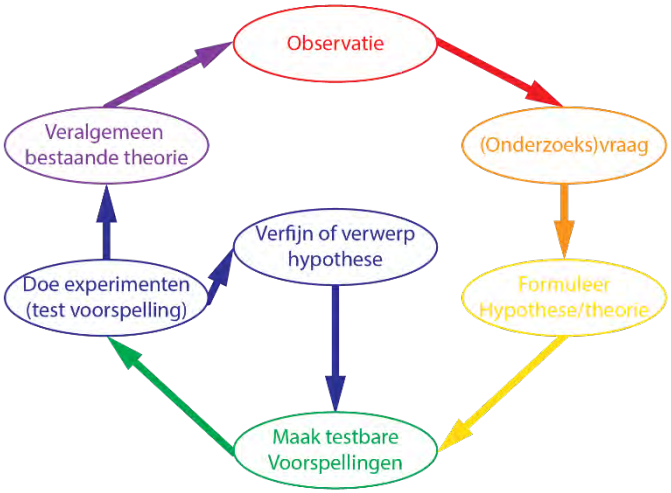
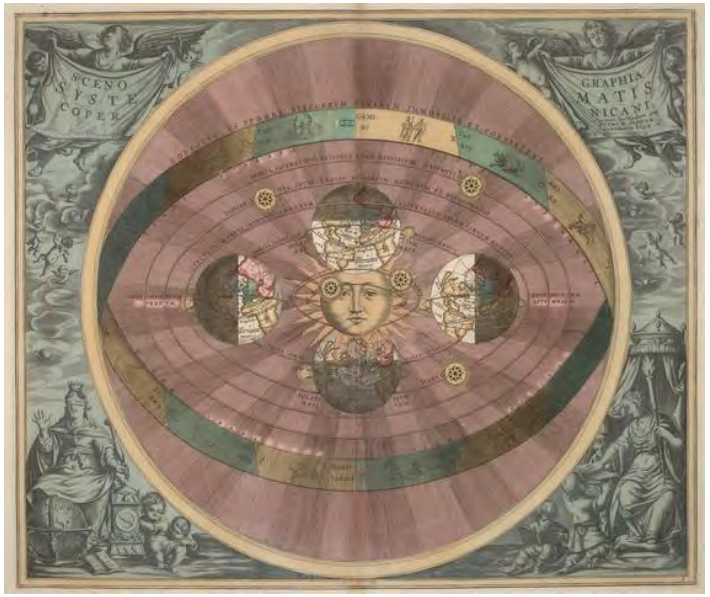
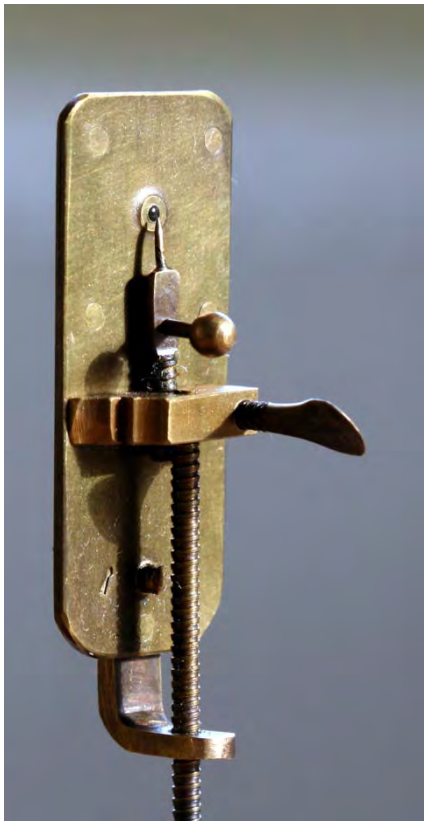
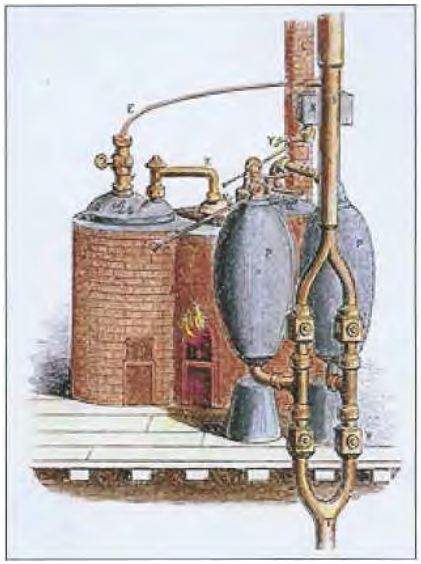
Universiteit Antwerpen

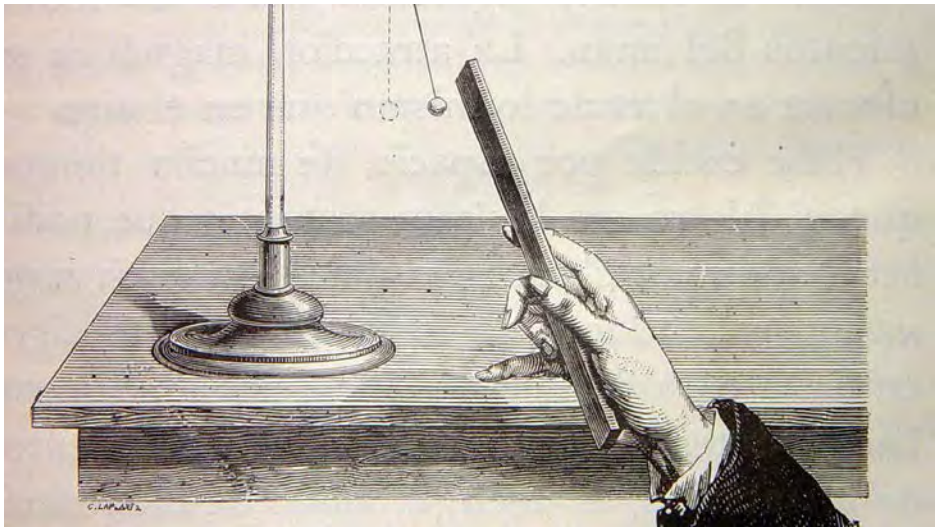
17e eeuw: De wetenschappelijke revolutie







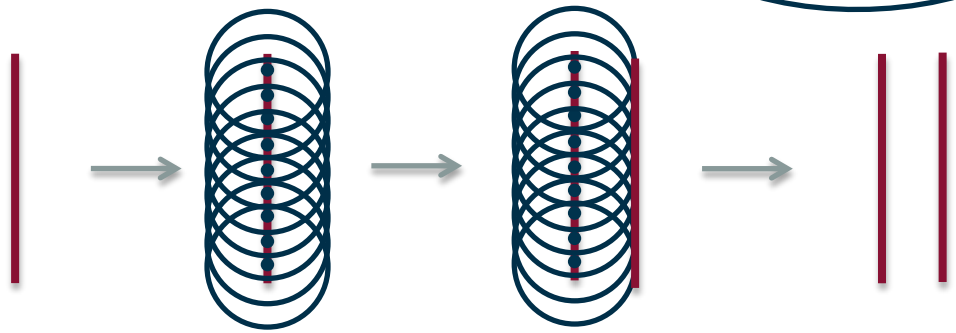


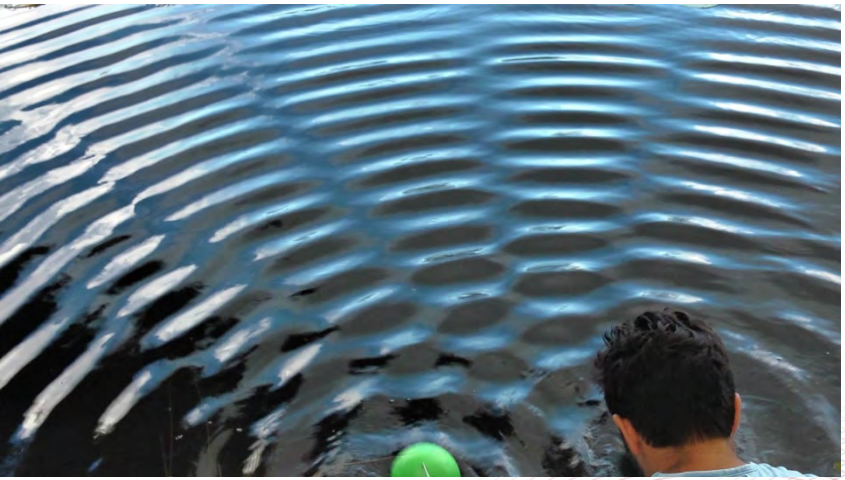


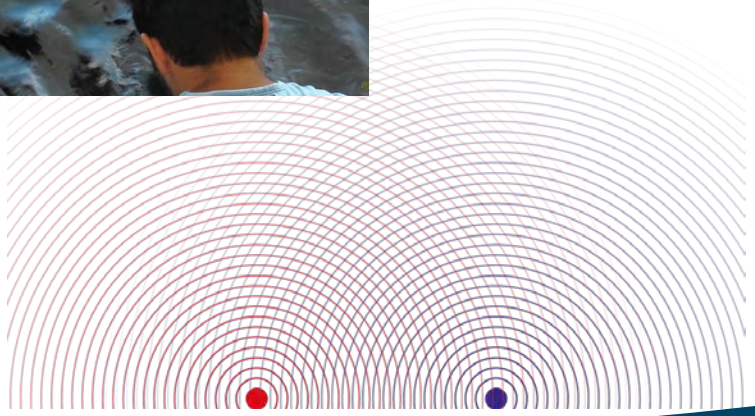
Huygens (1678)

