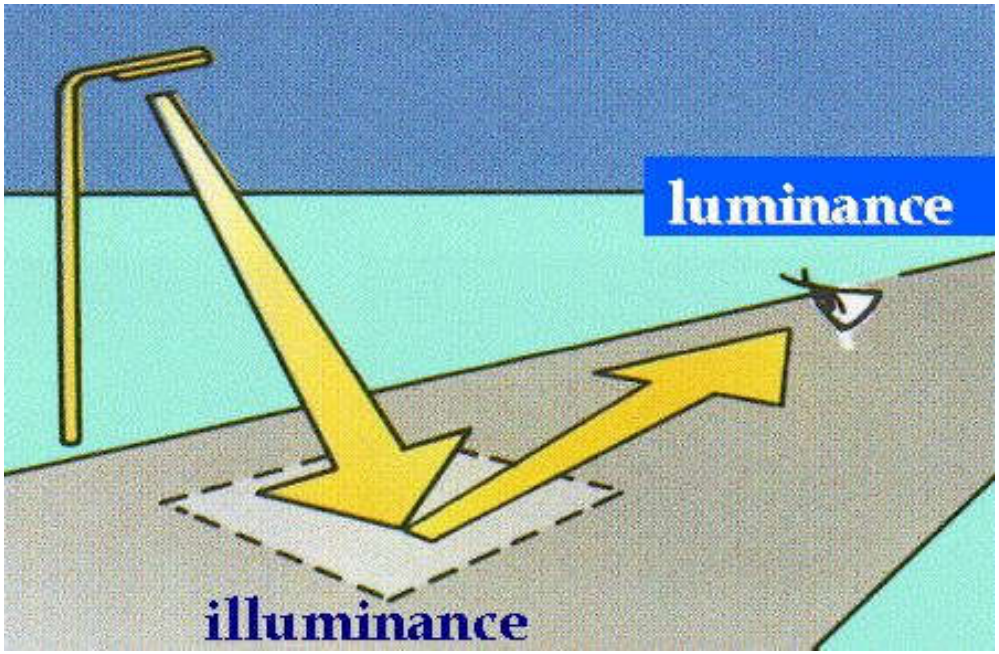
- Luminous flux density (I) leaving a projected surface in a particular direction (often called “brightness”)
- $L = I / dA.\cos\theta = (d\Phi/d\omega) / dA.\cos\theta$
  - $d\omega$ = solid angle containing the given direction
  - dA = area of a section of that beam (the source side) containing the given point
  - θ = the angle between the normal to that section and the direction of the beam

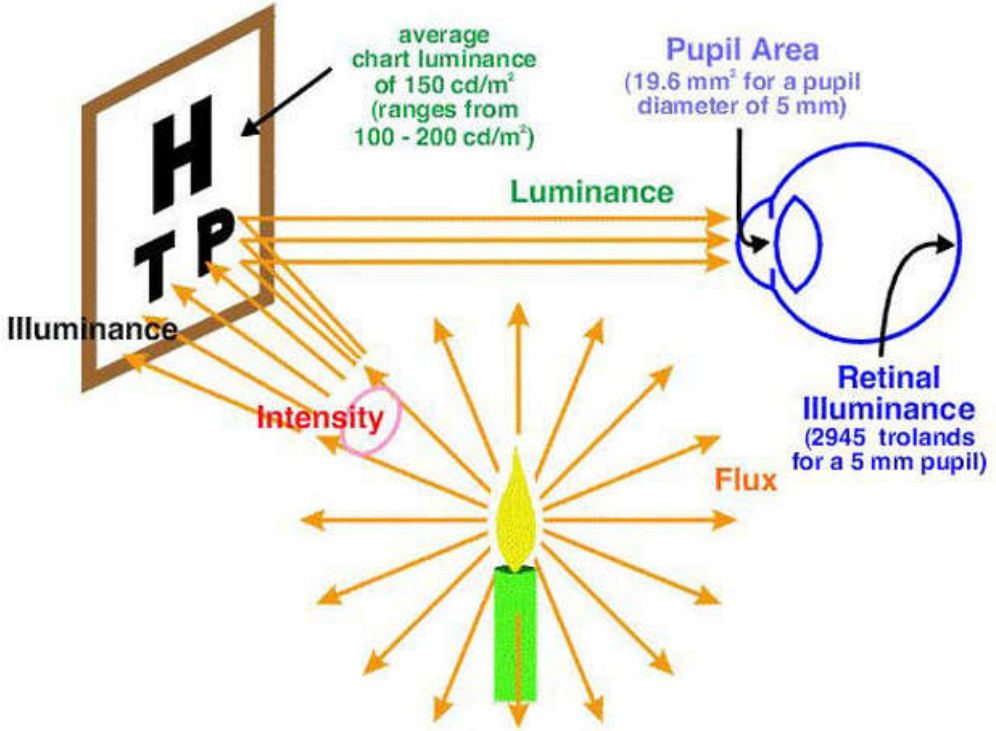
Practical examples of luminance 亮度

Surface of the sun	1 650 000 000 cd/m^2
Filament of a clear incandescent lamp	7 000 000 cd/m^2
Bulb of an 'Argenta' incandescent lamp	200 000 cd/m^2
Fluorescent lamp	5000 -15 000 cd/m^2
Surface of the full moon	2500 cd/m^2
Sun-lit beach	15 000 cd/m^2
White paper (reflectance 0,8) under 400 lux	100 cd/m^2
Grey paper (reflectance 0,4) under 400 lux	50 cd/m^2
Black paper (reflectance 0,04) under 400 lux	5 cd/m^2
Road surface under artificial lighting	0,5 - 2 cd/m^2

(Source: Philips Lighting, http://www.lighting.philips.co.in)

Illuminance and luminance (Source: Lessons in Lighting, http://www.lightolier.com)



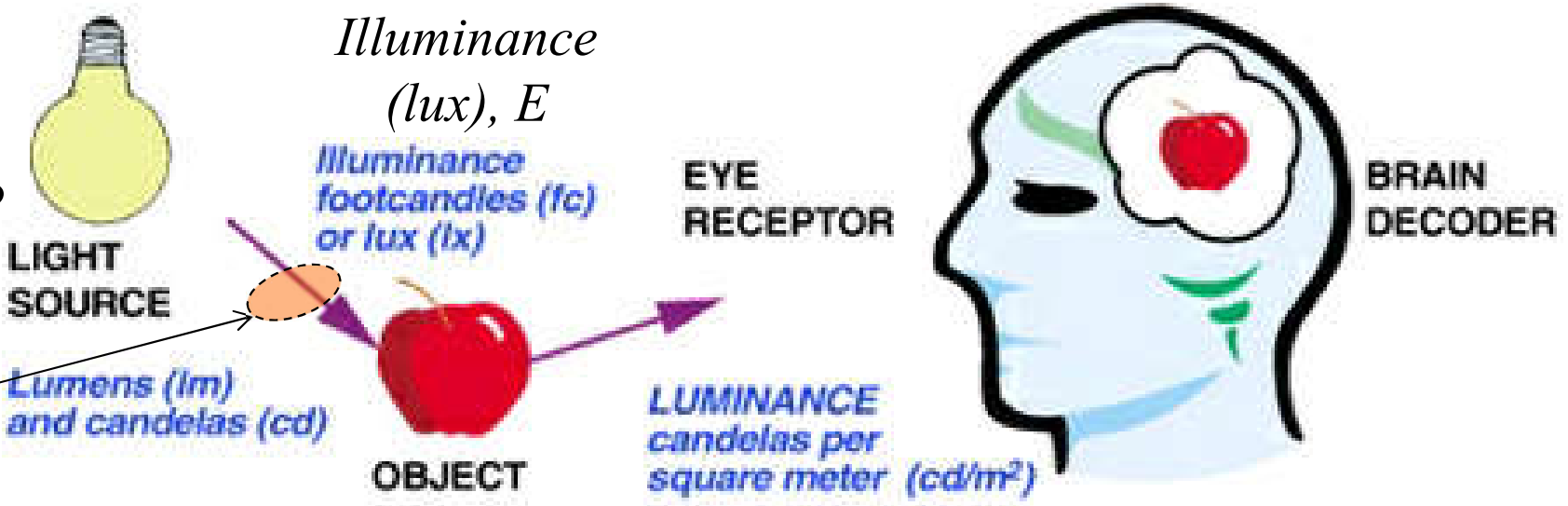


Luminous flux (lm), Φ

Illuminance (lux), E

Luminous intensity (cd), I

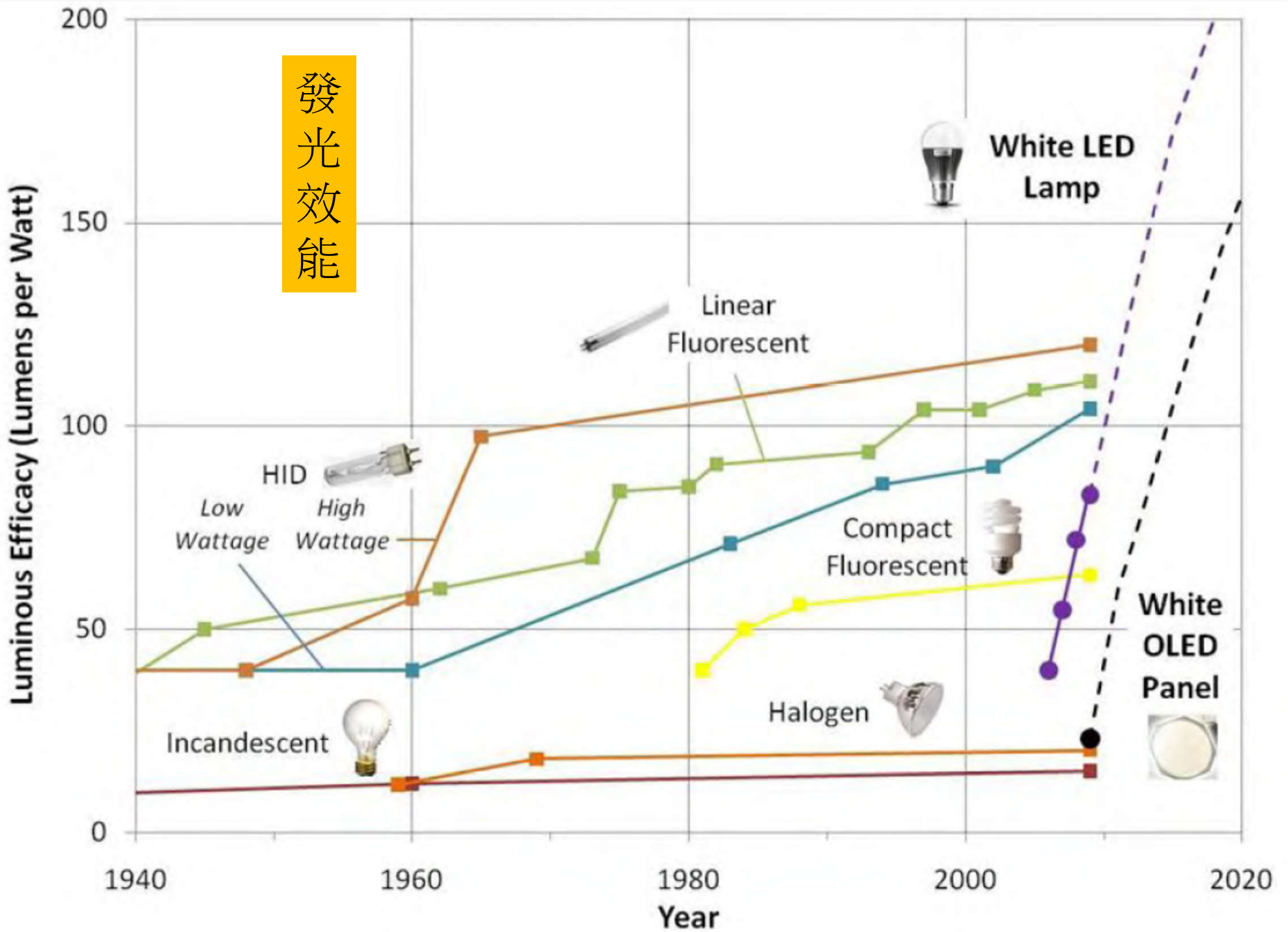
Luminance (cd/m²), L



Lighting terminology

- Important terms
  - 發光效能 Luminous efficacy of a source (lm/W), η
    - Ratio between the luminous flux emitted and the power consumed by the source
    - How well a light source produces visible light
    - http://en.wikipedia.org/wiki/Luminous_efficacy
  - 光譜功率分配 Spectral power distribution (SPD) curves
    - Curves to show the visual profile and colour characteristics of a light source
    - Plot of relative power emitted in the different regions of the spectrum

