Determination of the Speed of Light in a Medium Using the Sagnac Effect

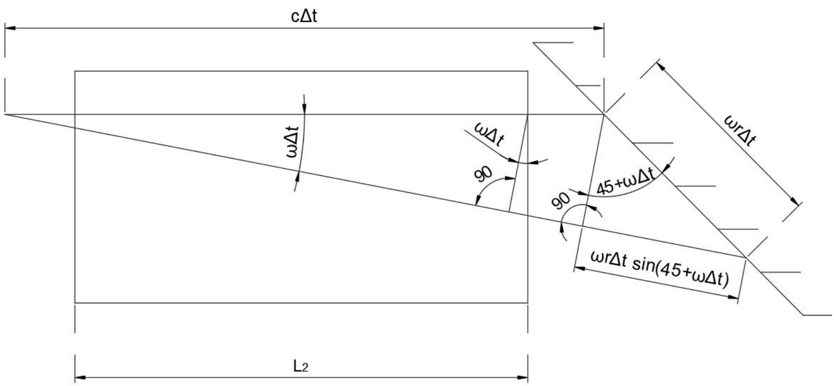
Rajeev Kumar*

Abstract

In this paper a method for the determination of the speed of light in a medium using the Sagnac effect has been presented.
Keyword : Speed of light.

1 PATH DIFFERENCE AND AVERAGE SPEED

Let the Sagnac experimental setup be situated in air (medium 1) and let L_2 be the length of the medium 2 introduced in the path of a light ray while traversing from one mirror to the next mirror. Since medium 2, in practice, cannot occupy the complete light path between the two mirrors, the path difference will correspond to the air. Let L_2 be approximately equal to L and consequently the average speed of the light ray (or photons) will be approximately equal to the speed of the light ray (or photons) in the medium 2. Then, the path difference for a clockwise moving light ray in going from one mirror to the next mirror for counterclockwise rotating platform as compared to non-rotating platform in the Sagnac experiment



*rajeevkumar620692@gmail.com

$$\zeta_{+} \approx \omega r \Delta t \sin 45^{o} \qquad \left[\because \omega r << c \Rightarrow \omega \Delta t << 45^{o}\right]$$

$$\Rightarrow \zeta_{+} \approx \omega r \sin 45^{o} \times \frac{L}{c}$$

where

ω = angular speed of rotation of the platform

L = distance between two consecutive mirrors

Now the average speed of the light ray

$$c = \frac{c_1 \Delta t_1 + c_2 \Delta t_2}{\Delta t_1 + \Delta t_2} \approx c_2 \qquad \left[\because L_2 \approx L \Rightarrow \Delta t_1 << \Delta t_2 \approx \Delta t\right]$$

$$\Rightarrow \zeta_{+} \approx \omega r \sin 45^{o} \times \frac{L}{c_2}$$

Similarly, the path difference for a counterclockwise moving light ray in going from one mirror to the next mirror for counterclockwise rotating platform as compared to non-rotating platform in the Sagnac experiment

$$\zeta_{-} \approx -\omega r \Delta t \sin 45^{o}$$

$$\Rightarrow \zeta_{-} \approx -\omega r \sin 45^{o} \times \frac{L}{c} \approx -\omega r \sin 45^{o} \times \frac{L}{c_2}$$

2 SAGNAC EXPERIMENT

The total additional path difference between a clockwise moving light ray (moving against the sense of rotation of the platform) and a counterclockwise moving light ray (moving with the sense of rotation of the platform) in travelling from the source to the interference screen

$$\zeta = 4\zeta_{+} - 4\zeta_{-} = \left(4\omega r \sin 45^{o} \times \frac{L}{c_2}\right) - \left(-4\omega r \sin 45^{o} \times \frac{L}{c_2}\right)$$

$$\Rightarrow \zeta = 8\omega r \sin 45^{o} \times \frac{L}{c_2}$$

So, the fringe shift (additional optical path difference) for rotating platform as compared to non-rotating platform in the Sagnac experiment

$$\delta = \frac{\zeta}{\lambda_1}$$

$$\Rightarrow \delta = \frac{8\omega L r \sin 45^{o}}{\lambda_1 c_2} = \frac{16\pi N L r \sin 45^{o}}{\lambda_1 c_2} \qquad \left[\omega = 2\pi N\right]$$

$$\Rightarrow \delta = \frac{4\omega A}{\lambda_1 c_2} = \frac{8\pi N A}{\lambda_1 c_2} \qquad \left[A = 4 \times \frac{1}{2} L r \sin 45^{o}\right]$$

$$\Rightarrow c_2 = \frac{4\omega A}{\lambda_1 \delta} = \frac{8\pi N A}{\lambda_1 \delta}$$

References

1. Hugh D. Young, Roger A. Freedman, Albert Lewis Ford, *“Sears’ and Zemansky’s University Physics with Modern Physics 13th edition.”*

2. G. Sagnac, *“The Demonstration of the Luminiferous Aether by an Interferometer in Uniform Rotation”, Comptes Rendus, 1913.*