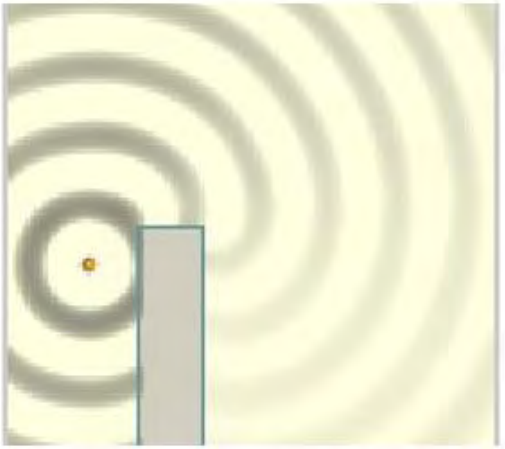
(°1629, †1695)

Licht is een golf





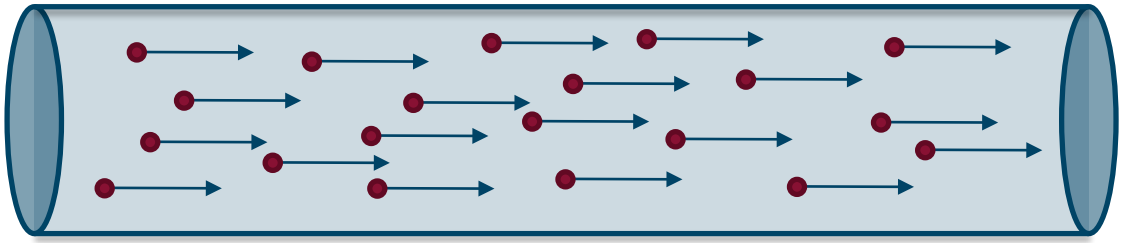


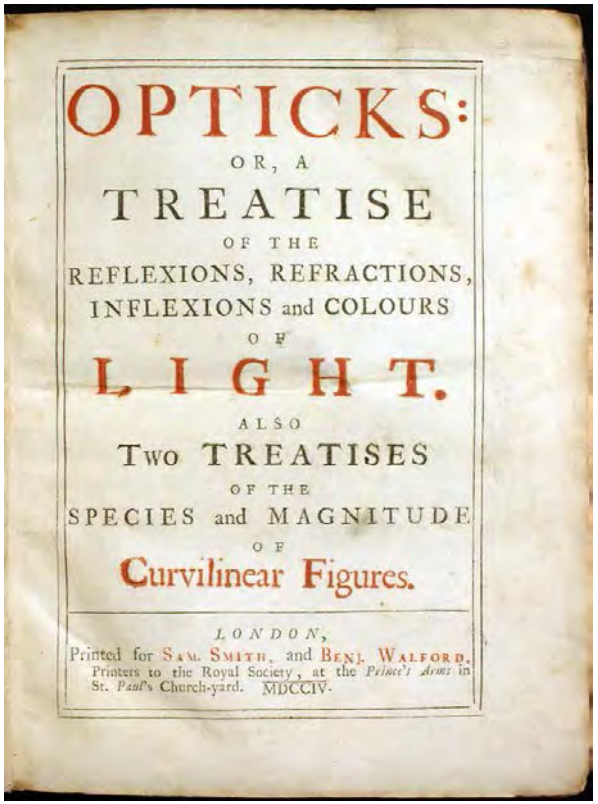


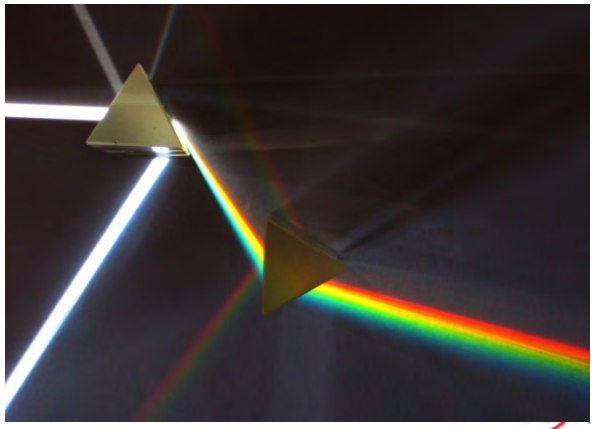
Newton (1704)

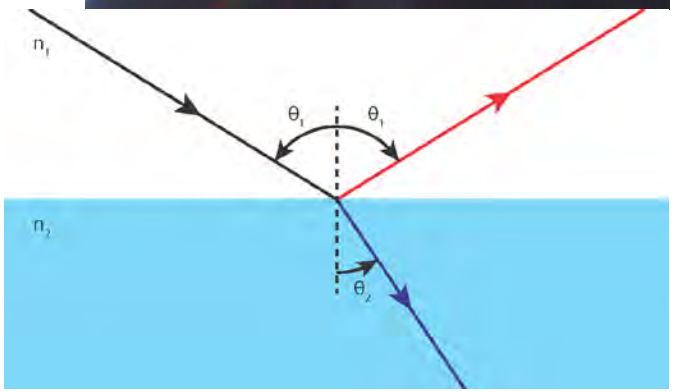
(°1643, †1727)

Onzin,
licht is een deeltje!

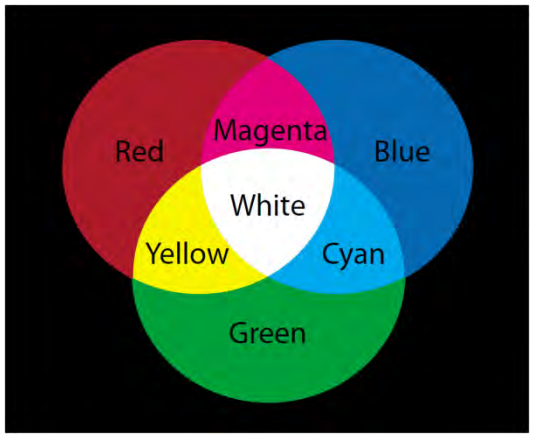




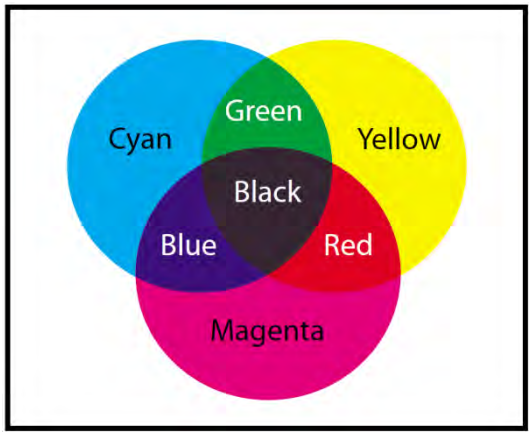




Toepassing: kleurmanagement



Additieve kleurenmenging: RGB



Substractieve kleurenmenging: CMYK

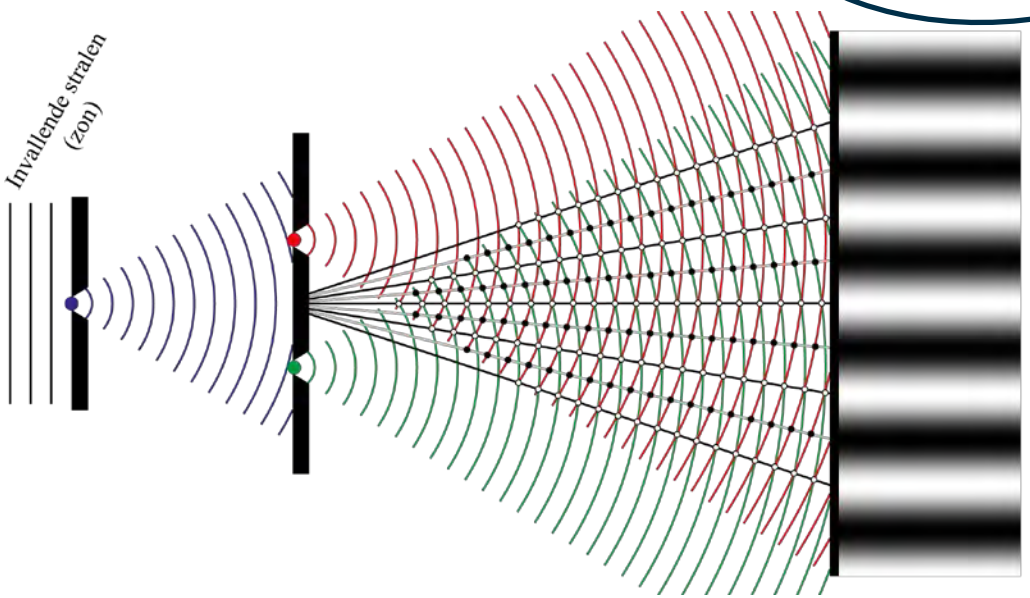
De Royal Society beslist (1715)

