



Key Scientific questions in the definition of the SI unit of luminous intensity, the candela

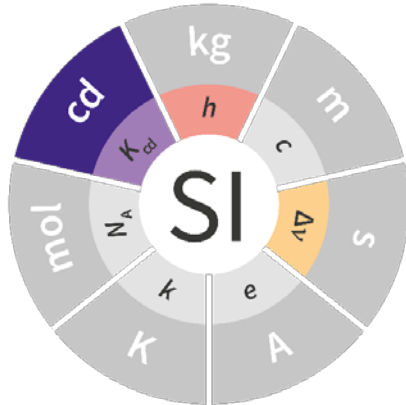
25th Meeting of the CCU

Bureau
| **I**nternational des
| **P**oids et
| **M**esures





- Introduction of **defining constant** for photometry, K_{cd}
luminous efficacy of monochromatic radiation of frequency $540 \times 10^{12} \text{ Hz}$
- **Reformulation** of definition of the candela
 - (not a redefinition), to bring it in **explicit constant** form:



THE CANDELA

The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency $540 \times 10^{12} \text{ Hz}$, K_{cd} , to be 683 when expressed in the unit lm W^{-1} , which is equal to cd sr W^{-1} , or $\text{cd sr kg}^{-1} \text{m}^{-2} \text{s}^3$, where the kilogram, metre and second are defined in terms of h , c and $\Delta\nu_{\text{Cs}}$.



- K_{cd} makes a direct link between photometric and radiometric quantities for monochromatic radiation of frequency 540 THz

flux

$$\text{lm} \leftrightarrow \text{W} \\ K_{cd}$$

illuminance

$$\text{lx} \leftrightarrow \text{W} \cdot \text{m}^{-2} \\ K_{cd}$$

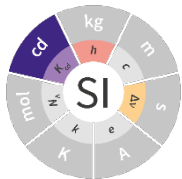
intensity

$$\text{cd} \leftrightarrow \text{W} \cdot \text{sr}^{-1} \\ K_{cd}$$

luminance

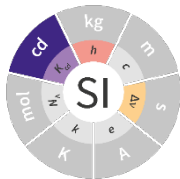
$$\text{cd} \cdot \text{m}^{-2} \leftrightarrow \text{W} \cdot \text{sr}^{-1} \cdot \text{m}^{-2} \\ K_{cd}$$

- [*Mise en pratique* for the definition of the candela in the SI](#) (20 May 2019)
- BIPM report 05/2019: [Principles governing photometry](#) (20 May 2019)
- [Appendix 3 Units for photochemical and photobiological quantities](#) (20 May 2019)



The present definition serves very well all practical requirements for global trade, science and society.

However, still there is a key scientific challenge related to the fact the defining constant, linking the given photometric unit to the corresponding radiometric unit, has no fundamental character.



COMITÉ CONSULTATIF

DE PHOTOMÉTRIE ET RADIOMÉTRIE

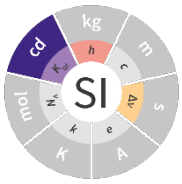
9^e SESSION — 1977

COMITÉ CONSULTATIF

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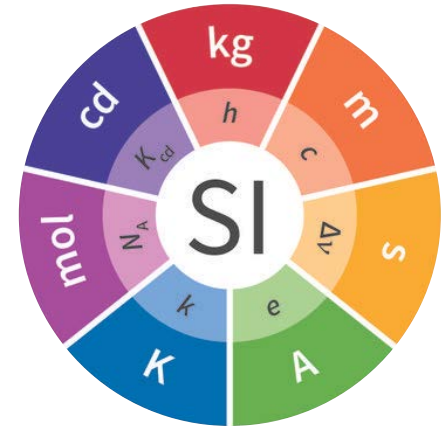
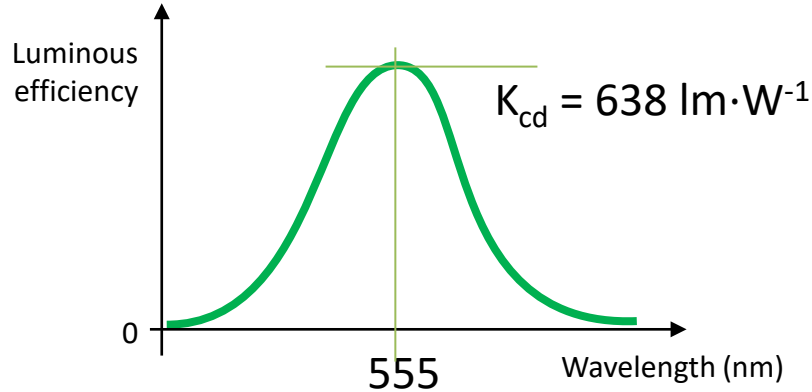
8^e SESSION — 1975