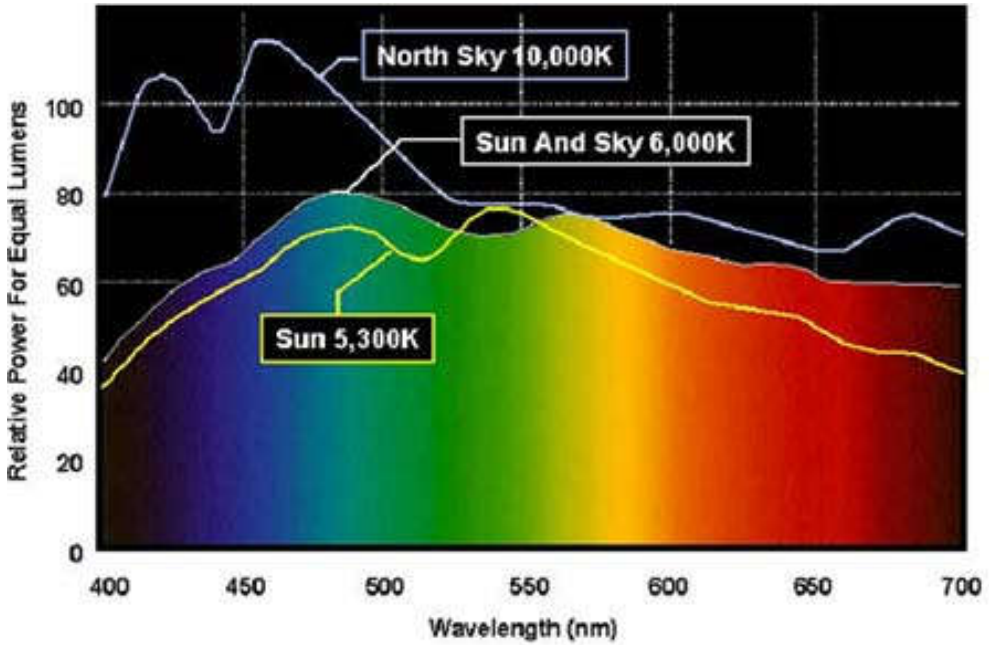
Historical and predicted luminous efficacy of light sources



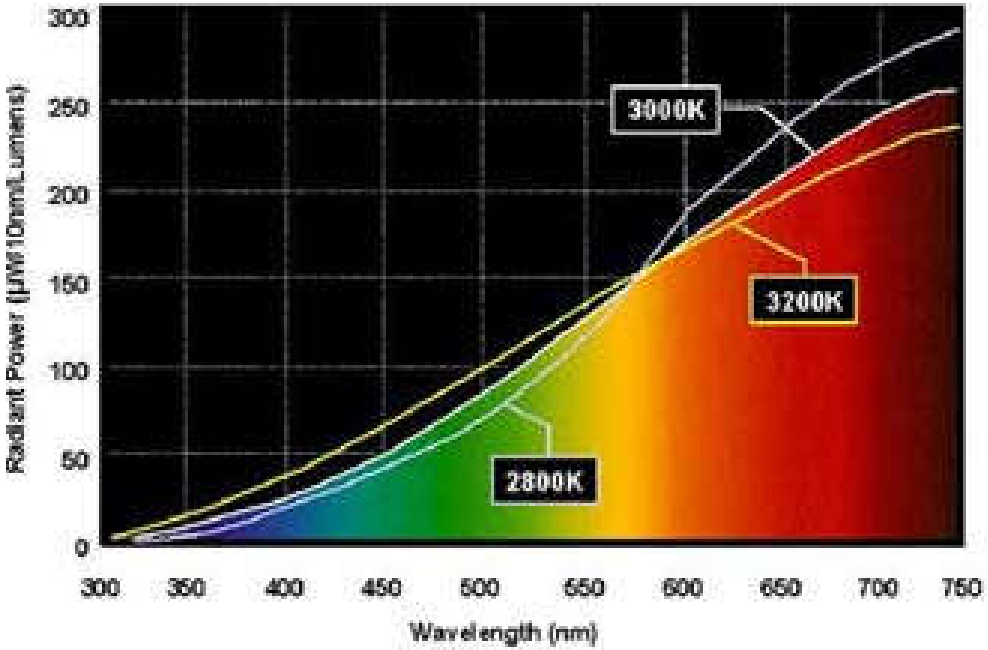
(Source: US Department of Energy)

Spectral power distribution (SPD) curves 光譜功率分配

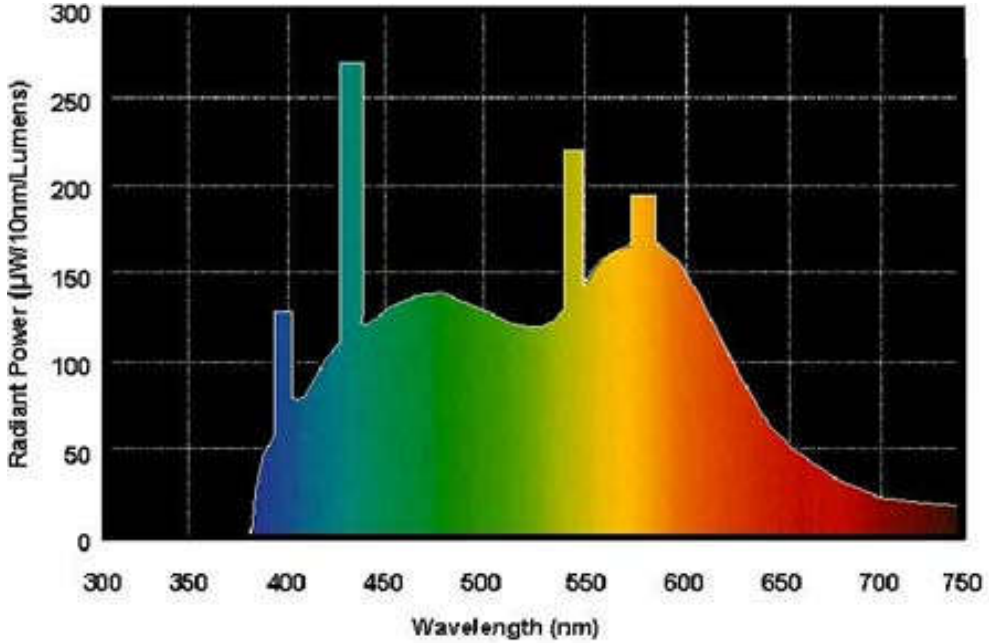
Outdoor daylight



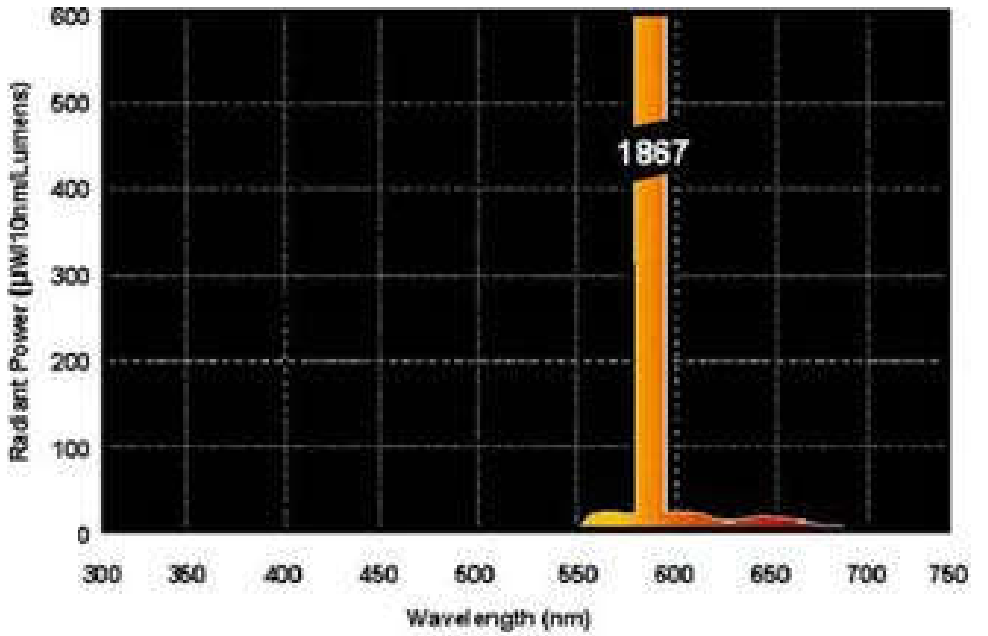
Incandescent



Fluorescent lamp (Daylight)

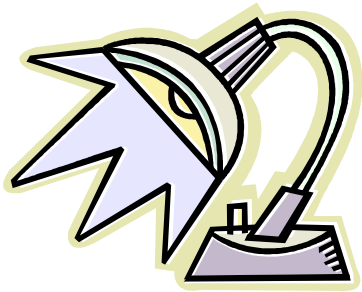


Low pressure sodium (LPS)