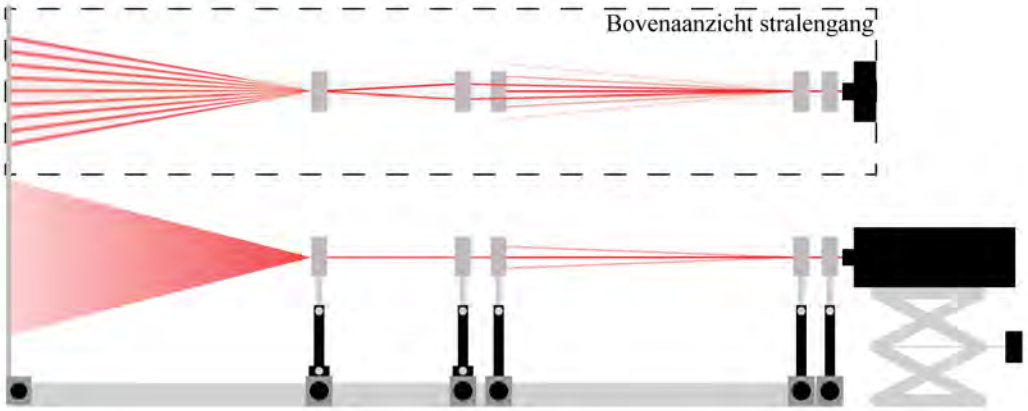
Huygens		Newton
Verklaart • Reflectie en breking • Onscherpe schaduwranden • Diffractie en interferentie	**Pro**	Verklaart • Reflectie en breking • Waarom licht in rechte lijnen gaat • Lenzenformule
Verklaart niet • Waarom licht in rechte lijnen gaat • Lenzenformule	**Contra**	Verklaart niet • Onscherpe schaduwranden • Diffractie en interferentie

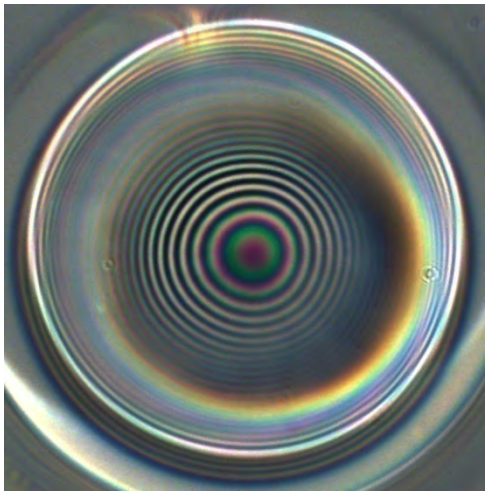
Young (1803)

(°1773, †1829)

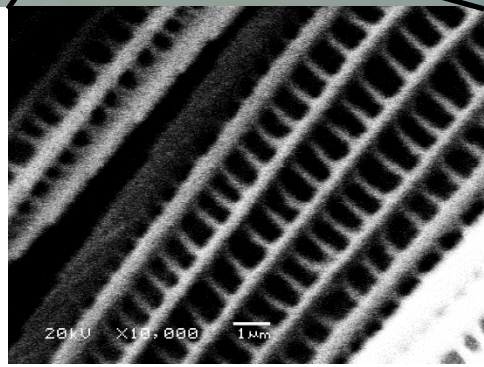
Interferentie kan niet met deeltjes







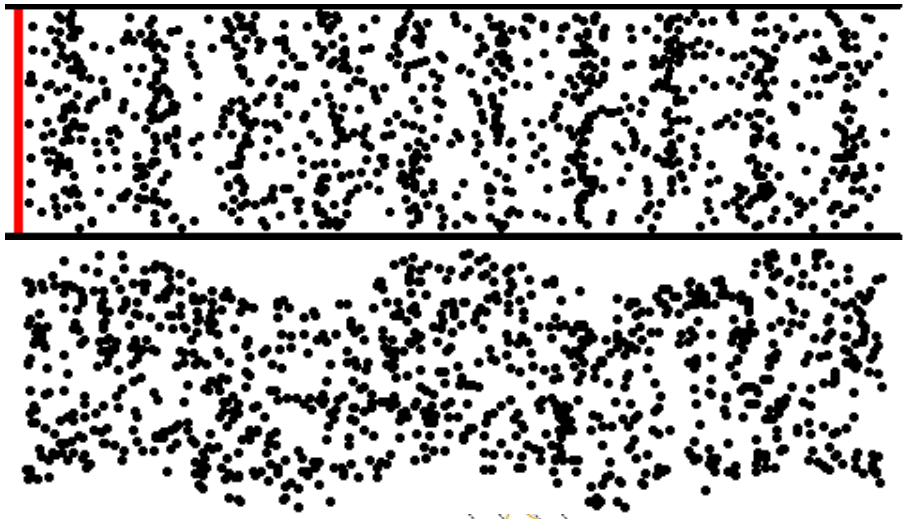
Interferentie in het dagelijkse leven

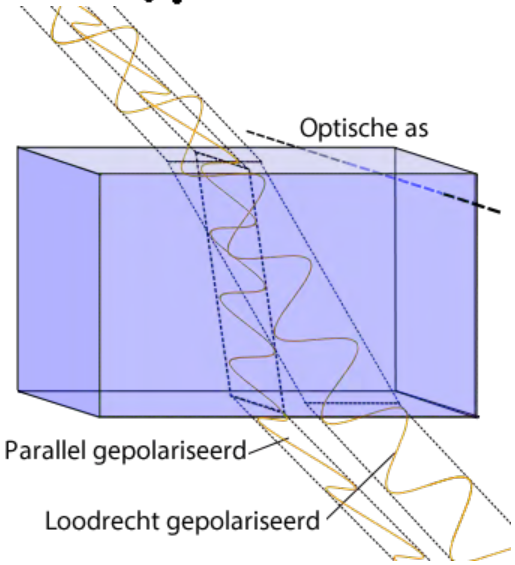


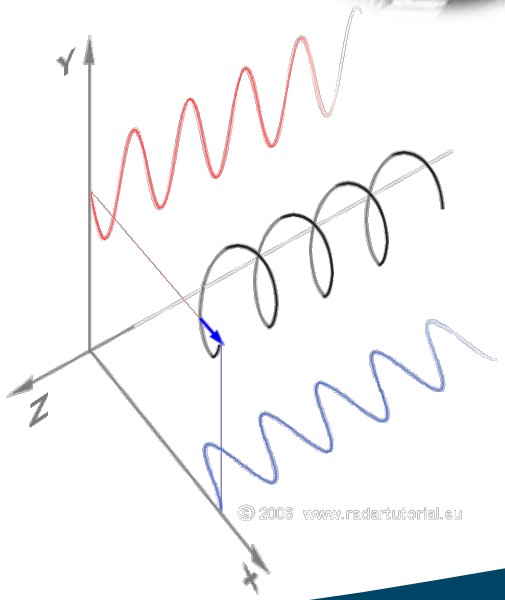
Fresnel (1817)

(°1788, †1827)

Licht is een transversale golf!







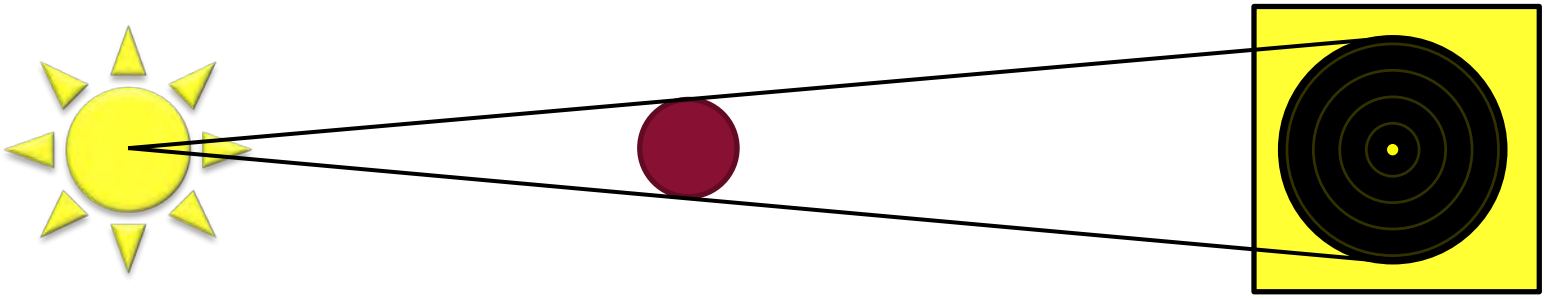
Poisson en Arago (1818)

(°1781, †1840) *(°1786, †1853)*

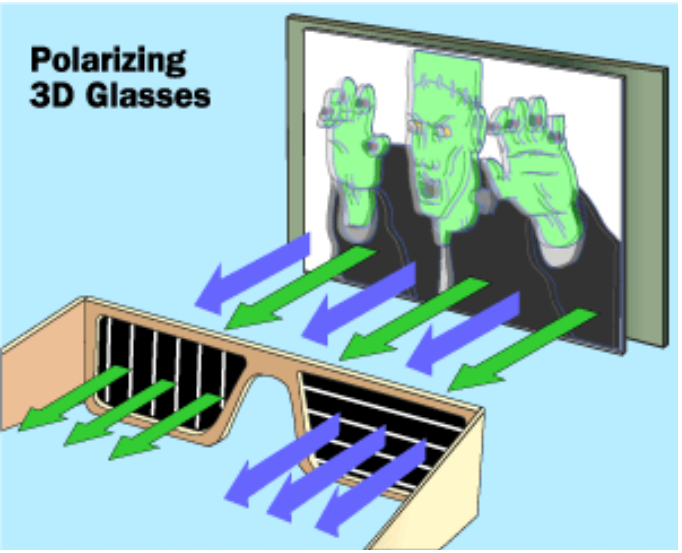
INSTITUT DE FRANCE
Académie des sciences

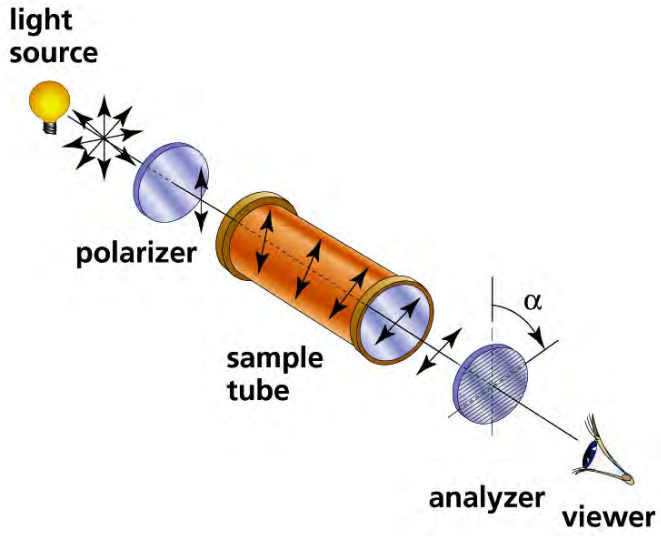
Fresnel, licht is een deeltje zeg ik u!

