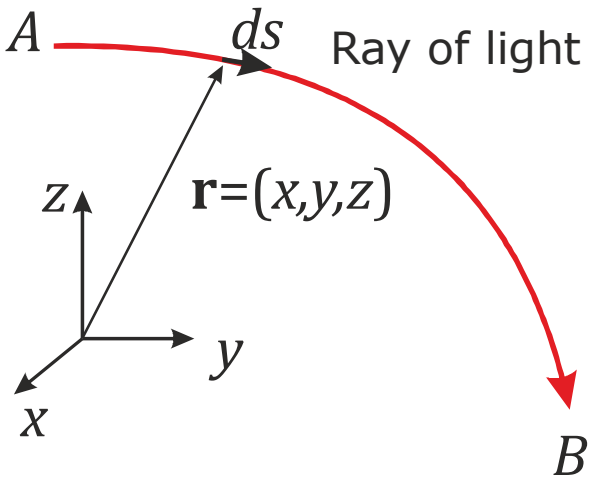
Fermat's Least Time Principle

Pierre de Fermat
1601-1665
French lawyer and mathematician, who made notable contributions to analytic geometry, probability, and optics. He is best known for his principle for light propagation,and his last theorem in number theory.

https://en.wikipedia.org/wiki/Pierre_de_Fermat

The laws of **geometrical optics** are derived from the Fermat's Principle: the path taken between two points by a ray of light is the path that can be traversed in the least time.



The medium where light is propagating is characterized by its **refractive index**:

$$n = \frac{c}{v}$$

c = speed of light in vacuum (≈300.000 km/s)
v = speed of light in the medium

Materials with **high refractive index** are described as **optically dense materials**

Alternatively it can be described as the path with least **optical path**, defined as the product of the refractive index by the real path

$$L_{AB} = \int_A^B n(\vec{r})\,ds = c\int_A^B \frac{ds}{v(\vec{r})} = c\int_A^B dt = cT_{AB}$$

Refractive indices of some transparent materials

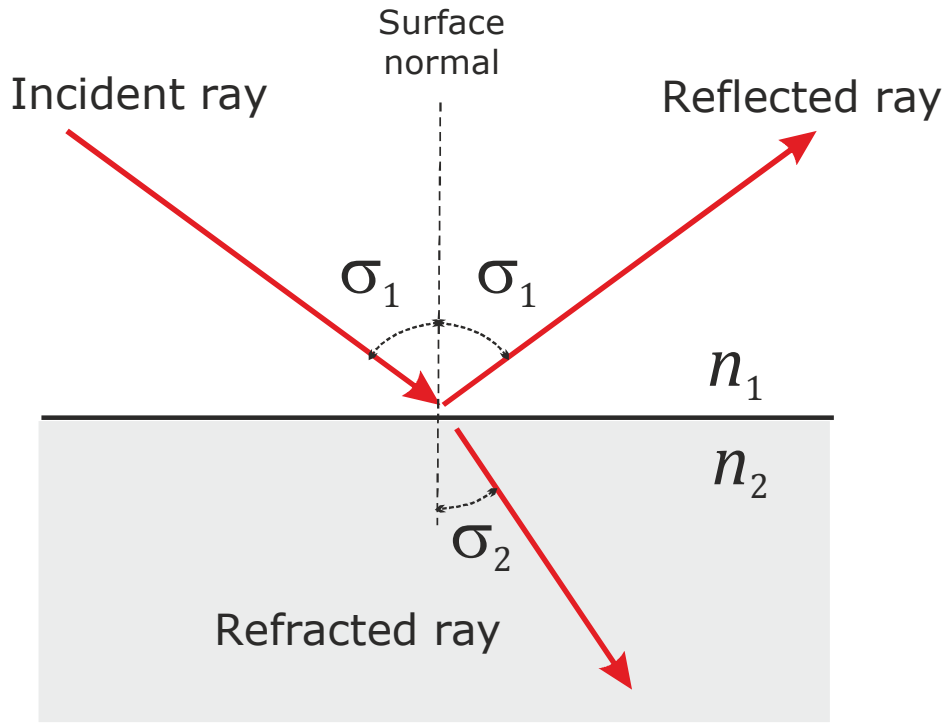
Gas (0º, 1 atm)		Liquid (20ºC)		Solid (20ºC)	
Air	1.000293	Water	1.333	Diamond	2.419
Helium	1.000036	Benzene	1.501	Methacrylate	1.489
Hidrogen	1.000132	Etanol	1.361	Fused silica	1.458
CO_2	1.00045	Monobromine naphtalene	1.68	NaCl	1.50

Basic Laws of Geometrical Optics

They are derived directly from the Fermat's principle, and it is based on the concept of **refractive index**:

$$n = \frac{c}{v}$$

c = speed of light in vacuum (≈300.000 km/s)
v = speed of light in the medium



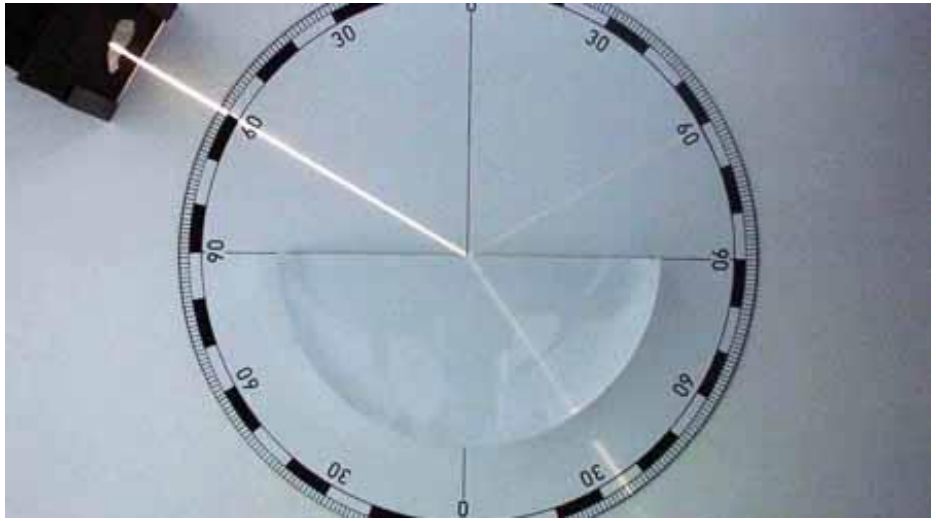
1) Light travels in straight lines in homogeneous media (media with constant n).

2) **Law of reflection**: $\sigma'_1 = \sigma_1$

3) **Law of refraction – Snell's law**: $n_1 \sin\sigma_1 = n_2 \sin\sigma_2$

4) **The reflected and refracted rays are within the plane of incidence**.

5) **Light trajectories are reversible**.



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