Optical Path Length

Fermat's Principle of Least Time states that:

light takes the path which requires the shortest time.

Using this principle we can derive law of reflection ($\theta_i = \theta_r$) and law of refraction ($n_1 \sin\theta_1 = n_2 \sin\theta_2$).

The idea can be extended as follows. Consider a light beam travels a distance s in a medium whose index of refraction is n. The Optical Path Length is then defined as:

$$OPL = ns$$

If there are a number of mediums then

$$OPL = n_1 s_1 + n_2 s_2 + \cdots + n_m s_m = \sum_{i=1}^{m} n_i s_i$$

If the medium consists of continues materials, like atmosphere, then:

$$OPL = \int nds$$

Distance traveled by light in optical medium is $s = vt$, where v is the speed of light in medium, namely $v = c/n$. Then, time elapsed by light in the medium is

$$t = \frac{s}{v} = \frac{s}{c/n} = \frac{ns}{c} = \frac{OPL}{c}$$

c is the speed of light in vacuum which is a constant. Fermat's principle is related to optimum time. That is, Fermat's principle is equivalently related to optimum OPL. Therefore, last form of the Fermat's principle can be written as:

light travels in medium such that its total optical path length is optimum.