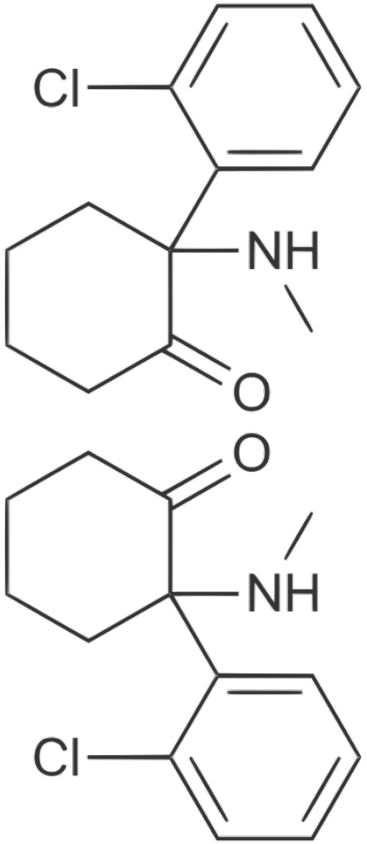
Anders nemen we gewoon de proef op de som ?



Polarisatie in het dagelijkse leven



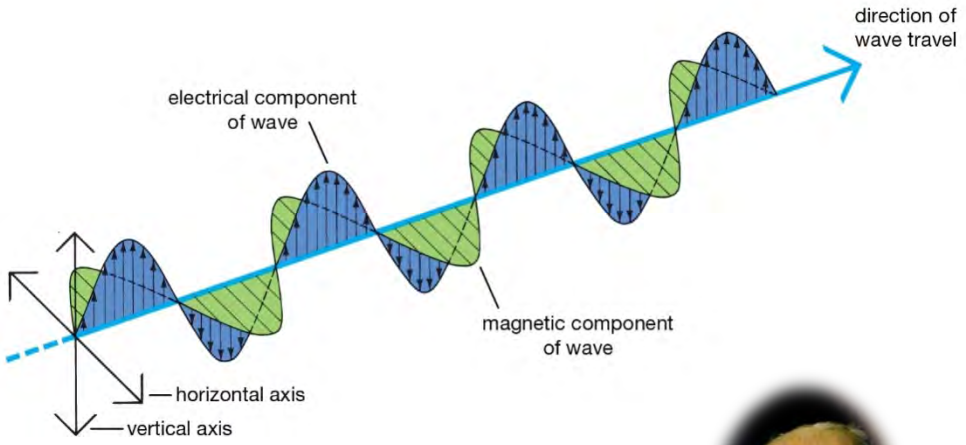




Maxwell (1873)

(°1831, †1879)

Elektomagnetisme en licht samen !?



$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

Carl Friedrich Gauss (1835)

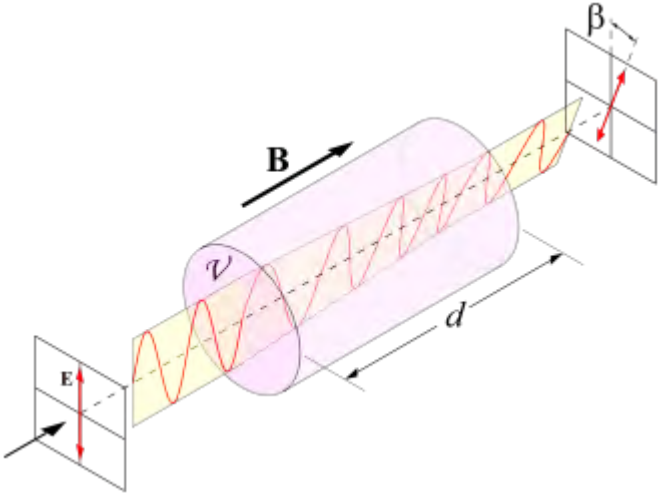
$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$

Michael Faraday (1831)

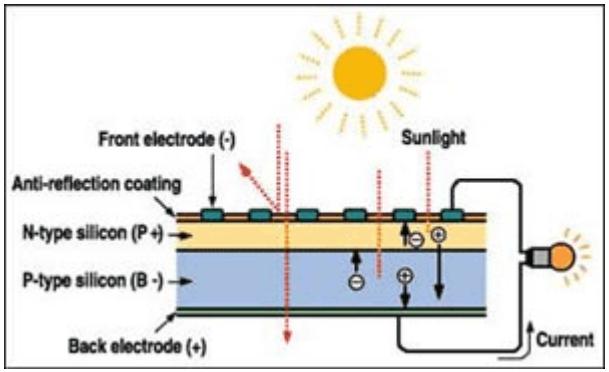
$$\nabla \times \mathbf{B} - \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} = \mu_0 \mathbf{J}$$

André-Marie Ampère (1826)

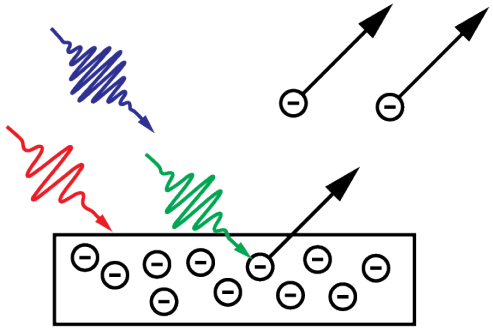
Maxwell's argumenten op een rijtje



Argument 1: Het Faraday effect (1845)

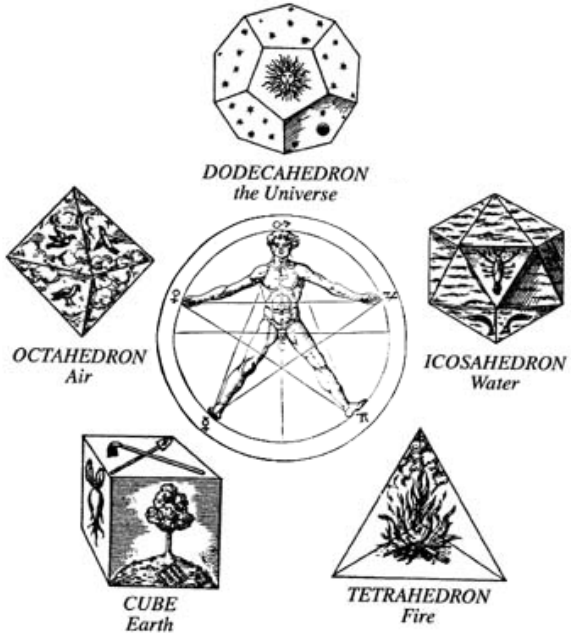


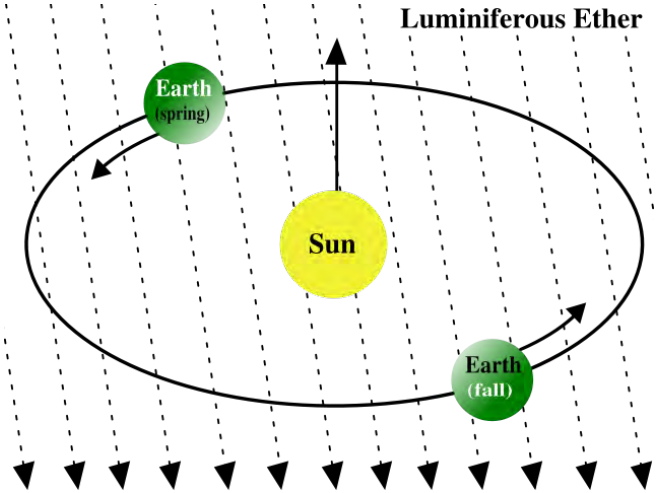
Argument 2: Het fotovoltaïsch effect (1839)

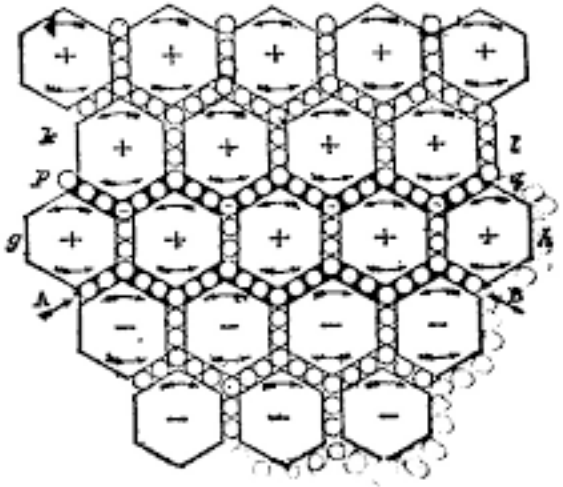


Argument 3: Het fotoelektrisch effect (1887)

En de ether dan?



