Reflection of Light From Moving Mirror

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The application of reflection symmetry to two inertial reference frames shows that the elapsed time is conserved in all inertial reference frames. The conservation of the elapsed time indicates that the reflection of light between a pair of stationary mirrors should take the same elapsed time in all inertial reference frames. In one reference frame, both mirrors are stationary. In other reference frames, both mirrors are moving. The distance traveled by the light between the moving mirrors depends on the direction. The conservation law shows that the light travels at a different speed upon reflection by a moving mirror.

I. INTRODUCTION

The symmetry in physics is associated with conservation and transformation. Within a single reference frame, the symmetry can generate conservation law. With multiple inertial reference frames, the symmetry can generate transformation law and conserved quantity.

For a pair of observers, the reflection symmetry shows that the position and the velocity of each observer's rest frame are related. The elapsed time in each rest frame can be derived with the definition of the velocity.

The light can be reflected between a pair of mirrors facing each other. For stationary mirror, the light maintain the same speed upon reflection and travels the same distance between the mirrors in both directions. For two mirrors moving at the same speed, the distance traveled by light between the mirrors depends on the direction. However, the elapsed times for both directions are identical as in the case of stationary mirrors. With both the elapsed time and the distance determined, the speed of light upon reflection by a moving mirror can be calculated precisely.

II. PROOF

Consider one dimensional motion.

A. Elapsed Time

The reflection symmetry can be applied to an isolated system of two persons.

Let the rest frame of a person P_1 be F_1. P_1 is stationary at the origin of F_1. Let another person P_2 be at a position x in F_1.

Let the rest frame of P_2 be F_2. P_2 is stationary at the origin of F_2. From the relative reflection symmetry, P_1 is at the position of -x in F_2.

Let F_2 move at the speed of v relative to F_1. From the relative reflection symmetry, F_1 is moving at the speed of -v relative to F_2.

Let t_1 be the time of F_1. P_2 moves at the speed of v in F_1. This motion can be described as

$$\frac{dx}{dt_1} = v \tag{1}$$

Let t_2 be the time of F_2. P_1 moves at the speed of -v in F_2. This motion can be described as

$$\frac{d(-x)}{dt_2} = -v \tag{2}$$

From equations (1,2),

$$dt_2 = dt_1 \tag{3}$$

$$t_2 = t_1 + A \tag{4}$$

The time of F_1 differs from the time of F_2 by a constant A which can be set to zero or any value by the initial condition.

From equation (3), the elapsed time is conserved in both F_1 and F_2. If dt_1 is zero then dt_2 is also zero. *Two simultaneous events in one inertial reference frame are also simultaneous in another inertial reference frame.*

B. Reflection from Stationary Mirror

Let a pair of mirrors be stationary relative to a reference frame F_3. Both mirrors face each other to reflect light back to each other. According to Fresnel's equations[1], both the incident light and the reflected light travel at the same speed in F_3.

Let the mirror closer to the origin of F_3 be M_1. The other mirror is M_2.

The time for the light to travel from M_1 to M_2 in F_3 is dt_3^i The time for the light to travel from M_2 back to M_1 in F_3 is dt_3^r

$$dt_3^i = dt_3^r \tag{5}$$

C. Reflection from Moving Mirror

Let another reference frame F_4 moves at a speed of v relative to F_3. Both mirrors move at the speed of -v relative to F_4. The distance between the mirrors is L in F_4.

Light travels from M_1 to M_2 in F_4 at the speed of C_i. Upon reflection, light travels from M_2 back to M_1 in F_4 at the speed of C_r.

Let the time for the light to travel from M_1 to M_2 in F_4 be dt_4^i. The total distance traveled by the light is

$$C_i * dt_4^i = L + (-v)dt_4^i \quad (6)$$

M_2 reflects the light back to M_1. Let the time for the light to travel from M_2 to M_1 in F_4 be dt_4^r. The total distance traveled by light is

$$C_r * dt_4^r = L - (-v)dt_4^r \quad (7)$$

From equation (3), the elapsed time is conserved in all inertial reference frames.

$$dt_4^i = dt_3^i \quad (8)$$

$$dt_4^r = dt_3^r \quad (9)$$

From equation (5,8,9),

$$dt_4^i = dt_4^r \quad (10)$$

From equation (6,7,10),

$$C_r = C_i + 2v \quad (11)$$

Light travels at a different speed upon reflection by a moving mirror.

D. Doppler Radar

Radar gun is used by the traffic police to measure the speed of an approaching car. It demonstrates how the detected frequency depends on the reference frame.

The equation from Doppler effect to calculate the frequency of the radar wave in radar gun[2,3] is

$$f_r - f_i = 2v\frac{f_i}{c} \quad (12)$$

f_r is the frequency of the reflected radar wave. f_i is the frequency of the incident radar wave. v is the speed of the car.

The wavelength of the incident radio wave is identical to the wavelength of the reflected radio wave. This is a direct property from the reflection symmetry and was verified by Su[4] in 2018.

$$\lambda_r = \lambda_i \quad (13)$$

From equation (11),

$$\frac{C_r}{\lambda_i} = \frac{C_i + 2v}{\lambda_i} \quad (14)$$

From equations (13,14),

$$\frac{C_r}{\lambda_r} = \frac{C_i + 2v}{\lambda_i} \quad (15)$$

$$f_r = f_i + \frac{2v}{\lambda_i} \quad (16)$$

$$f_r - f_i = 2v\frac{1}{\lambda_i} \quad (17)$$

This is exactly the formula used by radar gun in equation (12).

Doppler radar is an excellent experimental verification that the radio wave accelerates upon reflection by an approaching car.

III. CONCLUSION

The reflection symmetry shows that the elapsed time is conserved in all inertial reference frames. There is no time dilation between inertial reference frames.

The elapsed time for light to travel from one stationary mirror to another stationary mirror is conserved in all other inertial reference frames in which both mirrors move at the same speed.

Upon reflection by a moving mirror, light will travel at a different speed. The mirror will either accelerate or slow down the light. The speed of light is dependent on the reference frame. Therefore, the assumption from the theory of special relativity[5] about the constant speed of light is incorrect. The error of this theory comes from its foundataion, Lorentz transformation[6].

Lorentz transformation claims that two simultaneous events can not be simultaneous in another inertial reference frame because of time dilation. This is incorrect according to the conservation of the elapsed time. If the elapsed time is zero in one inertial reference frame, it is also zero in another inertial reference frame.

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