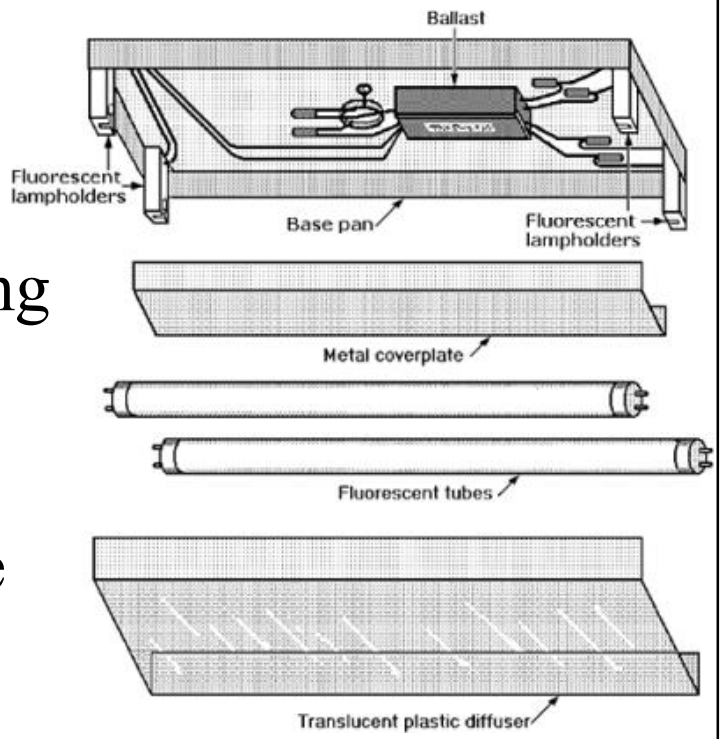


(Source: GE Lighting, http://www.gelighting.com)

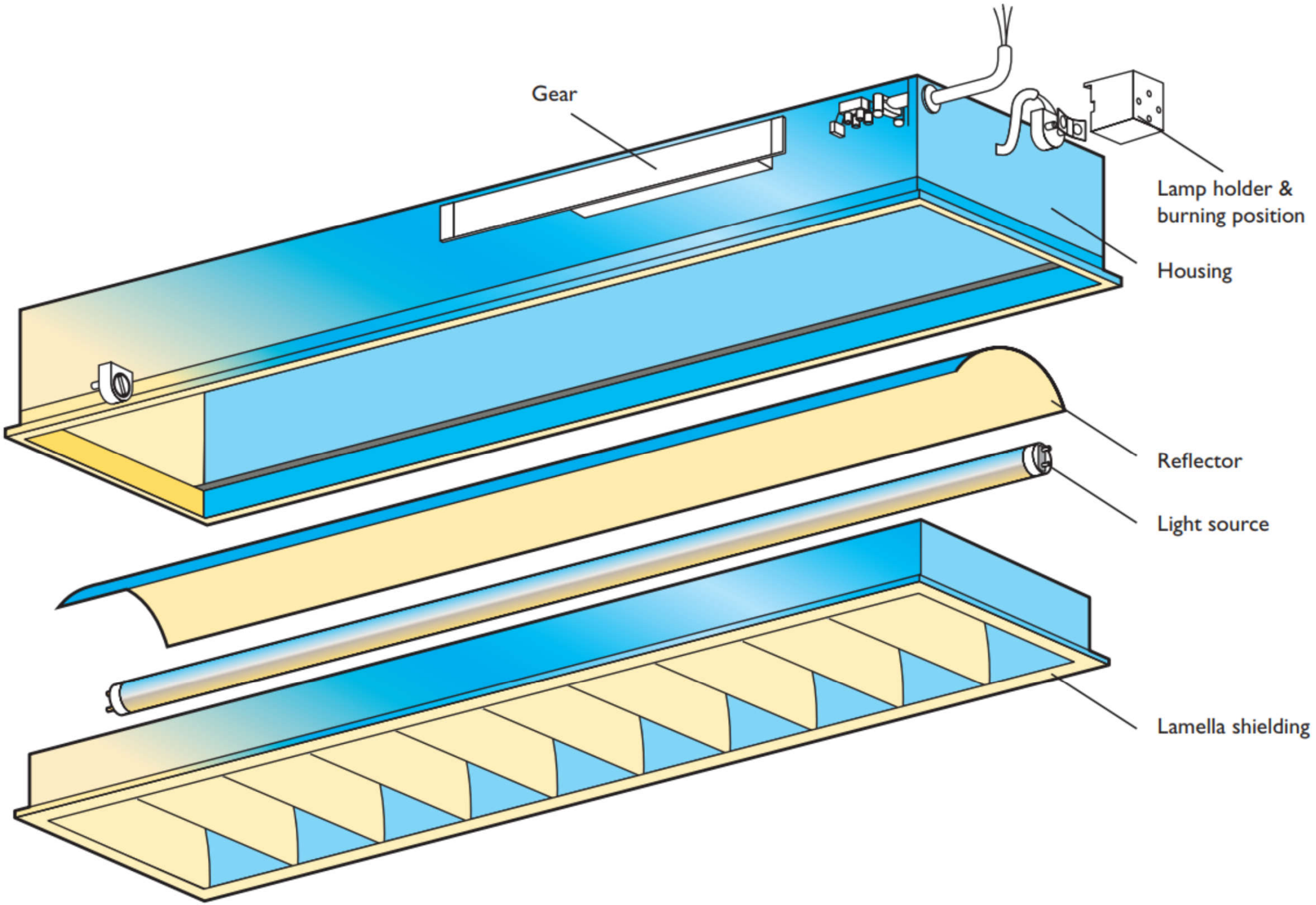
Lighting equipment



- Anatomy of a “lighting system”
  - Lighting components
    - Power source
    - Power controller: switching/dimming
    - Power regulators: ballasts
    - Light source: lamp
    - Optical control: luminaire or fixture
  - Environmental components
    - Room finishes: reflectances and texture
    - Spatial envelope: room boundaries
    - Fenestrations: windows and skylights



Basic components of luminaire 燈具的基本組成部分

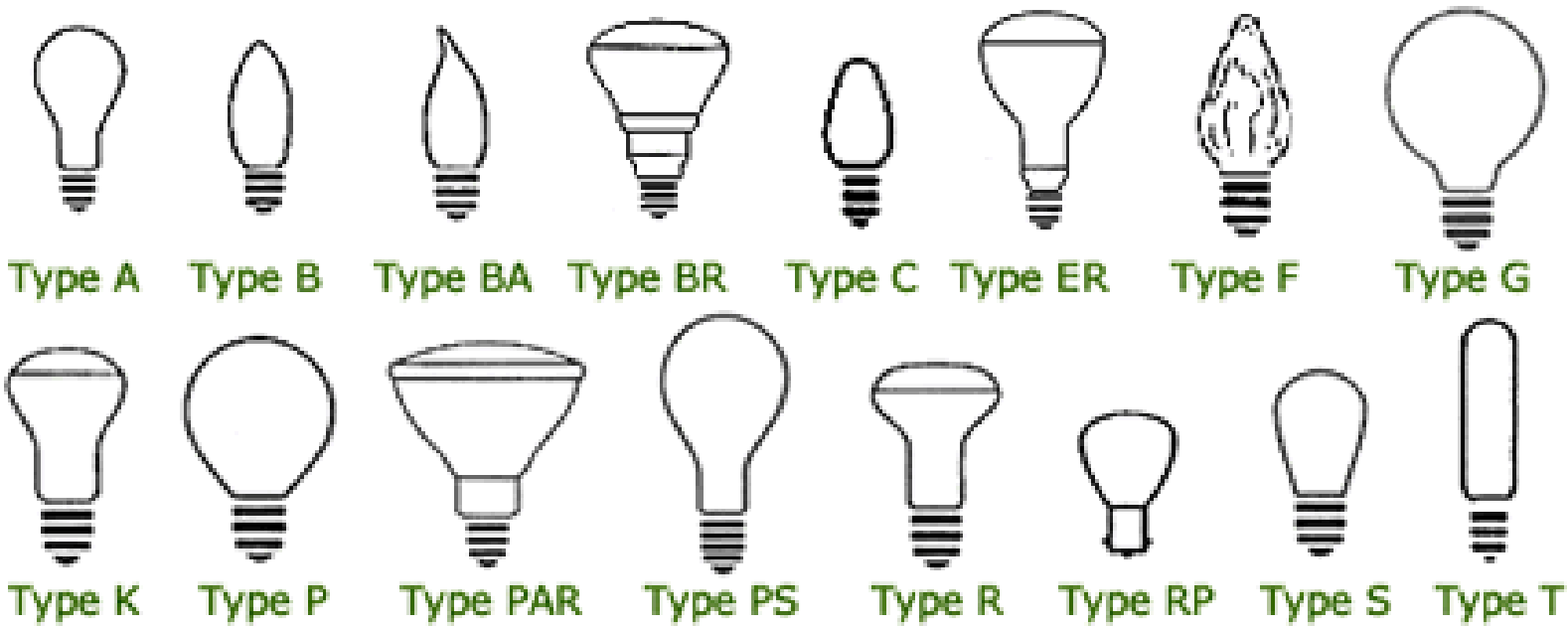


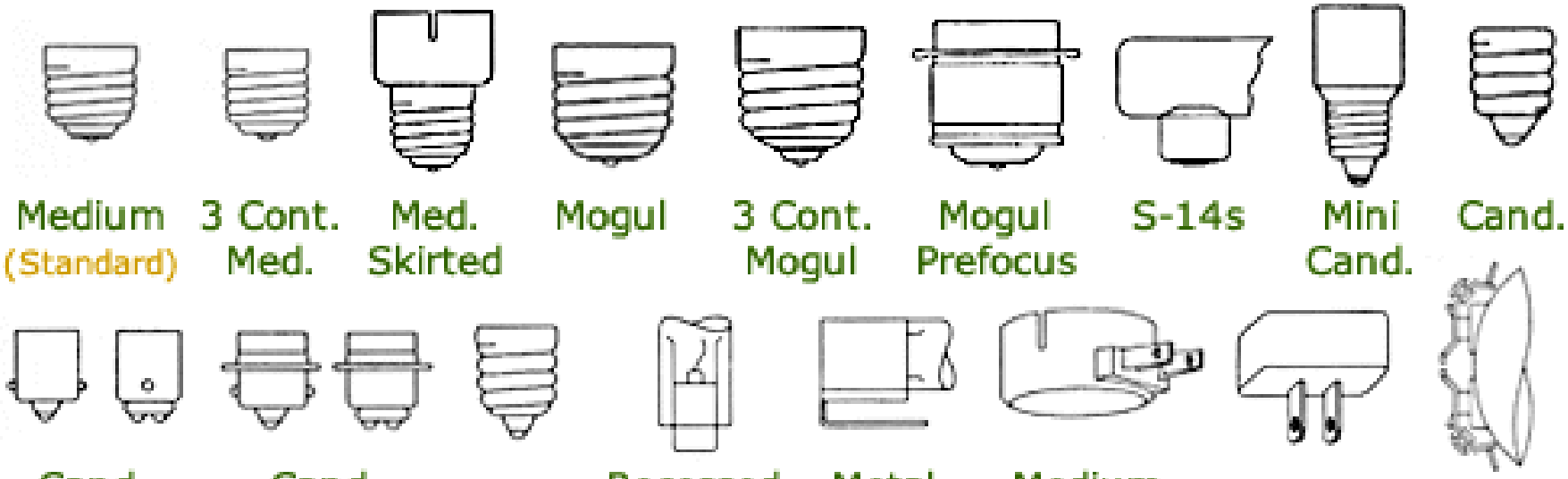
[Source: Philips Lighting]

Examples of light sources for general lighting

(Source: Advanced Lighting Guidelines)