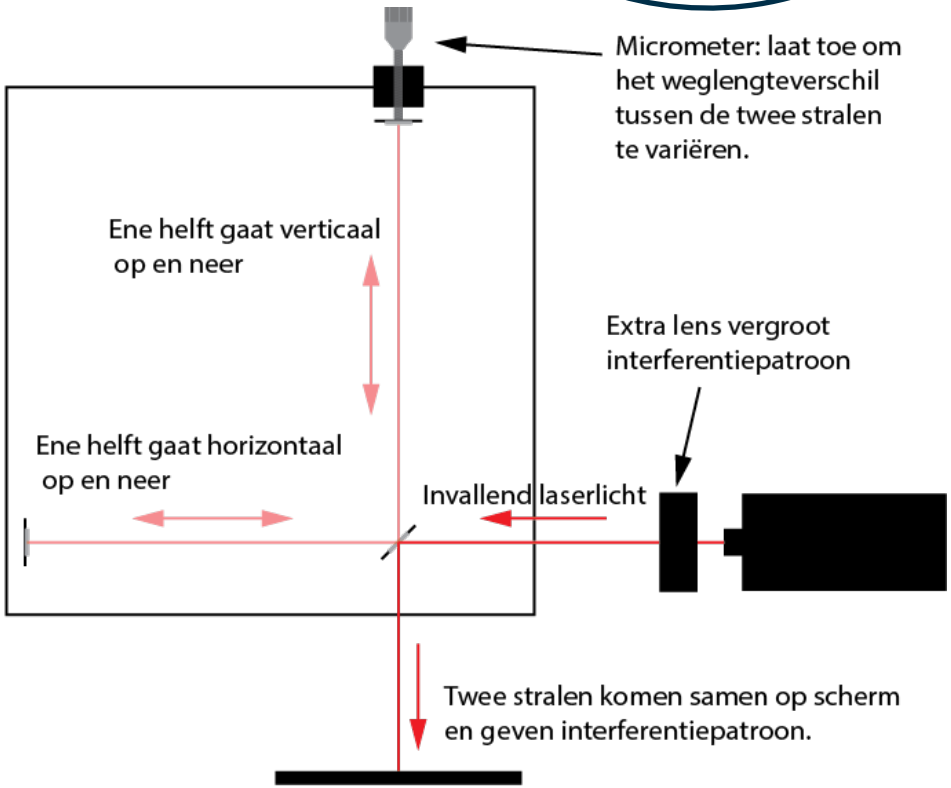


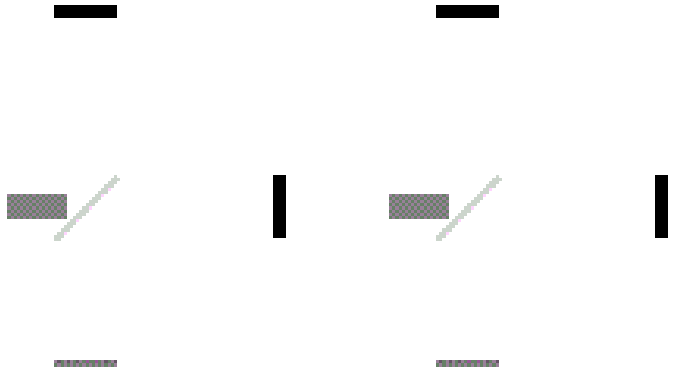


Michelson-Morley (1887)

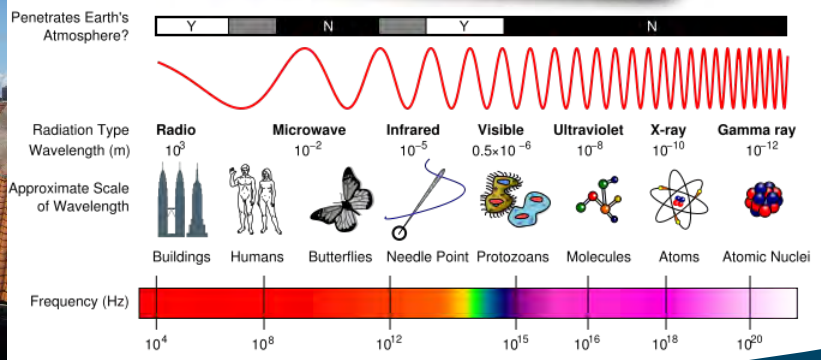
(°1852, †1931) *(°1838, †1923)*

Laten we die ether maar eens wat beter bestuderen



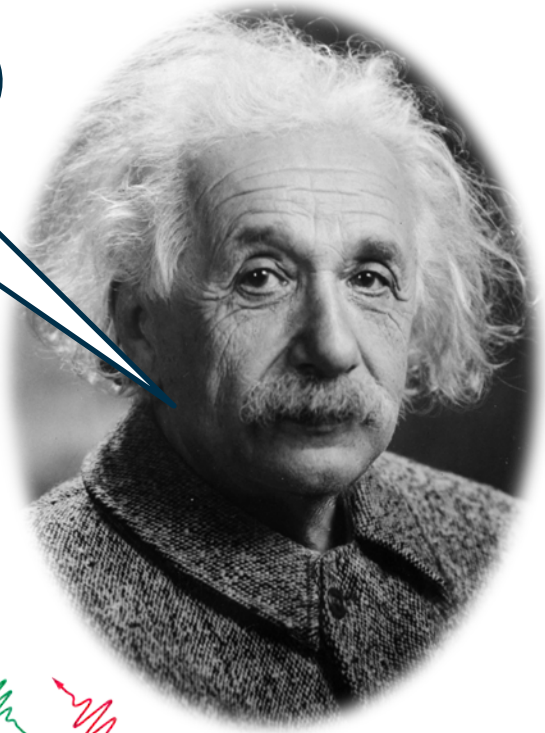


EM golven in het dagelijkse leven

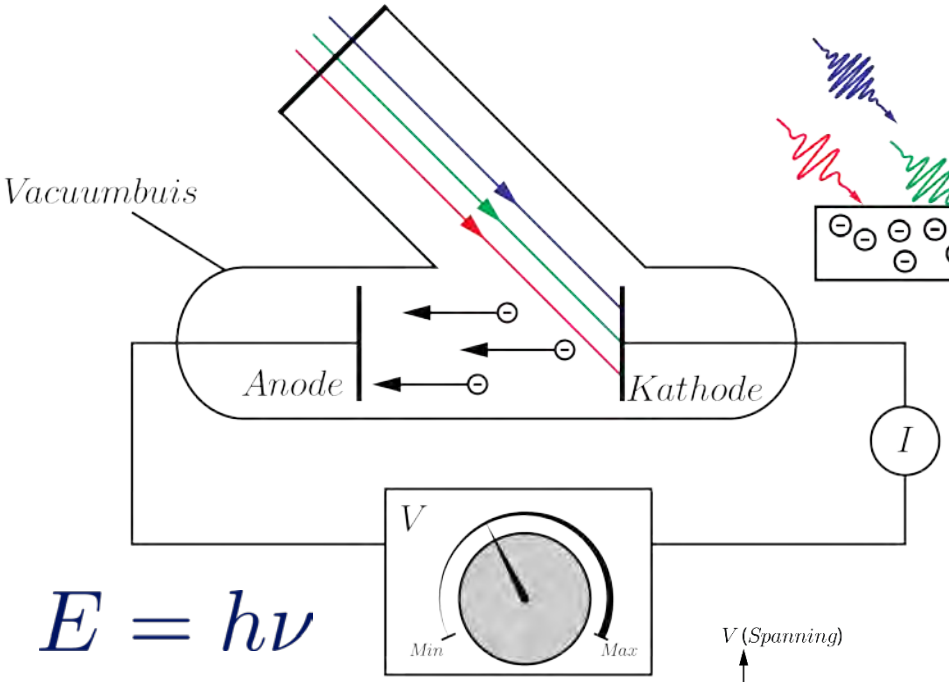


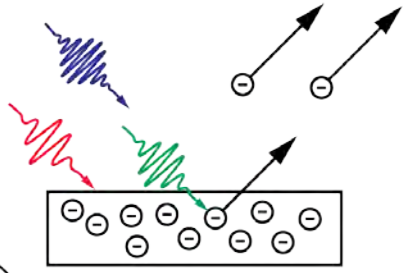
Einstein (1905)

(°1879, †1955)

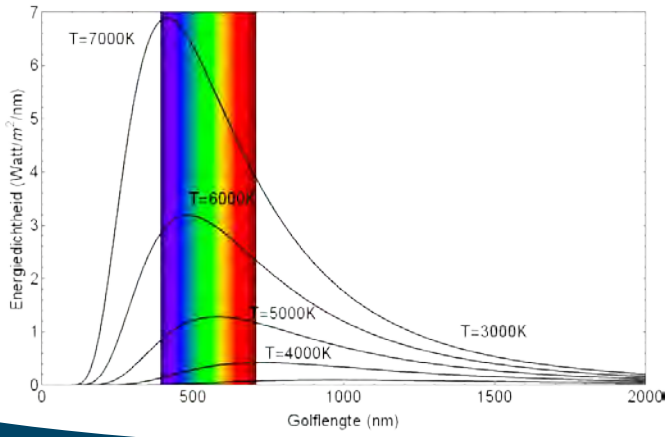


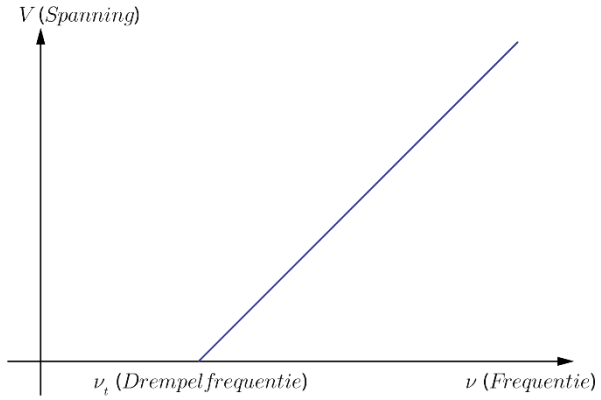
Is licht dan toch een deeltje ?

