# Jones Experiment Revisited

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**Abstract**

In this paper an alternative explanation of the result of the Jones experiment with a rotating glass disk has been presented.

**Keyword :** Jones experiment.

## 1 SPEED OF LIGHT IN A TRANSVERSELY MOVING BODY

Let $c_2$ be the speed of a light ray (or a photon) in a stationary body (medium 2) and let $c_{2,m}$ be the speed of the light ray (or a photon) in the body (medium 2) when it is moving with a velocity **v**. Let $\mathbf{c_1}$ be the velocity of the light ray (or a photon) in medium 1 and let $c_o$ be the speed of the light ray (or a photon) in vacuum. Now let's consider a ray of light incident perpendicularly on the interface of a body (medium 2) moving with a velocity **v** in a direction perpendicular to the direction of the incident light.

$$\left|\mathbf{c}_{2,m} - \mathbf{v}\right|^2 - \left|\frac{c_0}{c_1}\mathbf{c_1} - \mathbf{v}\right|^2 = c_2^2 - c_o^2$$

$$\Rightarrow \left[\; c_{2,m}^2 + v^2 - 2c_{2,m} v \cos(90^o - \theta) \;\right] - \left[\; c_o^2 + v^2 - 2c_0 v \cos 90^o \;\right] = c_2^2 - c_o^2$$

$$\Rightarrow \left[\; c_{2,m}^2 + v^2 - 2c_{2,m} v \sin\theta \;\right] - \left[\; c_o^2 + v^2 \;\right] = c_2^2 - c_o^2$$

$$\Rightarrow c_{2,m}^2 - (2v\sin\theta)c_{2,m} - c_2^2 = 0 \qquad (i)$$

$$\Rightarrow c_{2,m} = \frac{2v\sin\theta + \sqrt{4v^2\sin^2\theta + 4c_2^2}}{2} = v\sin\theta + \sqrt{v^2\sin^2\theta + c_2^2}$$

$$\Rightarrow c_{2,m} = v\sin\theta + c_2\left[1 + \left(\frac{v\sin\theta}{c_2}\right)^2\right]^{\frac{1}{2}}$$

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## 2 SPEED HYPOTHESIS

Let the speed of a light ray (or a photon), in a moving body (medium 2), along the x direction

$$c_{2,m,x} = \left(\frac{\beta_2}{\mu_2}\right)^k 2v \qquad \left[\beta_2 = \frac{c_2}{c_o} \quad ; \quad k > 0\right]$$

Now from (i), we have

$$c_{2,m}^2 - (2v\sin\theta)c_{2,m} - c_2^2 = 0$$

$$\Rightarrow c_{2,m}^2 = 2vc_{2,m}\sin\theta + c_2^2$$

$$\Rightarrow c_{2,m,x}^2 + c_{2,m,y}^2 = 2vc_{2,m}\sin\theta + c_2^2$$

$$\Rightarrow c_{2,m,x}^2 + c_{2,m,y}^2 = 2vc_{2,m,x} + c_2^2 \qquad \left[c_{2,m}\sin\theta = c_{2,m,x}\right]$$

$$\Rightarrow \left(\frac{\beta_2}{\mu_2}\right)^{2k} 4v^2 + (c_2 + \Delta c_{2,y})^2 = \left(\frac{\beta_2}{\mu_2}\right)^k 4v^2 + c_2^2 \qquad \left[c_{2,m,x} = \left(\frac{\beta_2}{\mu_2}\right)^k 2v\right]$$

$$\Rightarrow (\Delta c_{2,y})^2 + 2c_2\Delta c_{2,y} = \left(\frac{\beta_2}{\mu_2}\right)^k \left[1 - \left(\frac{\beta_2}{\mu_2}\right)^k\right] 4v^2 = b_k^2 \quad \text{(let)}$$

$$\Rightarrow (\Delta c_{2,y})^2 + 2c_2\Delta c_{2,y} - b_k^2 = 0$$

$$\Rightarrow \Delta c_{2,y} = \frac{-2c_2 + \sqrt{4c_2^2 + 4b_k^2}}{2} = -c_2 + \sqrt{c_2^2 + b_k^2}$$

$$\Rightarrow \Delta c_{2,y} = c_2\left[\sqrt{\left(1 + \frac{b_k^2}{c_2^2}\right)} - 1\right]$$

$$\Rightarrow \tan\theta = \frac{c_{2,m,x}}{c_2 + \Delta c_{2,y}} = \frac{\left(\frac{\beta_2}{\mu_2}\right)^k 2v}{c_2 + c_2\left[\sqrt{\left(1 + \frac{b_k^2}{c_2^2}\right)} - 1\right]} = \frac{2v}{c_2} \times \frac{\left(\frac{\beta_2}{\mu_2}\right)^k}{\sqrt{\left(1 + \frac{b_k^2}{c_2^2}\right)}}$$

$$\Rightarrow c_{2,m} = \sqrt{(c_{2,m,x})^2 + (c_2 + \Delta c_{2,y})^2} = \sqrt{\left(\frac{\beta_2}{\mu_2}\right)^{2k} 4v^2 + \left(1 + \frac{b_k^2}{c_2^2}\right)c_2^2}$$

$$\Rightarrow c_{2,m} = \sqrt{\left(\frac{\beta_2}{\mu_2}\right)^{2k} 4v^2 + \left(c_2^2 + \left(\frac{\beta_2}{\mu_2}\right)^k \left[1 - \left(\frac{\beta_2}{\mu_2}\right)^k\right] 4v^2\right)} = \sqrt{\left(\frac{\beta_2}{\mu_2}\right)^k 4v^2 + c_2^2}$$