Lamp shapes and bases 燈的形狀和底座

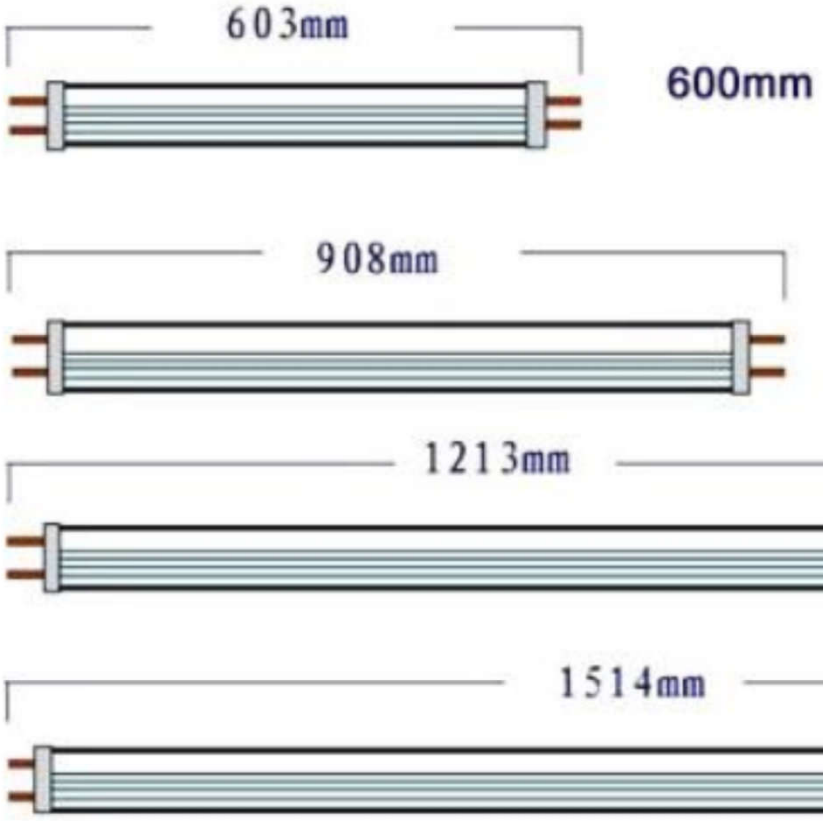




Lamp receptors 燈座

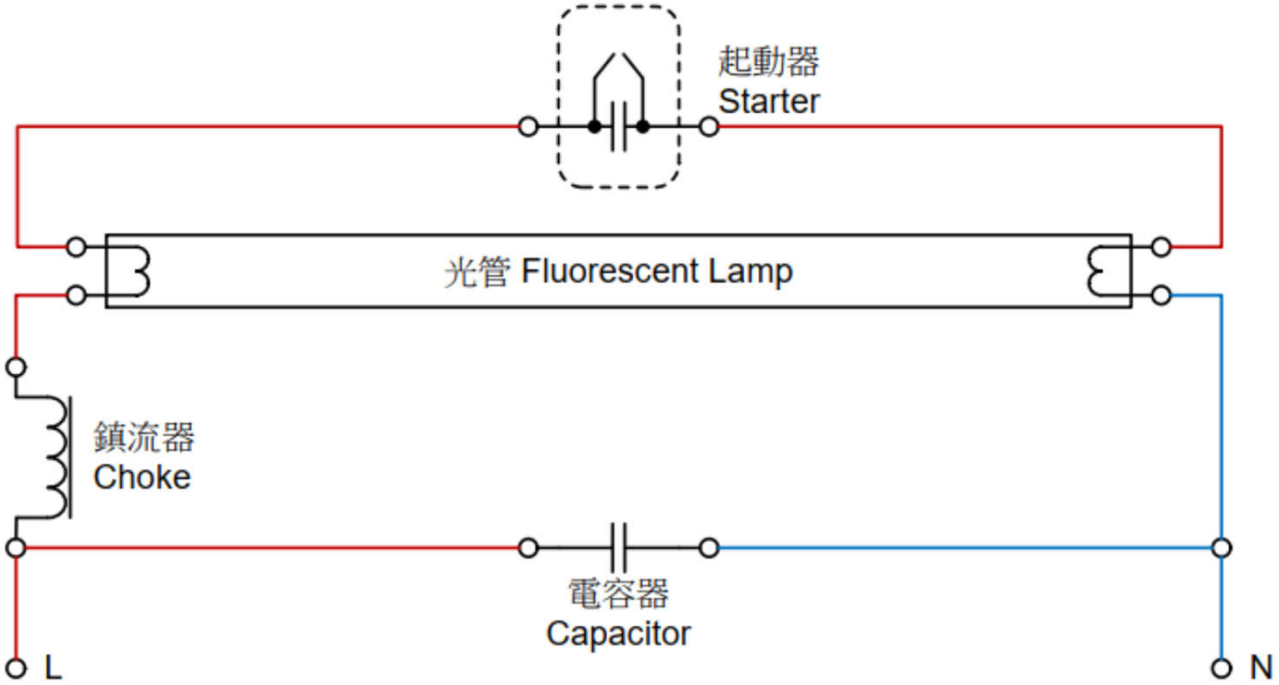
[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Fluorescent lamps & starters 螢光管和起動器

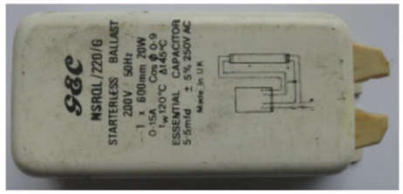


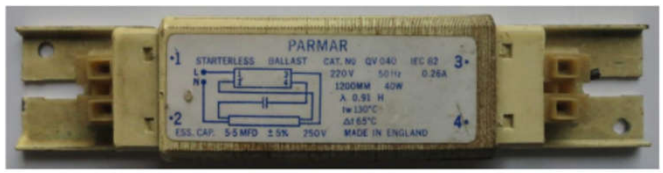
[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

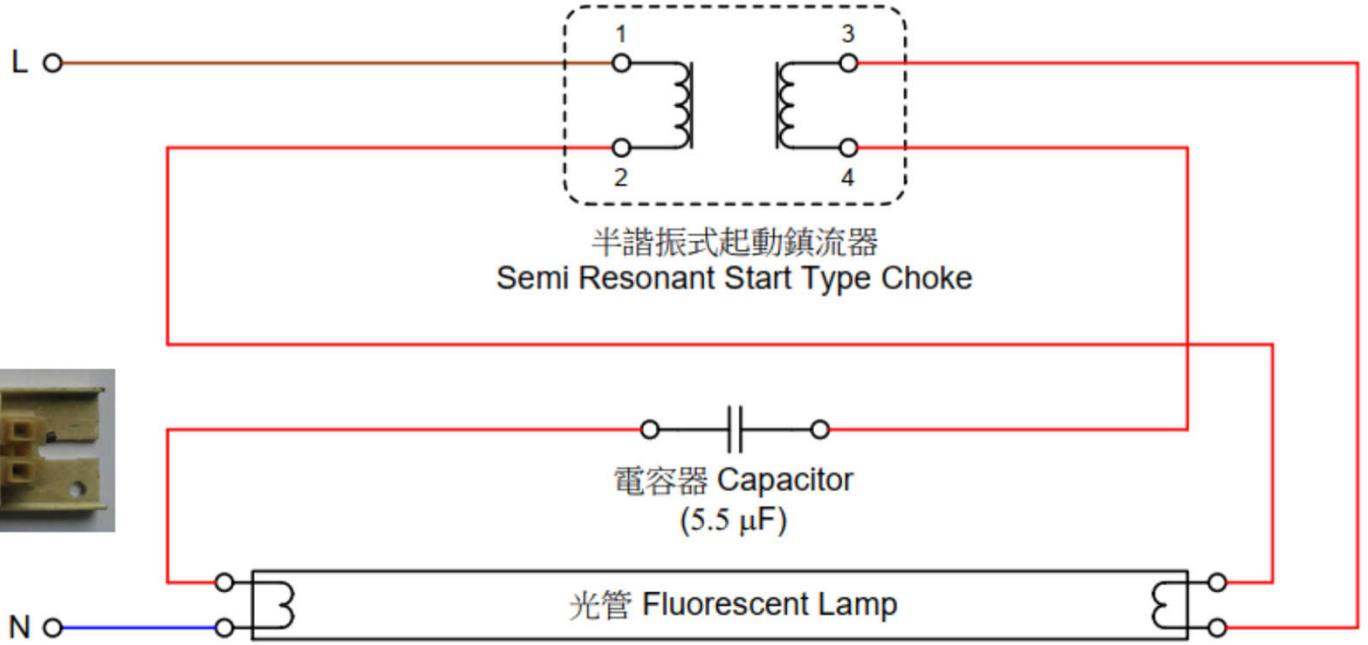
Glow Type Fluorescent Lamp Circuit (啟輝式光管電路):



Semi Resonant Start Type Fluorescent Lamp Circuit (半諧振式起動光管電路):