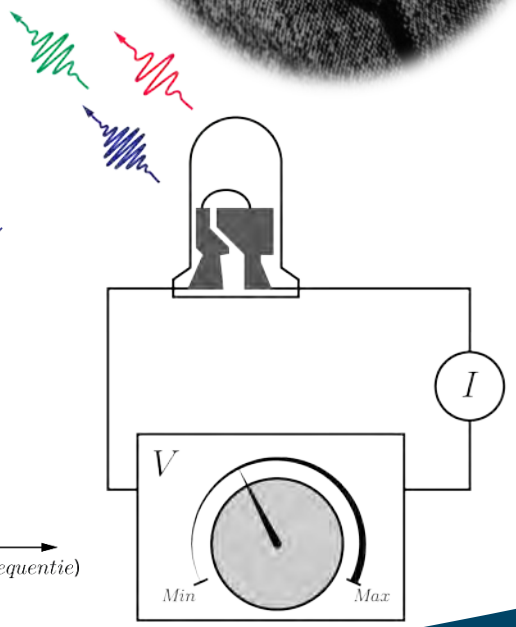




$$E = h\nu$$



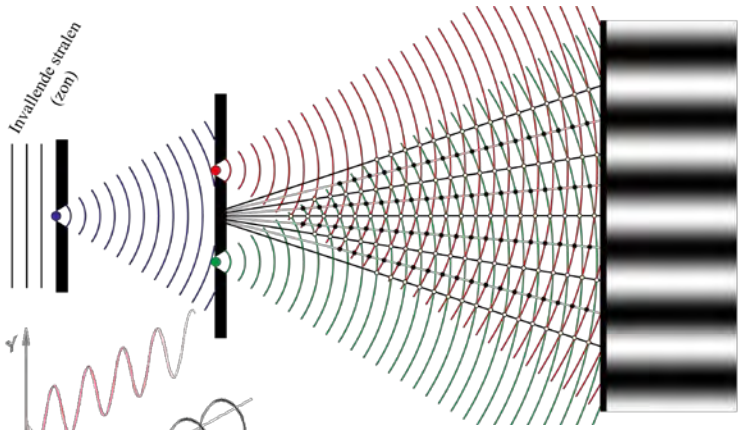


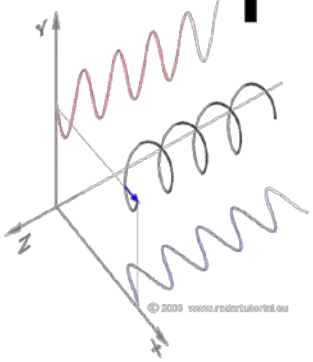


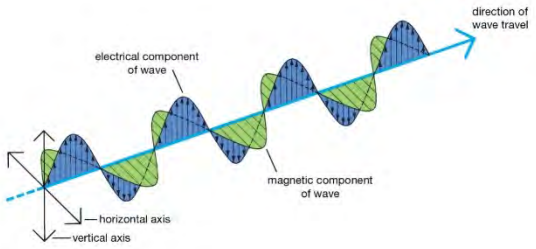
Golf-Deeltjes dualiteit: licht is …

of een golf

- Diffractie, interferentie en polarisatie
- Elektromagnetische golf (alles is continu)

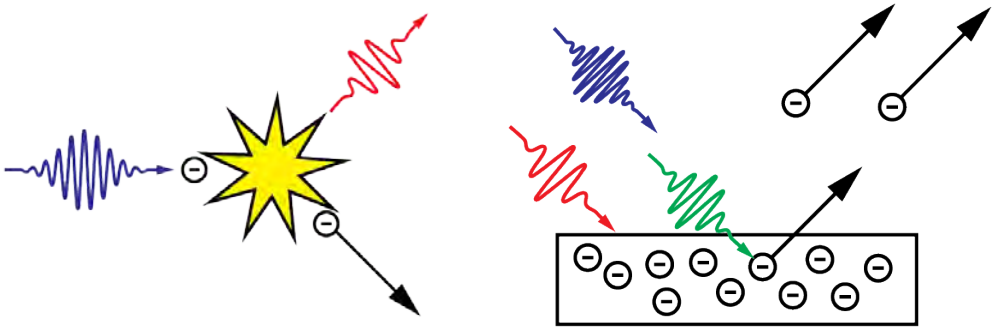


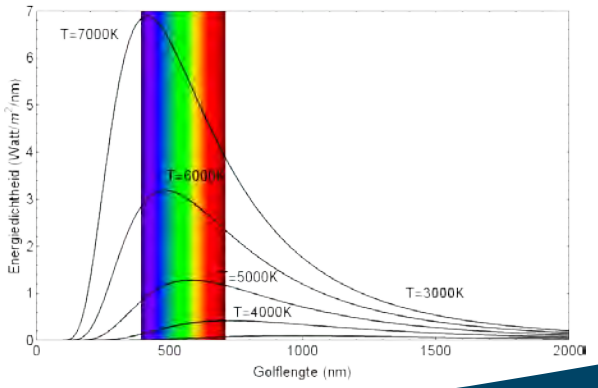




of een deeltje

- Fotonen (energiepakket hν)
- Alles wordt **gekwantiseerd**

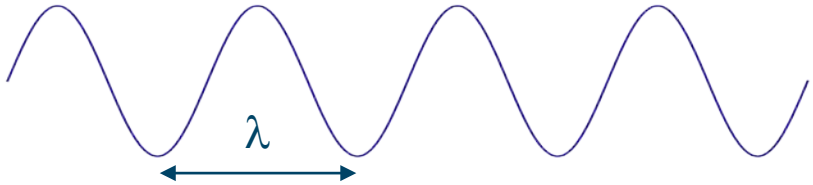




De fysica-definitie van deeltjes en golven

Golf

- Golflengte en frequentie
- Plaats en snelheid onbekend
- Geen vaste afmetingen

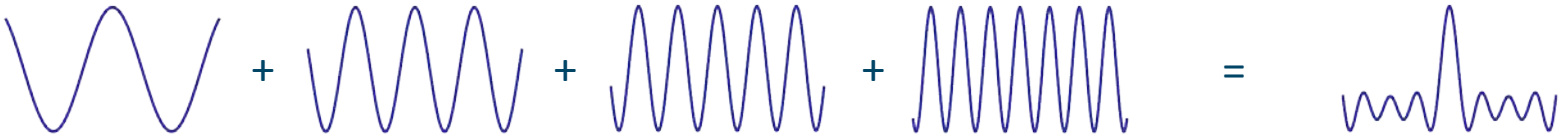


Deeltje

- Energie en impuls
- Plaats en snelheid bekend
- Vaste afmetingen

Deeltje is hier

Optellen van meerdere golfjes met verschillende λ geeft:



de Broglie (1924)

(°1879, †1955)

Hebben deeltjes dan ook golfgedrag ?

Relativiteit

$$E = m^* c^2 = \sqrt{p^2 c^2 + \cancel{m^2 c^4}}$$

Foto-elektrisch effect

$$E = h\nu = \frac{hc}{\lambda}$$

Impuls v/e foton

$$p = \frac{h}{\lambda}$$

Hypothese: ook voor deeltjes?

Deeltjeseigenschappen
- Impuls
- Energie

$$p = \frac{h}{\lambda}$$

$$E = h\nu$$

Golfeigenschappen
- Golflengte
- Frequentie

Deeltjes als golfjes en vice-versa ?