(3-5 septembre)



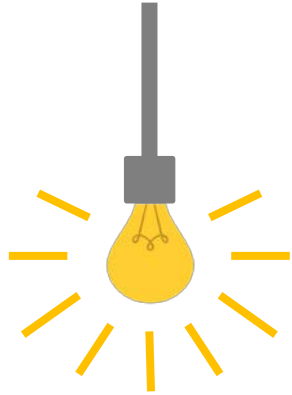
Success story : Photometry

Standard Photopic observer
(CIE 1924)

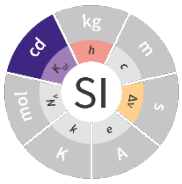


SI brochure

Principle governing photometry



Luminous intensity
(visual)



$$L = K_m \int L_{e,\lambda} V(\lambda) d\lambda$$

Photometry – a success story

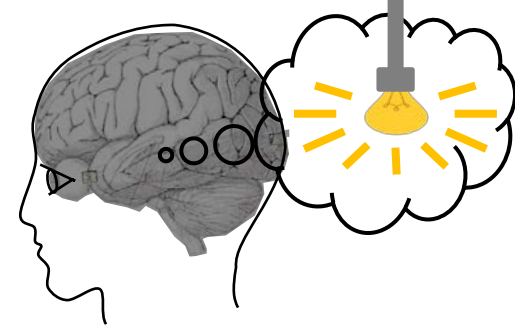
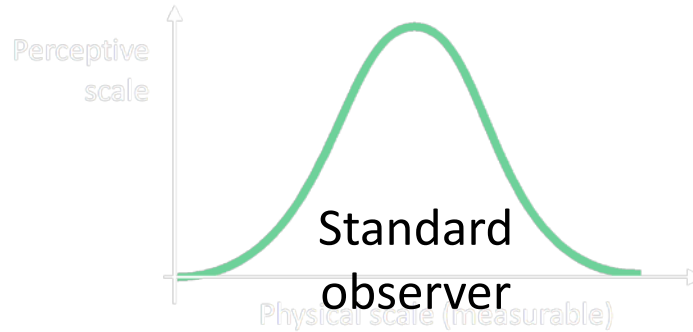


Radiometry & spectrophotometry

Current method



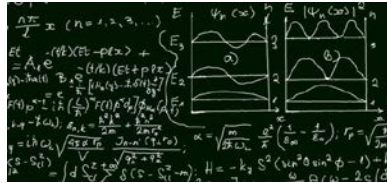
Psychophysical experiments



Perception model

$$\int_{380}^{780} P_{\lambda} \cdot V(\lambda) d\lambda$$

Normalization activity





Photometry

Photometry is the science of the measurement of light, in terms of its perceived brightness to the human eye.