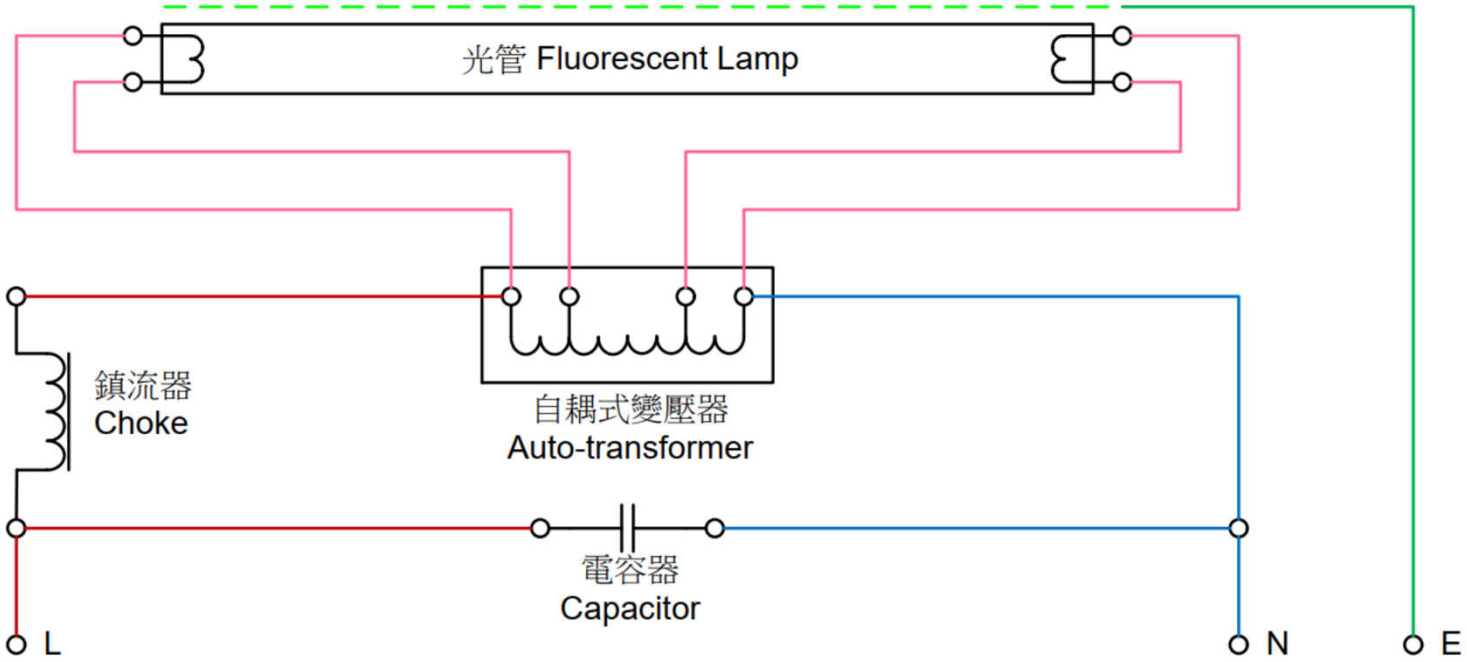




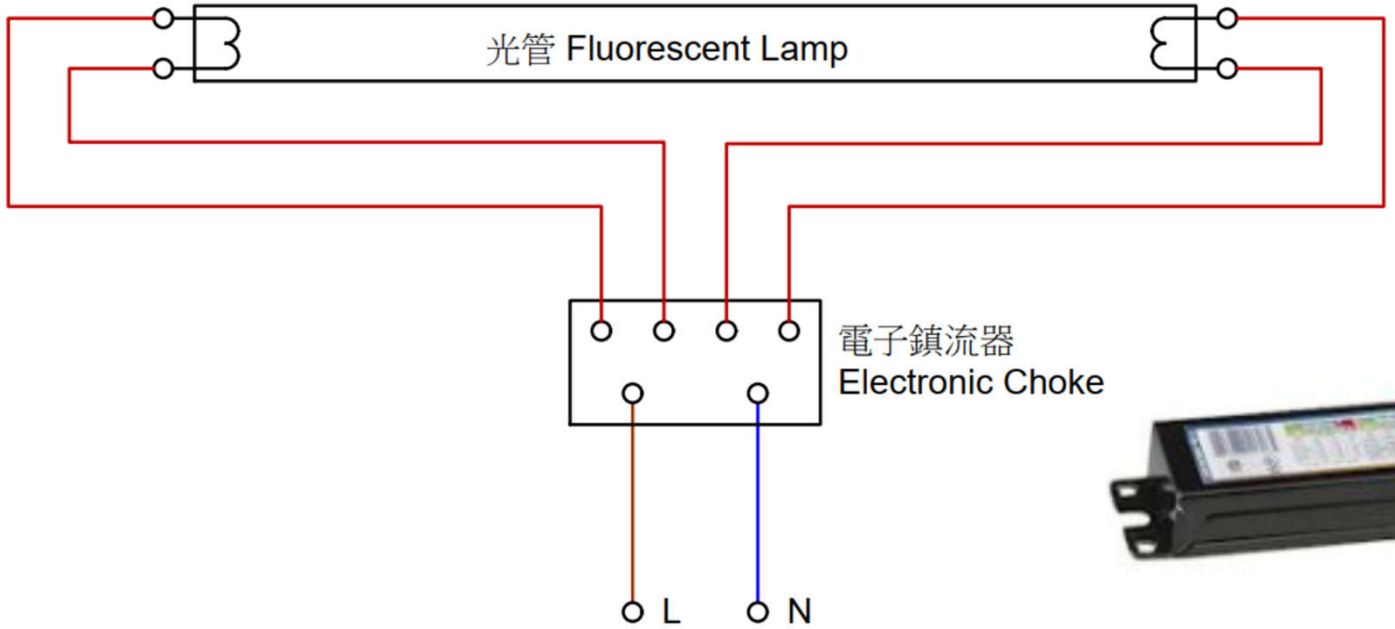


[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Quick Start Fluorescent Lamp Circuit (快速起動光管電路):

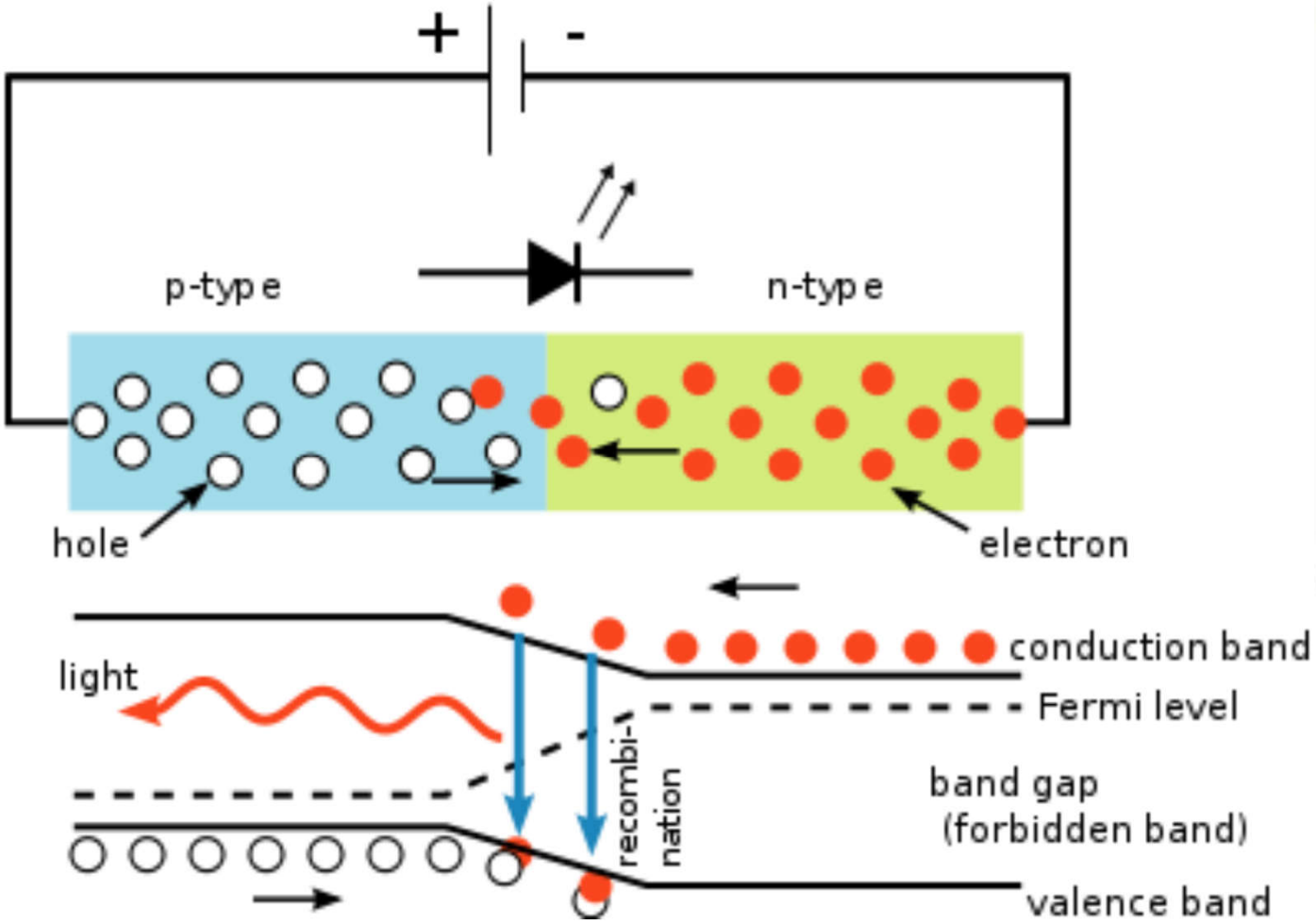


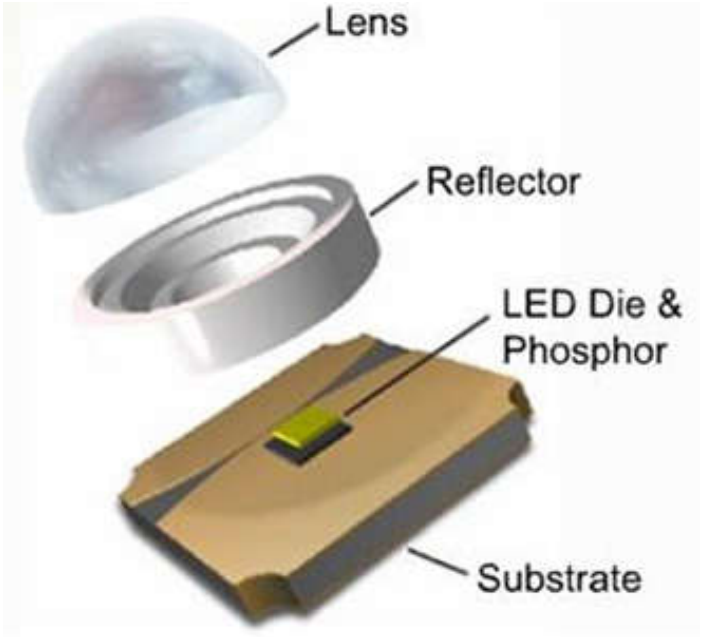
Electronic Choke Fluorescent Lamp Circuit (電子鎮流器光管電路):



[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Principle of LED and structure of high power white LED*
LED原理及大功率白光LED結構





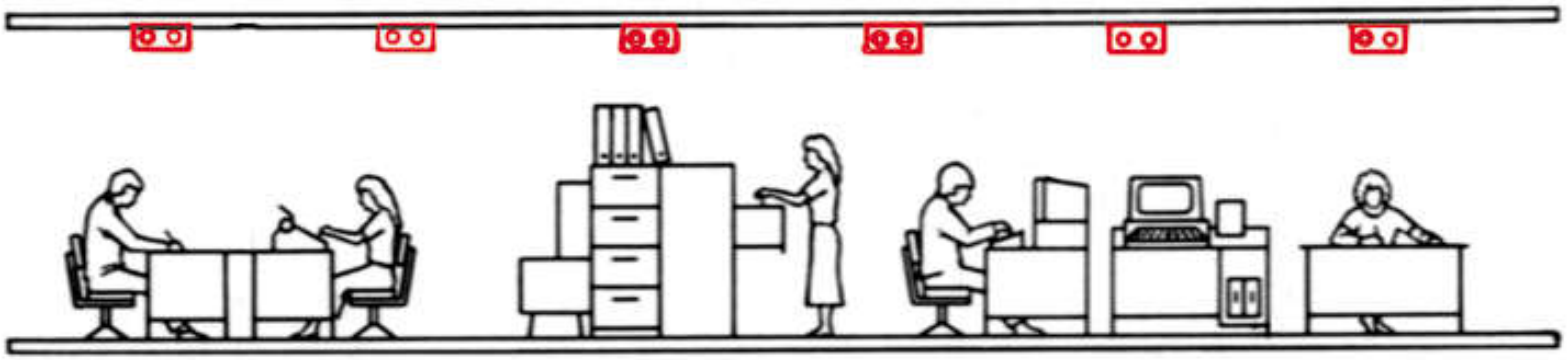
Structure of high power white LED

(* See How LED Works, http://www.omslighting.com/ledacademy/)