Dus:

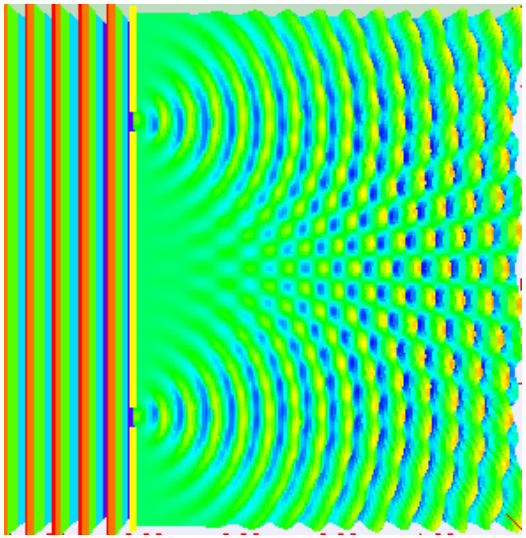
- Uit de golftheorie weten we dat (voor diffractie):

$$n\lambda = \frac{xd}{L}$$

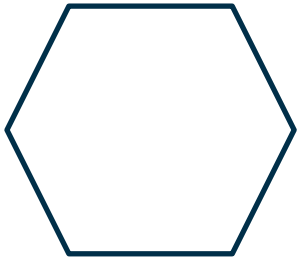
- Daarnaast zegt De-Broglie ons dat (voor deeltjes):

$$p = \frac{h}{\lambda}$$

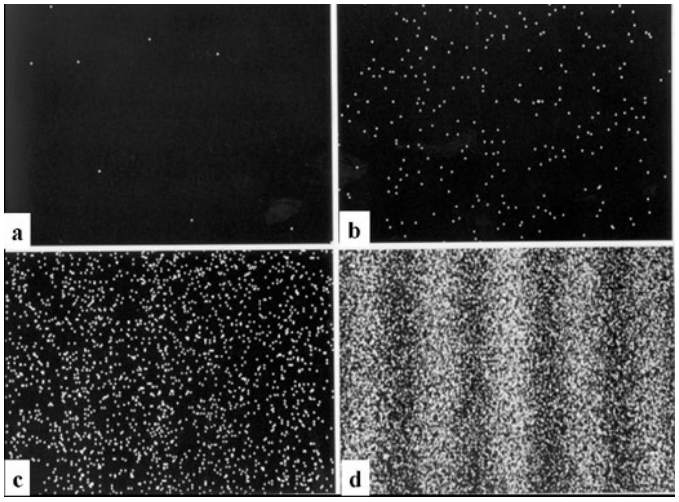
We herdoen het twee-spletenexperiment ditmaal met elektronen



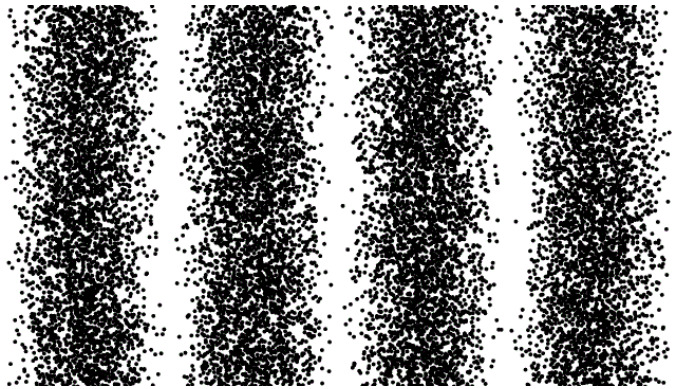
Het kwantumverhaal: experiment

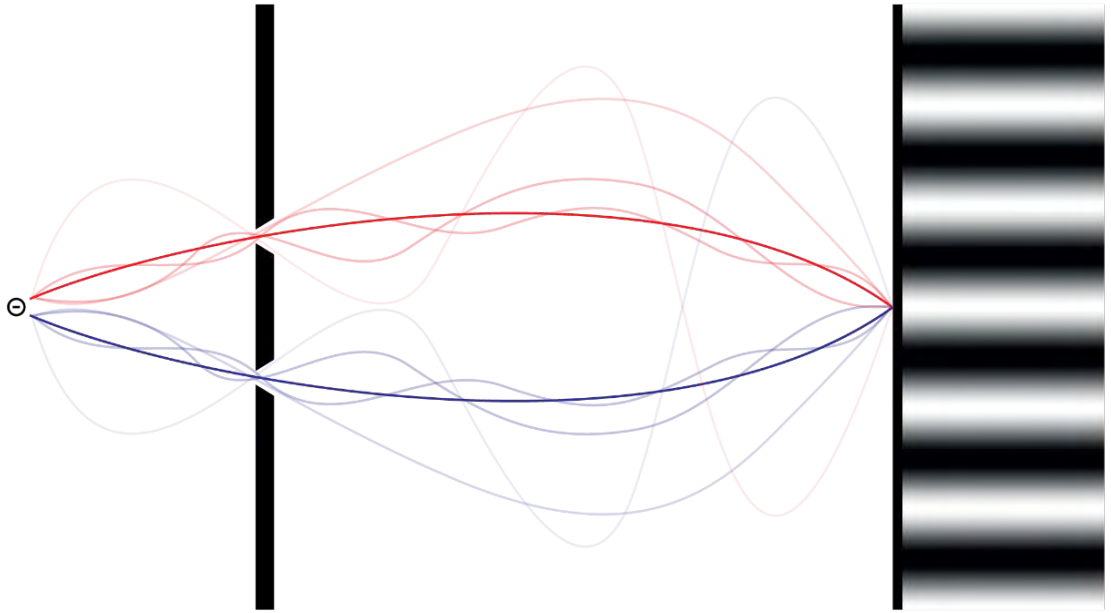


Het kwantumverhaal: theorie

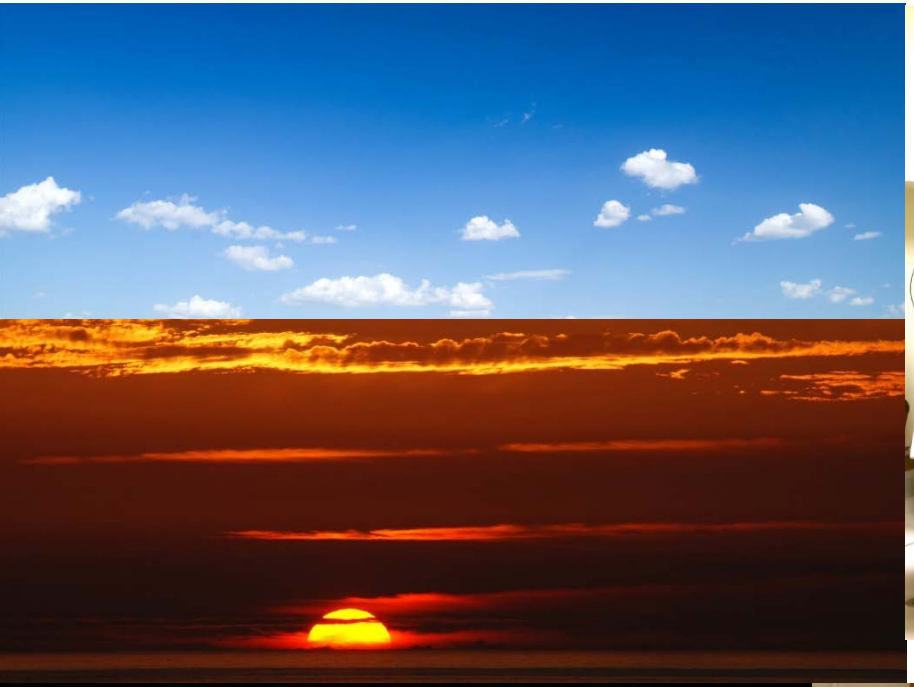


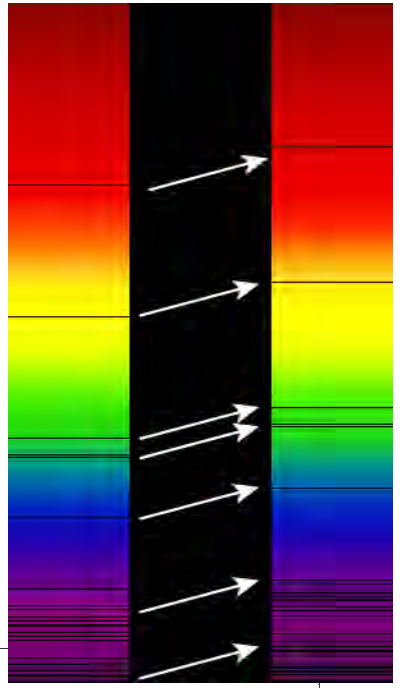
a) 8 elektronen
b) 270 elektronen
c) 2000 elektronen
d) 160 000 elektronen

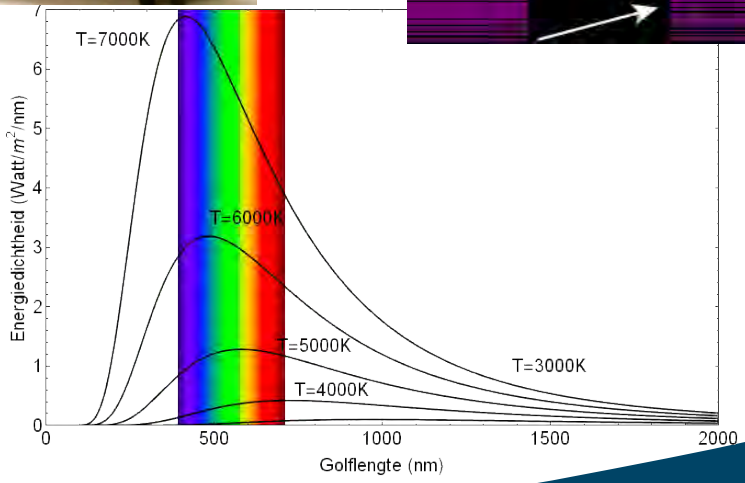




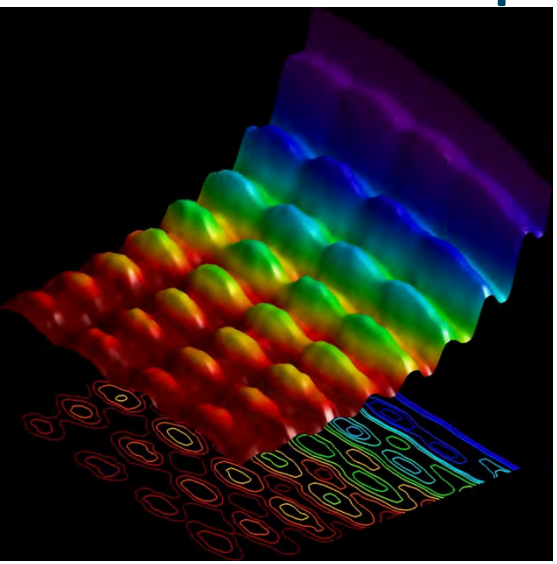
Kwantumelektrodynamica in het dagelijkse leven