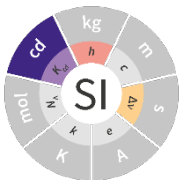
light
stimulus



eyes



brain

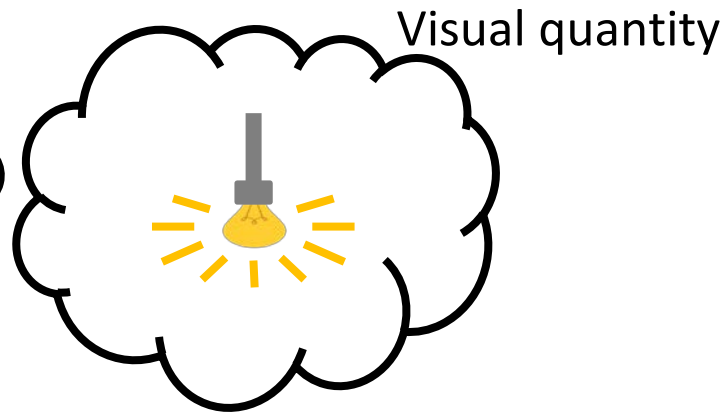
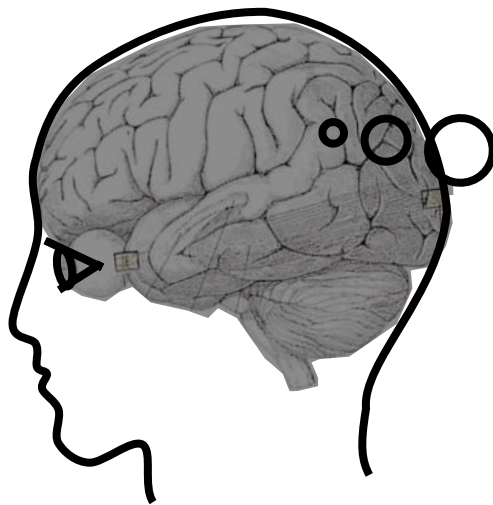
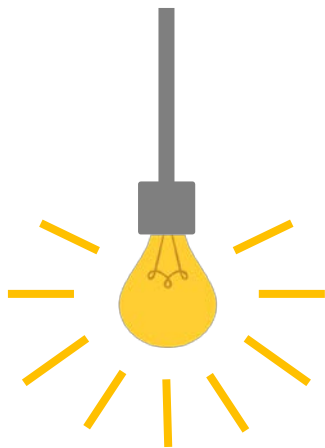


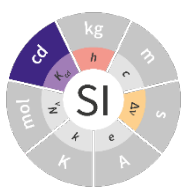
Measurement of visual quantities

Photometry deals with visual quantities.