Design & maintenance practice

- Three main functions of lighting: 照明的三大主要功能
  - Ensure the safety of people 人員安全
  - Facilitate the performance of visual tasks 視覺任務
  - Aid the creation of an appropriate visual 視覺環境 environment

General lighting 一般照明



[Source: CIBSE Lighting Code]

Localised lighting 局部照明

[Source: CIBSE Lighting Code]

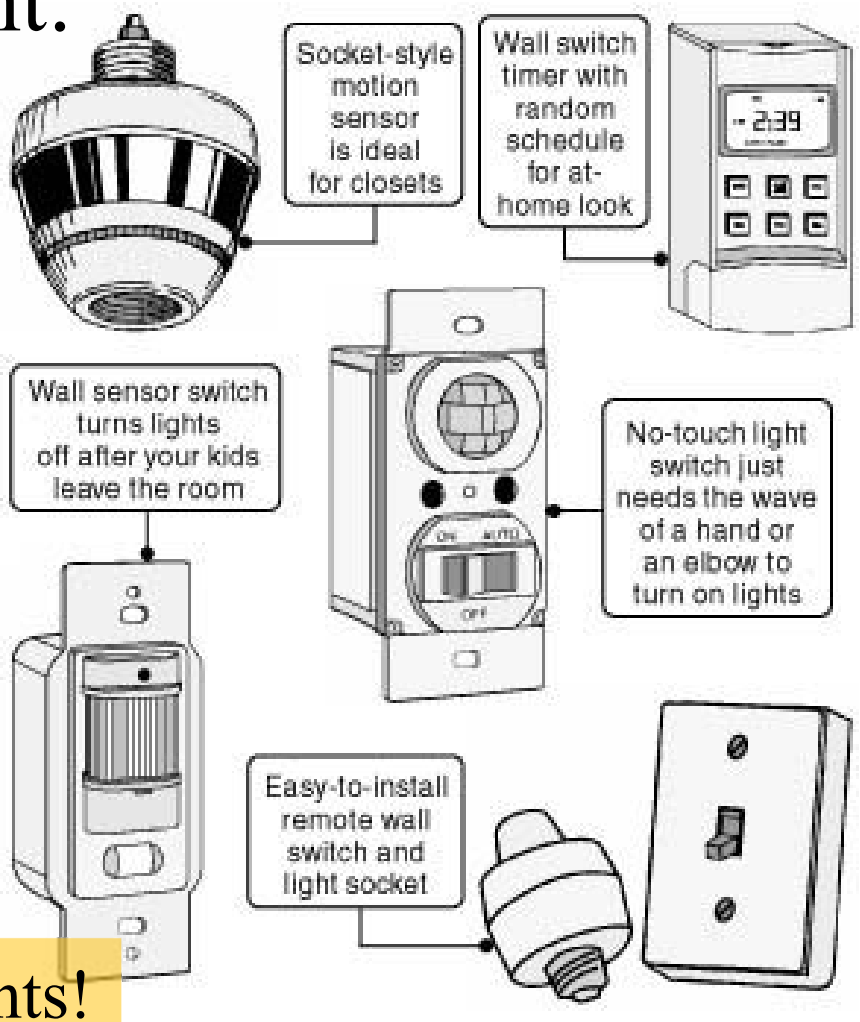
Local (task) lighting 局部（任務）照明

[Source: CIBSE Lighting Code]

Design & maintenance practice

- Lighting control equipment:
  - Switches
  - Occupancy sensing
  - Scheduling (timeclocks)
  - Daylight dimming
  - Tuning
  - Preset dimming
  - Building management

燈光控制設備



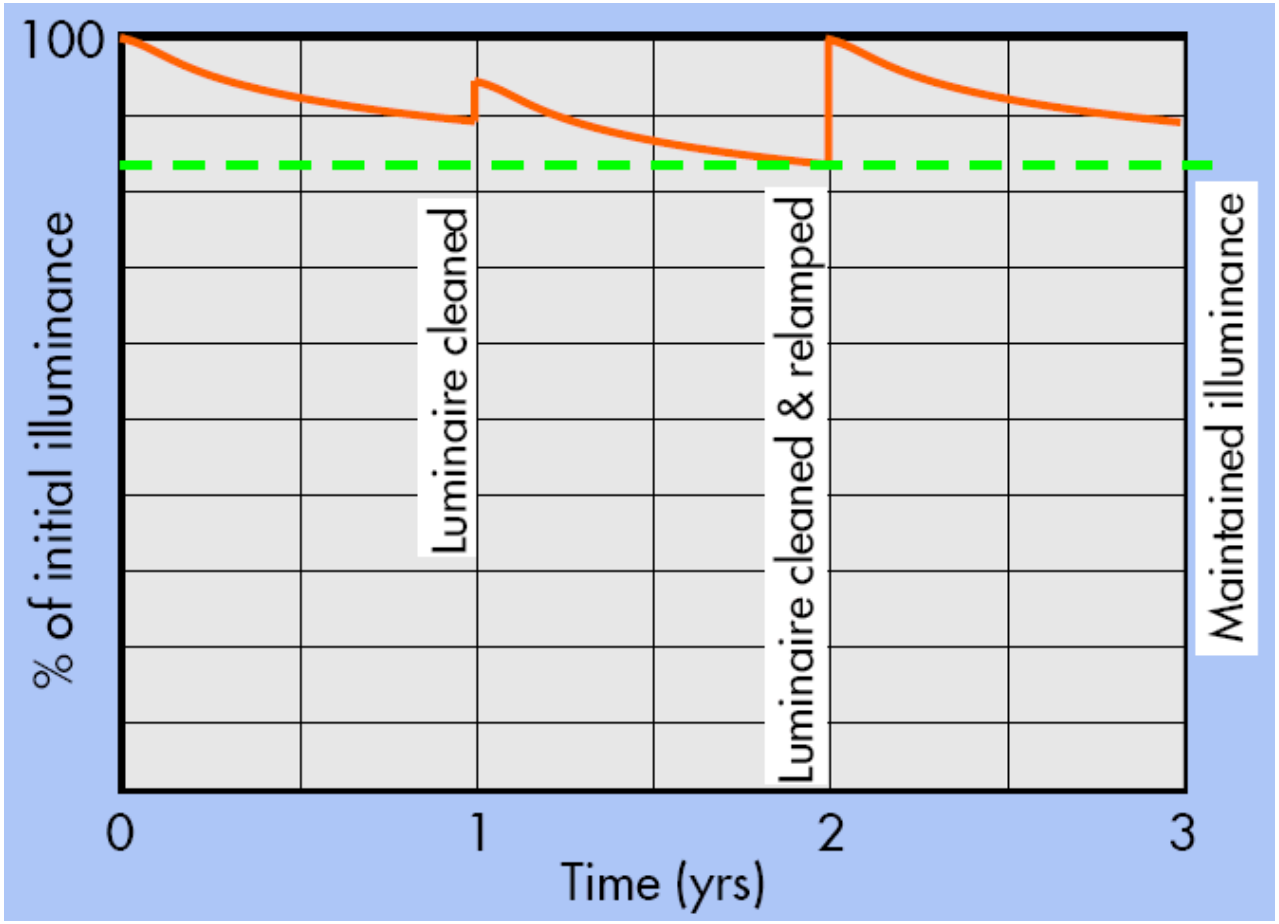
Remember: switch off unnecessary lights!

Design & maintenance practice

照明系統的維護

- Maintenance of lighting system
  - Periodic cleaning of lighting fixtures & lamps
    - Decreases light loss & improve light levels
  - Spot or group replacement of lamps
  - Reballasting (starters)
  - Miscellaneous maintenance
    - e.g. replace lenses or louvers, damaged parts
  - Periodic repainting or cleaning of the room surfaces (ceiling, walls, and floor) to maintain optimum light reflection characteristics

Lamp maintenance effect 燈具保養效果



Maintained illuminance is the value below which the average illuminance is not allowed to fall. When a lighting installation is planned, account needs to be taken of the fact that luminaires, lamps and rooms age and become soiled in the course of time. As a result, illuminance decreases. To compensate for the loss, every new installation needs to be designed for higher illuminances (= illuminance on installation). The lighting designer takes account of the decrease by applying a maintenance factor:

Maintained illuminance = (maintenance factor) x (illuminance on installation)

[Source: Thorn Lighting]

緊急照明燈

Emergency lighting

- Main purpose (when normal lighting fails)
  - Guide people quickly & safely from the building
  - Enable specific tasks to be completed
  - Avoid panic
  - Restore confidence

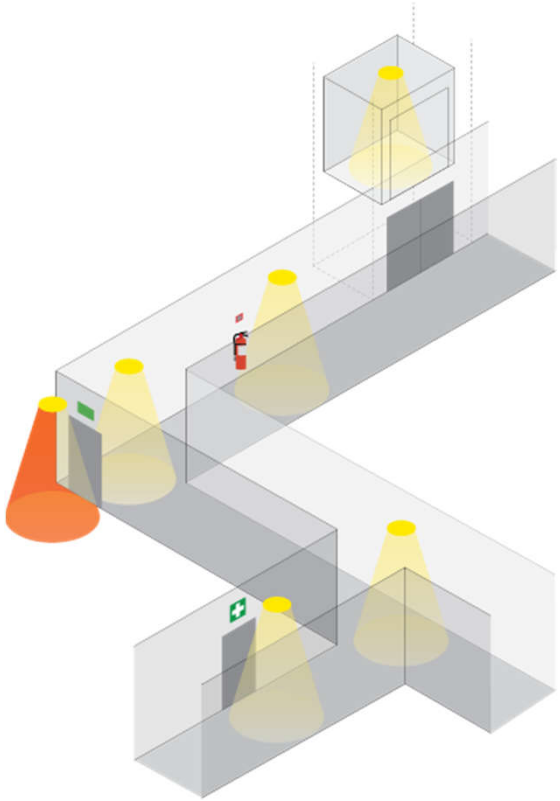
- Design shall follow the relevant regulations (e.g. fire services) & standards/codes (e.g. BS5266)
- Also, exit signs & signage lights

