Notes for -
B.Sc. Part - II
Paper - Third

"Fermat's Principle"

The optical path between any two points is proportional to the time of travel. Hence the Fermat's Principle is that - The actual path followed by light between two points is the one along which the optical path is a minimum. However it has been found that there are number of cases where the optical path is neither a maximum nor a minimum but stationary. Hence the Fermat's Principle in general may be stated as -

" A ray of light in passing from one point to another through a set of media by any number of reflections or refractions choose a path along which the optical path is either a minimum or a maximum or stationary."

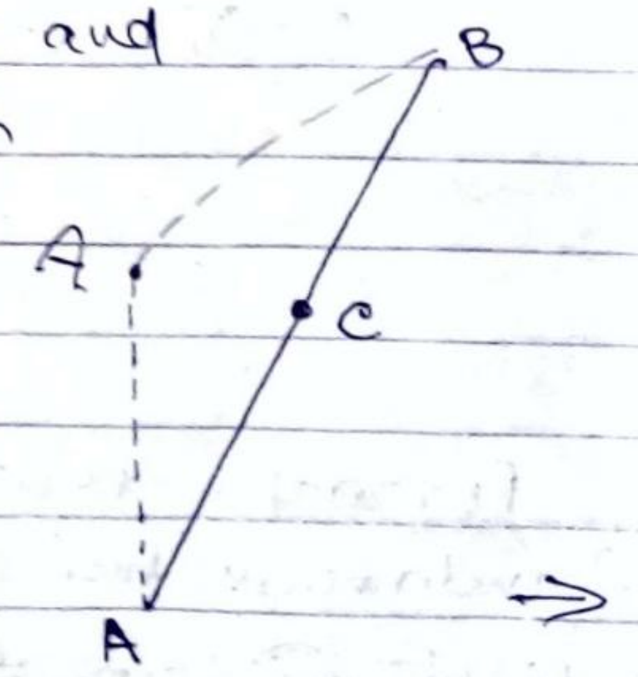
At one time the Fermat thought the path that of the least distance, and least time as the decisive factor. In fact the path chosen by the disturbance between any two points is such that the time of travel is stationary.

Hence the Fermat's Principle may be stated as -

" Between the any two points the time taken by light along actual path is extremum; it may be maximum or a minimum.

The Principle may be explained in brief as -

- Let us suppose that A and B are the terminals of optical path, ACB is the actual path and ADB is any neighbouring optical path with the same terminals A and B such that the difference δt between the time of transit along the actual path and neighbouring path is infinitesimal as compared to the displacement of the path. →



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→ This means that along the actual path δt vanishes.

Therefore, according to condition of maxima and minima t is extremum (maximum or minimum) i.e Time taken by light along the actual path is extremum.

In mathematical form Fermat's Principle of extremum time may be written as -

$$\int_A^B \frac{ds}{v} = \text{maximum or minimum or stationary} \longrightarrow (1)$$

where ds is a small element to path between any two points A and B and v is the velocity of light in the medium.

Since $\mu = \frac{c}{v}$ where c is the speed of light in vacuum. Hence equation (1) may be written as -

$$\int_A^B \frac{\mu\, ds}{c} = \text{maximum or minimum or stationary} \longrightarrow (2)$$

As speed of light (c) in vacuum is always constant therefore, we may write equation (2) in the form of Fermat's Principle of Extremum path as -

$$\int_A^B \mu\, ds = \text{maximum or minimum or stationary.}$$

i.e $$\delta \int_A^B \mu\, ds = 0 \longrightarrow (3)$$

Fermat's Principle is capable of deriving the following fundamental laws of Geometrical optics - (i) Rectilinear Propagation of light (ii) laws of reflection (iii) Laws of refraction.

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