The measurand is not accessible by the measuring instrument

The measurand may vary from an observer to another





Human eye

Lens

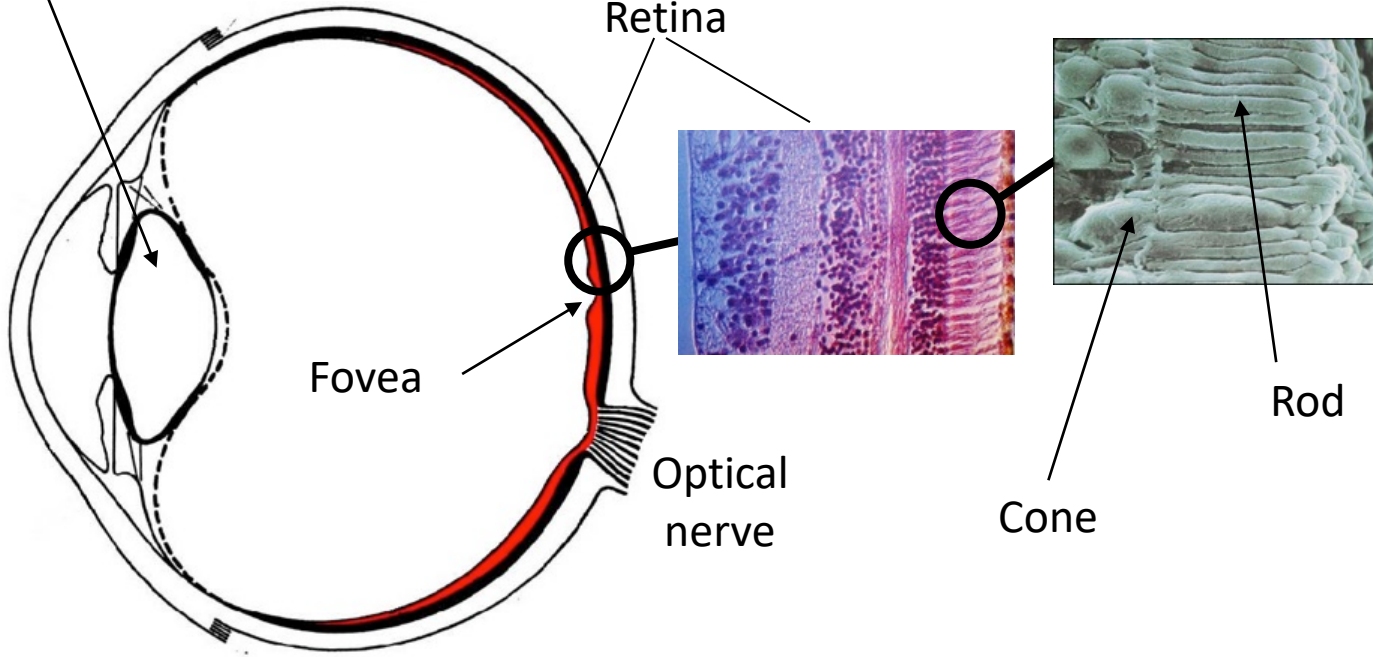
Retina

Fovea

Optical
nerve

Cone

Rod

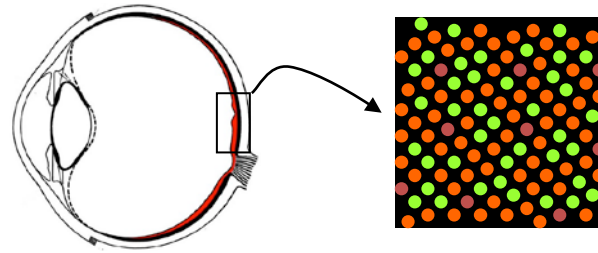
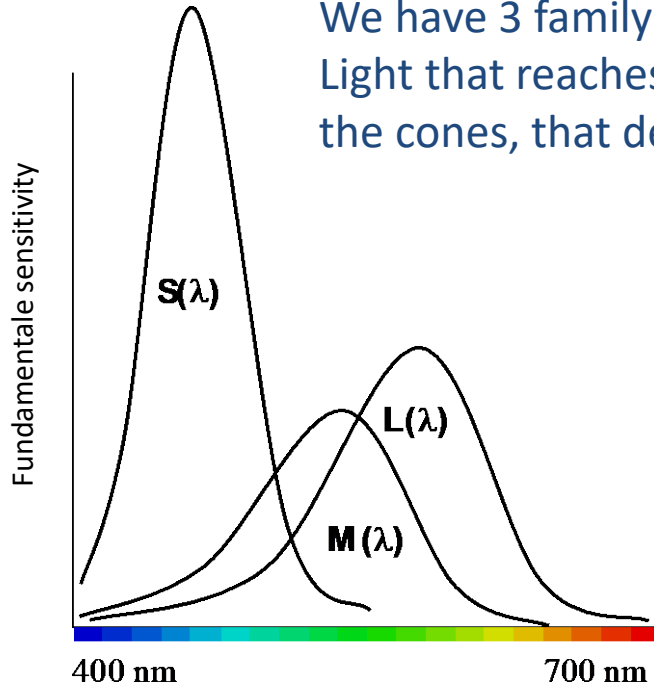




Cones (L M S)

We have 3 family of cones.