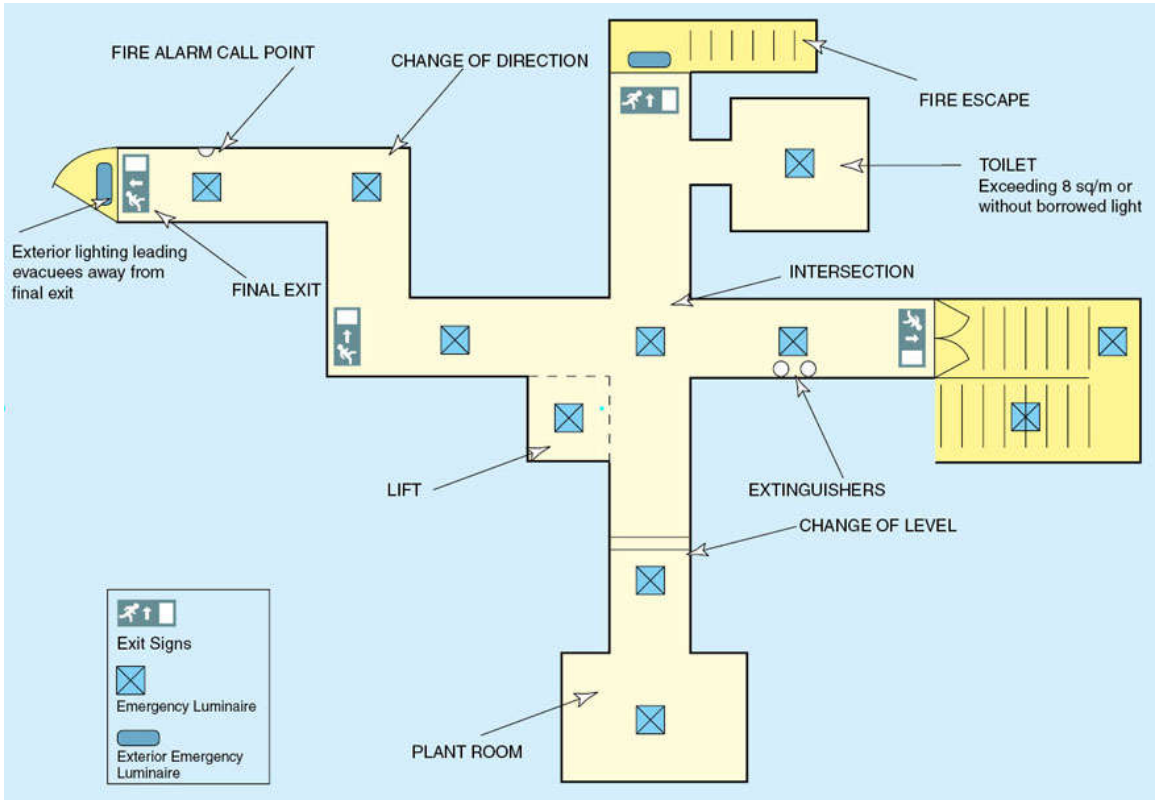
(See also: Emergency Light – Wikipedia http://en.wikipedia.org/wiki/Emergency_light)

Specific forms of emergency lighting and design drawings

應急照明的具體形式及設計圖紙

- Emergency Lighting
  - Emergency escape lighting
    - Escape route lighting
    - Open area (anti-panic area) lighting
    - High risk task area lighting
  - Standby lighting





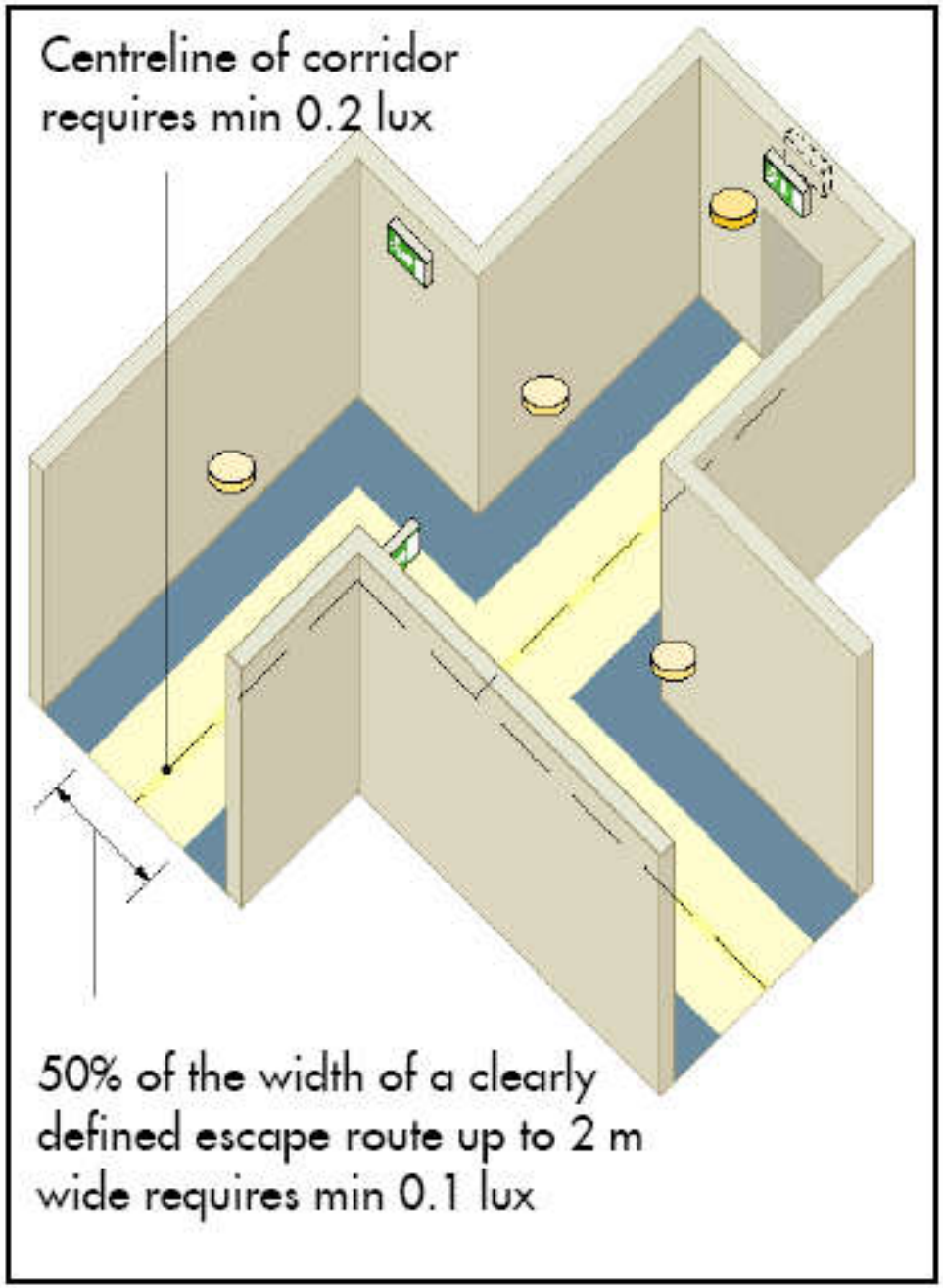
(Source: ICEL 1006: Emergency Lighting Design Guide http://www.icel.co.uk)

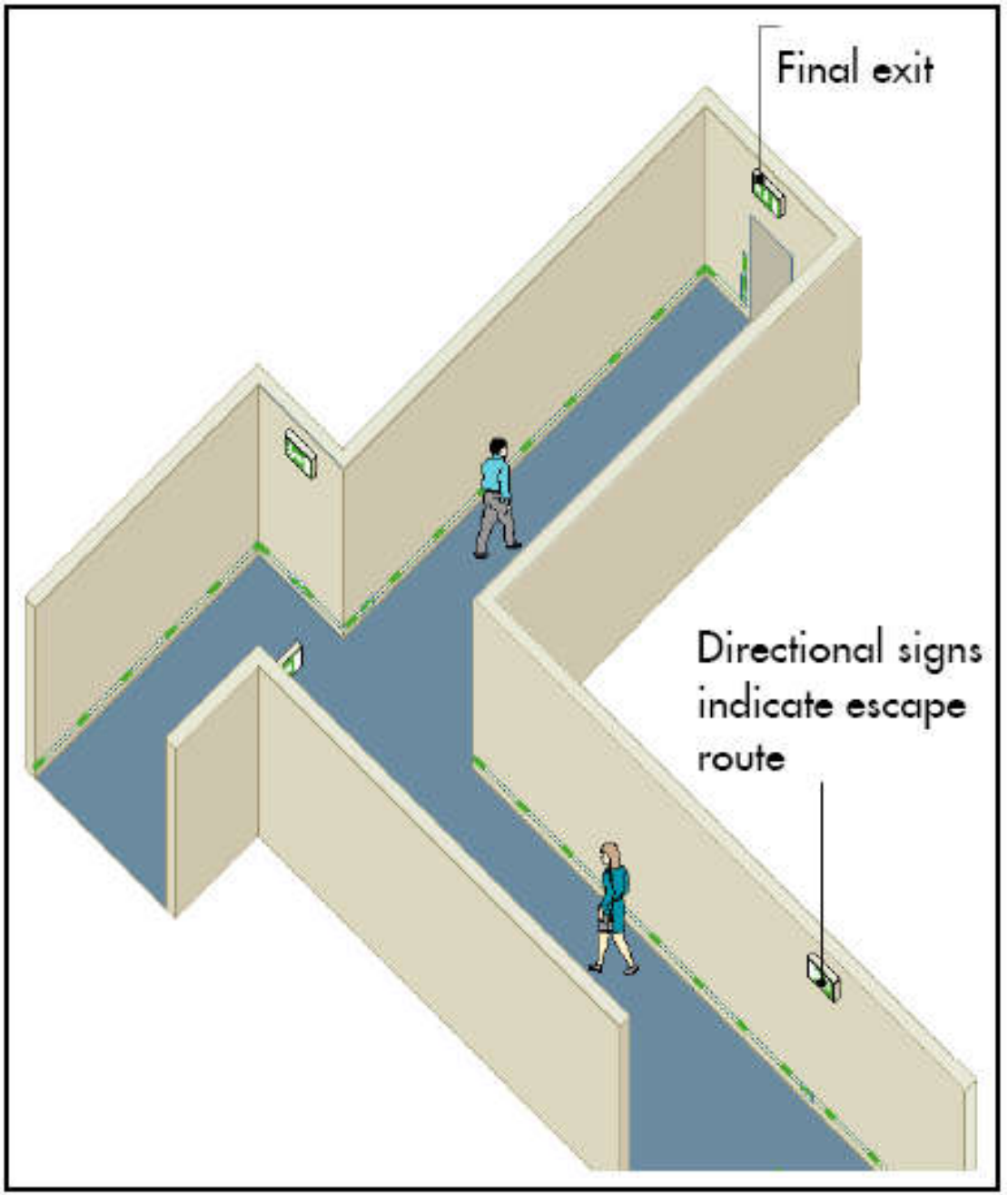
緊急照明燈

Emergency lighting

- Three typical types:
  - Emergency lighting (when normal lighting fails)
  - Escape lighting (assure means of escape)
    - Escape route, open area (anti-panic), high risk task area
  - Standby lighting
- Design requirements:
  - Illumination level = 1 lux; uniformity 40 : 1
  - Must be in operation ≤ 5 sec, last for 1 or 2 hours
  - Correct positioning & power supply
  - Battery backed up & automatic switch on

Emergency lighting & signage on escape route





逃生路線上的應急照明和標牌

(Source: Thorn Lighting, UK)

Emergency lighting 緊急照明燈

- Two types:
  - Maintained luminaires 保養燈具
    - Permanently illuminated, and remain illuminated when power fails, such as for emergency exit lighting
    - In some cases they may be switched off deliberately, but are usually required to be active when a building is occupied, or when the public are admitted, such as for a theatre

  - Sustained or non-maintained luminaires
    - May be switched on and off normally 持續或非維護燈具
    - If the power fails, they turn on automatically

