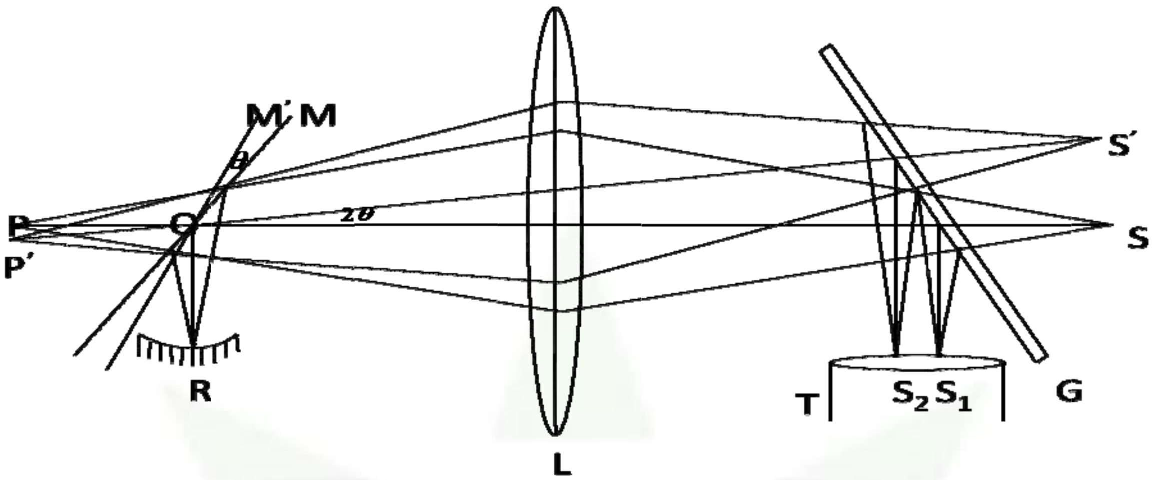
Velocity Of Light – Michelson Octagonal Mirror Method

Description: A point source of light is kept on the principal axis of a convex lens L. Rays from S pass through a plane glass plate G, kept inclined at an angle 45^o with axis of the lens.

Rays after refraction through the lens form an image at P. Hence S and P are conjugate points for the lens, but before meeting at P, the rays are reflected by a plane mirror M, to meet at R. Hence for the plane mirror M, P and R are the conjugate points. At R rays fall on a concave mirror, whose centre of curvature is at O hence the rays are incident on R normally and are reflected back along the same path to M and retrace back their path to S, but the glass plate the rays suffer partial reflection to meet at S1, hence for G, S and S1 are the conjugate points.

The image S1 is received at the cross wire of the telescope T. Let the mirror M be set into rotation about a vertical axis, passing through its centre O, consider an instant when M is the position of the mirror, the rays reflected from M go up to R, get reflected normally and find the position M' of the mirror. Since the mirror has rotated by some angle say Θ each ray reflected from this position now appear to diverge from the point P' and after refraction by the lens meet at S'. Hence P' and S' are the conjugate points for the lens. The rays before meeting at S' are partially reflected by the plane glass plate G to form an image at S_2 on the telescope. Hence S' and S_2 are the conjugate points for the plane glass plate. The shift of image S_1S_2 on the cross wire of the telescope is measured.

Calculation:



$SL = a, LO = b, OP = OR = d$

n = The frequency of rotation of the mirror

x = S_1S_2 = The shift of the image on the cross wire of the telscope due to the rotation of the mirror.

Let θ be the angle through which the mirror M is rotated by the time ray from O goes up to R and comes back to O i.e. the ray covered a distance 2d.

Time taken to rotate by angle θ, $t = \frac{\theta}{\omega} = \frac{\theta}{2\pi n}$

Speed of light $C = \frac{2d}{t} = \frac{2d}{\frac{\theta}{2\pi n}} = \frac{4\pi n d}{\theta} \rightarrow (1)$

To find θ: $\angle POP' = 2\theta$, From $\Delta POP'$ $\tan 2\theta = \frac{PP'}{OP}$

$2\theta = \frac{PP'}{d}$ or $\theta = \frac{PP'}{2d} \rightarrow (2)$

Since P & S are conjugate points and P' & S' are also conjugate points for the lens hence

$\frac{PP'}{SS'} = \frac{PL}{LS}$ or $PP' = SS'\frac{(PO+OL)}{LS} = SS'\frac{(d+b)}{a}$

For the plane glass G (S & S_1) are the conjugate points S' & S_2 are also conjugate points

$SS' = S_1S_2 = x \rightarrow (4)$

Putting equation (4) and (3) in (2): $\theta = \frac{x(b+d)}{a.2d} \rightarrow (5)$

Putting equation (5) in (2): $C = \frac{4\pi n d}{x(b+d)/2ad} = \frac{8\pi n a d^2}{x(b+d)}$