The coefficient of restitution for the x direction

$$e_x = \frac{c_{2,m,x} - v}{v} = \frac{c_{2,m,x}}{v} - 1 = 2\left(\frac{\beta_2}{\mu_2}\right)^k - 1$$

Now the loss in kinetic energy is given as

$$|\Delta KE| = \frac{1}{2}\frac{m_a m_b}{m_a + m_b}(u_a - u_b)^2(1 - e^2)$$

So the loss in kinetic energy in the x direction

$$|\Delta KE_x| = \frac{1}{2}\frac{m_2 m_p}{m_2 + m_p}(v - 0)^2(1 - e_x^2)$$

$$\Rightarrow |\Delta KE_x| = \frac{1}{2}m_p v^2(1 - e_x^2) \qquad [m_p << m_2]$$

So the gain in kinetic energy in the y direction

$$|\Delta KE_y| = |\Delta KE_x|$$

$$\Rightarrow \frac{1}{2}m_p\left[(c_2 + \Delta c_{2,y})^2 - c_2^2\right] = \frac{1}{2}m_p v^2(1 - e_x^2)$$

$$\Rightarrow \left[(\Delta c_{2,y})^2 + 2c_2\Delta c_{2,y}\right] = v^2(1 - e_x^2)$$

$$\Rightarrow (\Delta c_{2,y})^2 + 2c_2\Delta c_{2,y} - v^2(1 - e_x^2) = 0$$

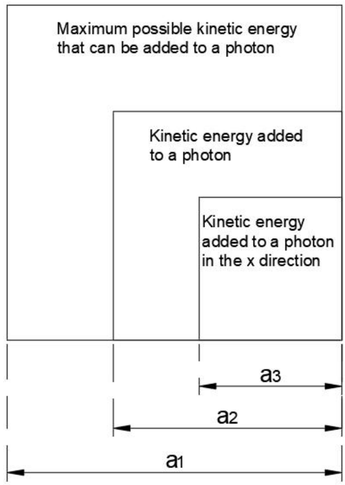
$$\Rightarrow \Delta c_{2,y} = \frac{-2c_2 + \sqrt{4c_2^2 + 4v^2(1 - e_x^2)}}{2} = -c_2 + \sqrt{c_2^2 + v^2(1 - e_x^2)}$$

$$\Rightarrow \Delta c_{2,y} = c_2\left[\sqrt{\left(1 + \frac{v^2}{c_2^2}(1 - e_x^2)\right)} - 1\right]$$

$$\Rightarrow \Delta c_{2,y} = c_2\left[\sqrt{\left(1 + \frac{v^2}{c_2^2}\left(1 - \left(2\left(\frac{\beta_2}{\mu_2}\right)^k - 1\right)^2\right)\right)} - 1\right]$$

$$\Rightarrow \Delta c_{2,y} = c_2\left[\sqrt{\left(1 + \frac{b_k^2}{c_2^2}\right)} - 1\right]$$

## 3 ENERGY DIAGRAM




$$a_1 = \sqrt{\left(\frac{1}{2}m_p\right)}2v$$

$$a_2 = \sqrt{\left(\frac{1}{2}m_p\right)}\left(\frac{\beta_2}{\mu_2}\right)^{\frac{k}{2}}2v$$

$$a_3 = \sqrt{\left(\frac{1}{2}m_p\right)}\left(\frac{\beta_2}{\mu_2}\right)^{k}2v$$

## 4 JONES EXPERIMENT

For light traversing a glass disk of 2.465 cm thickness and refractive index 1.524 at an operating radius of 13.75 cm, when the disk is reversed from +1501.9 to -1501.9 rev/min the displacement observed is 6.2 nm approximately, i.e., $\Delta = 6.2$ nm.

$$\Rightarrow \tan\theta = \frac{\left(\frac{\Delta}{2}\right)}{0.02465}$$

$$\Rightarrow \frac{\Delta}{2} = 0.02465 \times \tan\theta$$

$$\Rightarrow 3.1\times10^{-9} = 0.02465 \times \frac{2v}{c_2} \times \frac{\left(\frac{\beta_2}{\mu_2}\right)^k}{\sqrt{\left(1+\frac{b_k^2}{c_2^2}\right)}}$$

$$\Rightarrow 3.1\times10^{-9} \approx 0.02465 \times \frac{2v}{c_2} \times \left(\frac{\beta_2}{\mu_2}\right)^k \qquad \left[\frac{b_k^2}{c_2^2} << 1\right]$$

$$\Rightarrow 3.1\times10^{-9} \approx 0.02465 \times \frac{2\times\left[\left(\frac{1501.9}{60}\right)\times 2\pi \times 0.1375\right]}{(\beta_2 \times 3\times10^8)} \times \left(\frac{\beta_2}{1.524}\right)^k$$

$$\Rightarrow 3.1\times10^{-9} \approx 3.55\times10^{-9} \times \frac{\beta_2^{k-1}}{1.524^k}$$

$$\Rightarrow \frac{\beta_2^{k-1}}{1.524^k} \approx 0.873$$

Let's assume

$$\beta_2 = \frac{1}{\mu_2} = \frac{1}{1.524}$$

$$\Rightarrow \frac{1}{1.524^{2k-1}} \approx 0.873$$

$$\Rightarrow k \approx 0.66 \approx \frac{2}{3}$$

## 5 CONCLUSION

Since $\beta_2$ need not be equal to $1/\mu_2$ , Jones experiment needs to be performed again with water in a rotating transparent cylinder. By using $\mu_w = 4/3$ and $\beta_w = 0.7$ (as obtained via the Fizeau experiment with moving water), the precise value of k can be obtained.

## References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