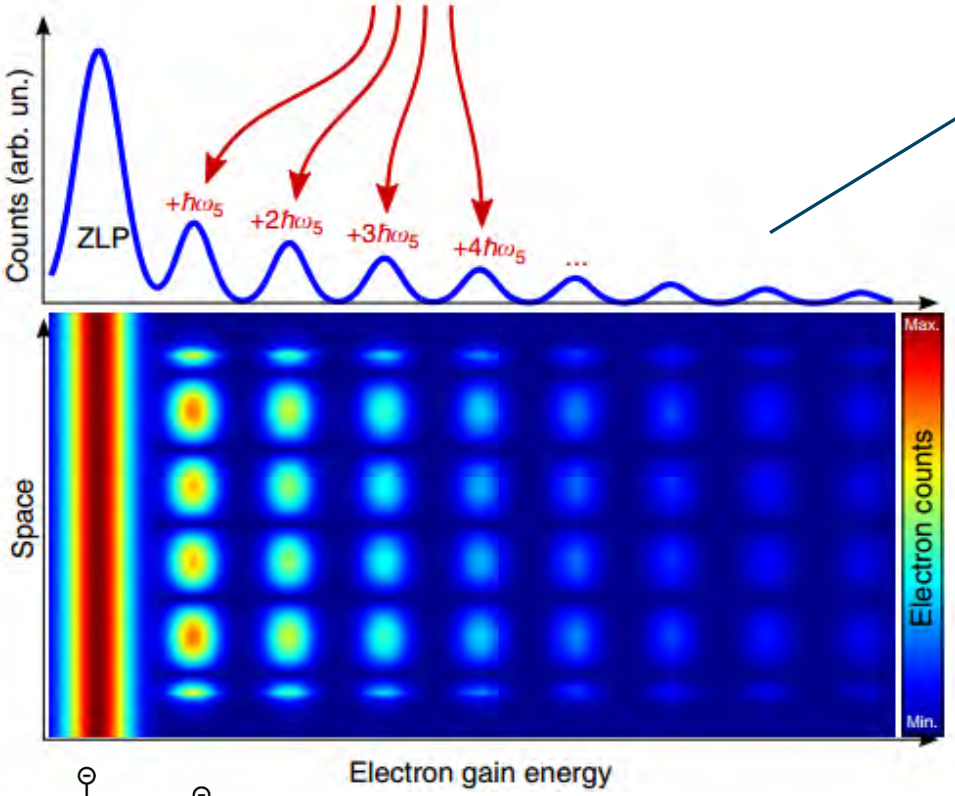






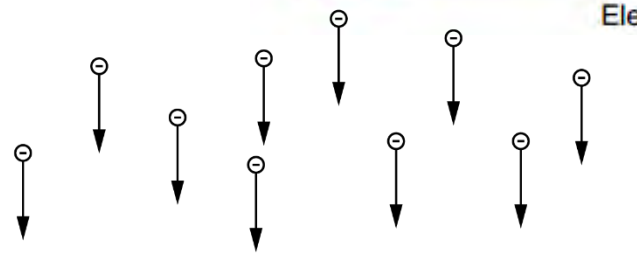
Recent experiment met licht (2015)



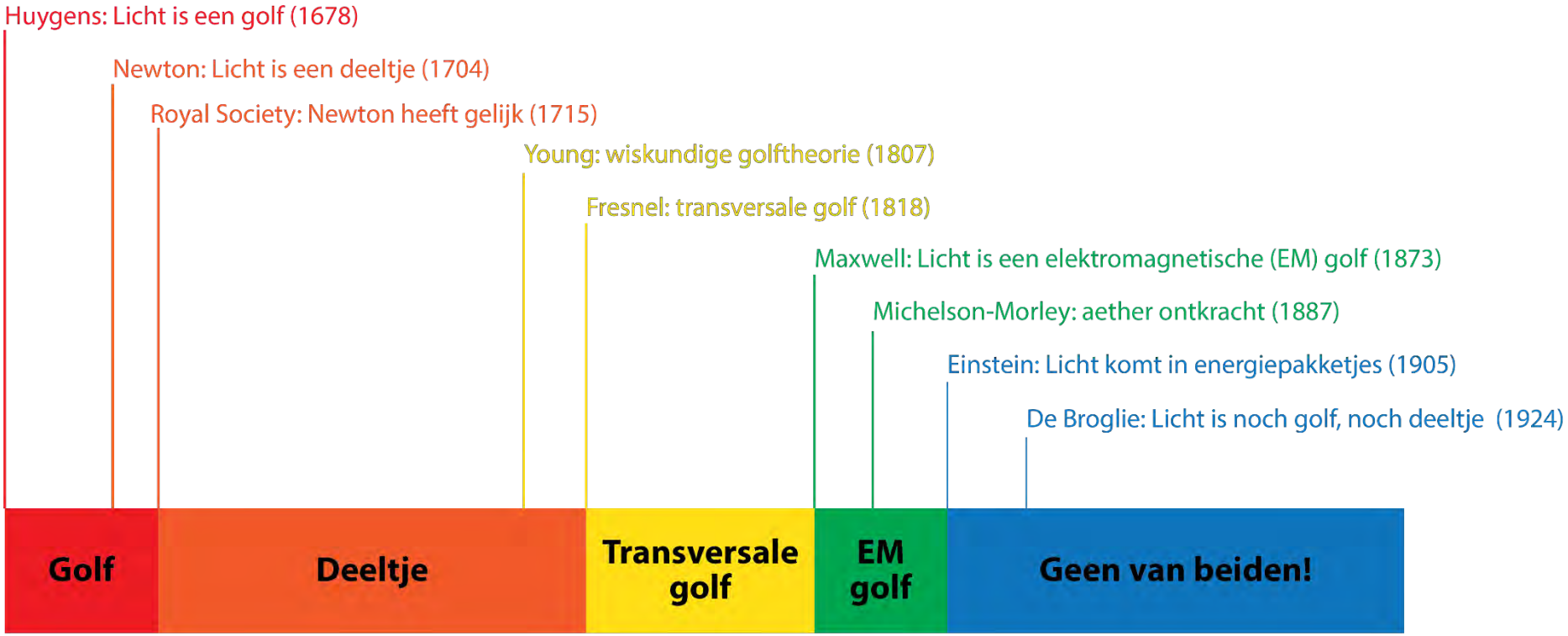


Deeltje

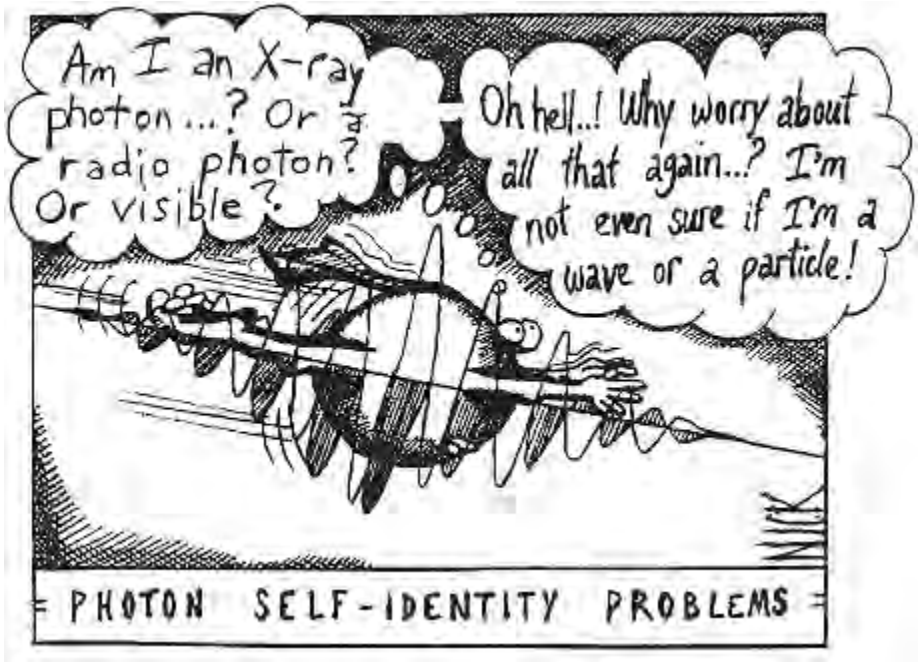
Golf



Alles even op een rijtje: licht is …



Vragen ?

God runs electromagnetics on Monday, Wednesday, and Friday by wave theory, and the devil runs them by quantum theory on Tuesday, Thursday and Saturday.

~ William Lawrence Bragg