Light that reaches the retina generates 3 signals in the cones, that depend upon the wavelength



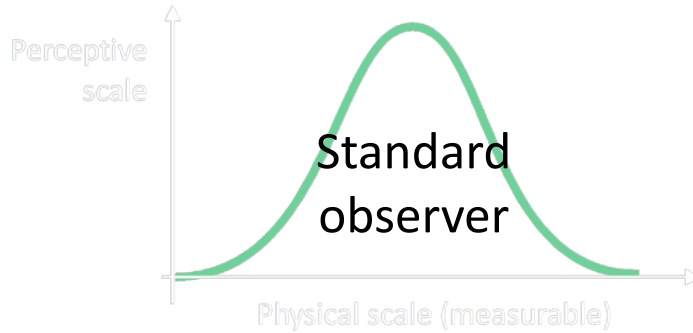
$S(\lambda)$	$\lambda_{\max} \cong 440 \text{ nm}$
$M(\lambda)$	$\lambda_{\max} \cong 540 \text{ nm}$
$L(\lambda)$	$\lambda_{\max} \cong 570 \text{ nm}$



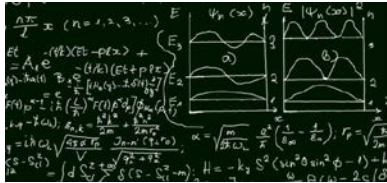
Measurement of perceptive quantities



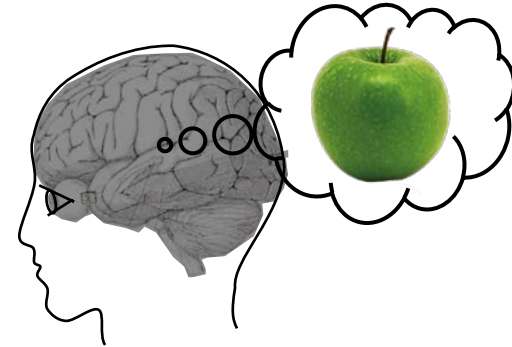
Radiometry & spectrophotometry



Perception models



Psychophysical experiments



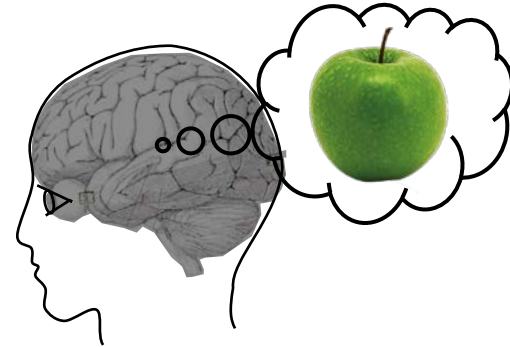
Normalization activity



Measurement of perceptive quantities

Future method

Machine Learning



Normalization activity



Artificial intelligence

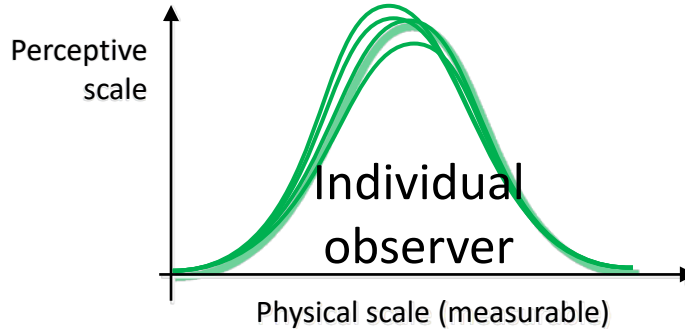
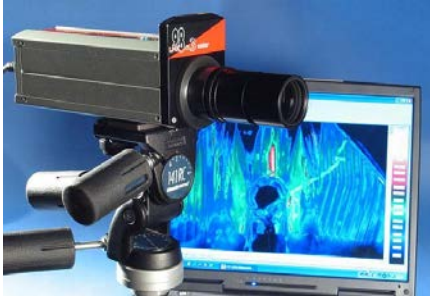
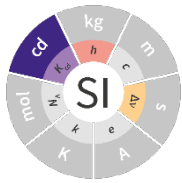


Image based radiometry





Taking into account the progress done so far and foreseeable in vision science and AI, there could be in few years some changes in the photometric quantities because of a much better understanding of the luminous perception using the cone-fundamentals system.



This cone-fundamental based photometric system would need a new link between photometry (lm, cd, lx,...) and radiometry (W, W/sr, W/m²...).

This link and its nature are the key scientific challenges in the definition of the candela for the next future.