Example of an escape route lighting design

逃生路線照明設計示例

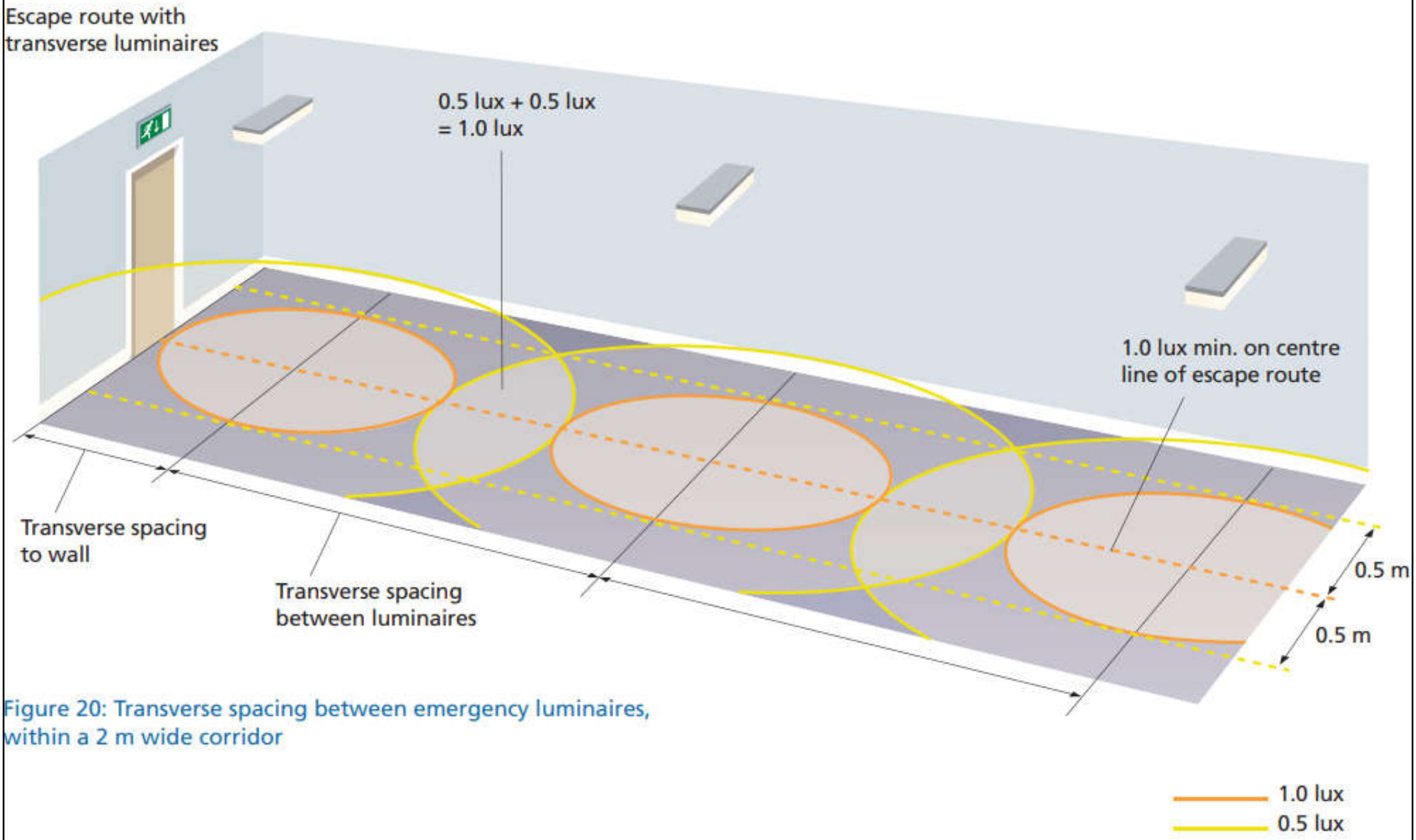


Figure 20: Transverse spacing between emergency luminaires, within a 2 m wide corridor

(Source: http://www.emergi-lite.co.uk/)

Energy efficient lighting

- HK Building Energy Code (BEC)*
  - Code of Practice for Energy Efficiency of Building Services Installations
    - 2018 Edition 《建築物能源效益守則》
  - Technical Guidelines on the Code of Practice
    - 2018 Edition
- Energy Efficiency Labelling Scheme (HK)* 能源效益標籤計劃
  - Compact fluorescent lamps (CFLs), LED

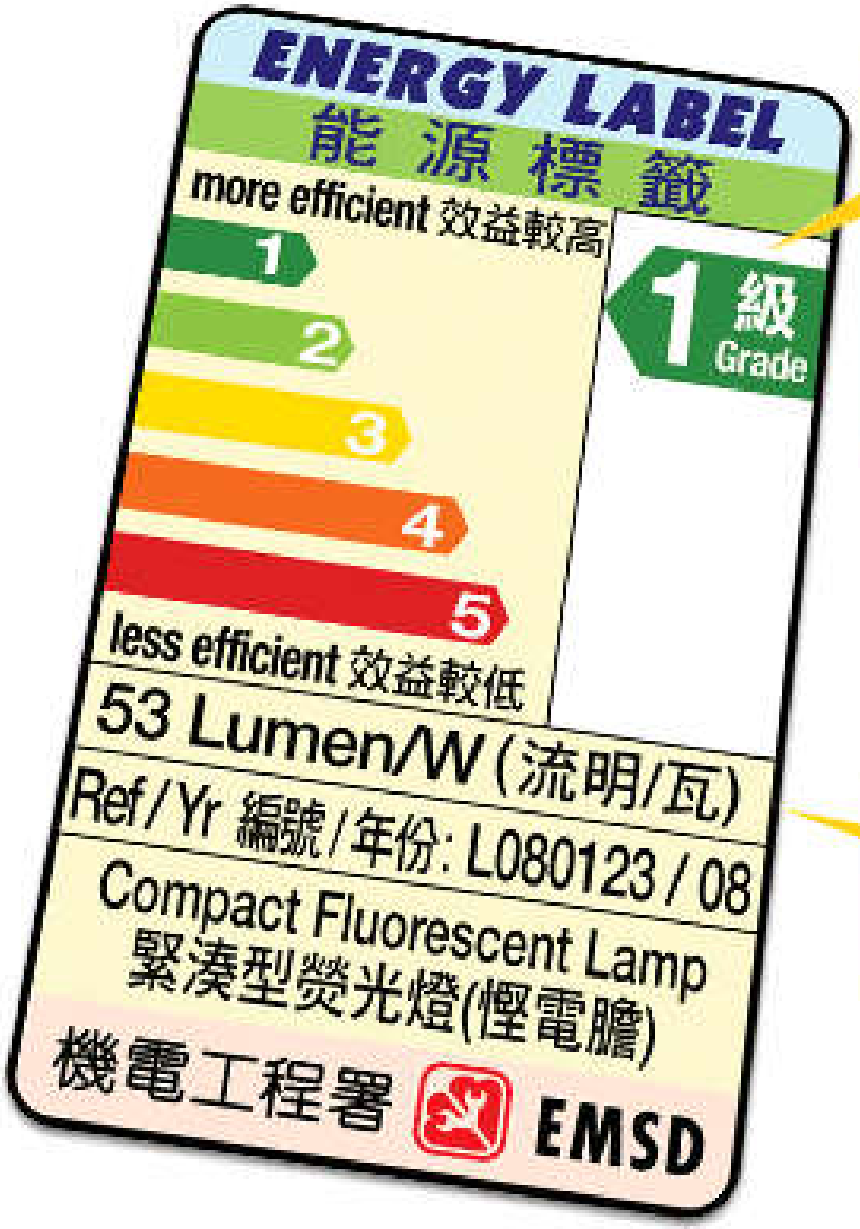
(* See also www.beeo.emsd.gov.hk and www.energylabel.emsd.gov.hk)

(Source: EMSD)

(See http://www.beeo.emsd.gov.hk for details)

UNDERSTANDING THE LABEL

Compact Fluorescent Lamps (CFLs)



This indicates the energy efficiency grading of the model. Grade 1 products are most efficient (green) and have an average lamp life of 8,000 hours or above. Grade 5 products have an average lamp life of below 6,000 hours (red).

Lamp luminous efficacy of the model. A higher number indicates that the product is more efficient.

PERCENTAGE OF ENERGY SAVING

Compact Fluorescent Lamps (CFLs)

Grade 1 vs Grade 5

18%

TIPS

Switch off lights that are not in use.

(Source: EMSD)

(See www.energylabel.emsd.gov.hk for details)

Energy efficient lighting

- HK Building Energy Code: energy efficiency requirements for lighting installation 照明裝置
  - 1. Lighting power density (LPD) 照明功率密度
    - Reduce lighting power
  - 2. Lighting control point 照明控制點
    - Facilitate effective operation; reduce energy use
  - 3. Automatic lighting control 自動照明控制
    - Such as daylight responsive control, occupant sensor, time scheduling, dimmer control system

Table 5.4 : Lighting Power Density and Automatic Lighting Control for Various Types of Space

Type of Space	Maximum Allowable LPD (W/m^2)	Automatic Lighting Control Required (Yes / No)
Atrium / Foyer with headroom over 5m	17	Yes
Bar / Lounge	13	No
Banquet Room / Function Room / Ball Room	17	No
Canteen	11	No
Car Park	5	Yes, at parking spaces only
Changing Room/ Locker Room	10	Yes
Classroom / Training Room	12	Yes
Clinic	15	No
Common Room/ Break Room	8	Yes
Computer Room / Data Centre	15	Yes
Conference / Seminar Room	14	Yes
Confinement Cell	12	No
Copy/ Printing Room, Photocopy Machine Room	10	Yes
Corridor	8	Yes
Court Room	15	Yes
Covered Playground (underneath building)/ Sky Garden	12	Yes
Dormitory	8	Yes
Entrance Lobby	13	Yes
Exhibition Hall / Gallery	15	No
Fast Food / Food Court	14	No
Guest room in Hotel or Guesthouse	13	No
Gymnasium / Exercise Room	11	Yes
Indoor Swimming Pool, for recreational or leisure purposes	15	No
Kitchen	13	No
Laboratory	15	No
Lecture Theatre	13	Yes
Library – Reading Area or Audio Visual Centre	12	No
Library – Stack Area	15	No
Lift Car	11	Yes
Lift Lobby	10	Yes
Loading & Unloading Area	8	Yes
Long Stay Ward for elderly	15	No
Nurse Station	13	No
Office, enclosed (Internal floor area at or below $15m^2$)	12	Yes
Office, Internal floor area above $15m^2$ and of or below $200m^2$	10	Yes
Office, Internal floor area above $200m^2$	9	Yes
Pantry	12	Yes

(Source: BEC 2018)

Sample calculation for lighting power density (LPD)

Table 5.7 : LPD Calculation for Multi-functional Space					
Space Function	Function-specific Luminaires			LPD (W/m^2)	
	Luminaire Designation	Quantity	Total Circuit Wattage (W)	Calculated	Max Allowable
Banquet room	LT1	96	480	[480 + 2880 + 1104] / 264 = 16.9	17
	LT2	90	2880		
	LT3	8	1104		
	LT4	Excluded in LPD			
Ball room	LT2	90	2880	[2880 + 1104] / 264 = 15.1	17
	LT3	8	1104		
	LT4	Excluded in LPD			
Seminar room	LT1	96	480	[480 + 2016] / 264 = 9.5	14
	LT5	112	2016		

(Source: Technical Guidelines on Building Energy Code 2018)