 doi:10.20944/preprints202204.0061.v1

Article

Emission, propagation, and reflection of light as mechanical phenomena

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Abstract: Emission, propagation, and reflection of light as mechanical phenomena in inertial frames are based on the behavior of balls at the limit when their mass is zero. The kinematics of massless balls is like that of balls with mass. Light as a wave or particle is a massless entity. Therefore, it is natural to apply the kinematics of the massless balls to light. Consequently, the kinematics of light depends on its kinetics of electromagnetic nature and its kinematics of mechanical nature in its interactions of emission and reflection with the matter. The study of the physics phenomena in the frame at absolute rest includes those in the inertial frames. Considering this and applying the emission, propagation, and reflection of light as mechanical phenomena in the vacuum of the frame at absolute rest, this study derives formulas for the speed of the wavefront of a ray of light reflected by a fixed and moving mirror when the light comes from a fixed and moving source. The derived formulas apply to the modified Michelson interferometer, employed independently by R. Tomaschek and D. C. Miller in their experiments.

Keywords: geometrical optics; speed of light; emission of light; propagation of light; reflection of light; Michelson-Morley experiment; modified Michelson interferometer.

1. Introduction

Michelson derives the fringe shift within his interferometer considering the hypotheses that the velocity of light is independent of the velocity of the source and the incident and reflected velocity have the universal speed $c \cong 3\times10^8$ m/s, in the frame at absolute rest, before, at, and after the instance of collision with a mirror in motion [1].

Opposingly to Michelson's approach, the reflection of light as a mechanical phenomenon considers the hypothesis that the velocity of light is independent of the velocity of the source, and the incident and reflected velocity have the same speed in the inertial frame of a mirror at the instance of collision with the mirror. This study is presented by Filipescu in “Reflection of Light as a Mechanical Phenomenon Applied to a Particular Michelson Interferometer” [2] and in “Opposing hypotheses of the reflection of light applied to the Michelson interferometer with a particular geometry” [3], which basically are the same article, and in “Opposing hypotheses of the reflection of light applied to the Michelson interferometer” [4].

“Emission, propagation, and reflection of light as mechanical phenomena in inertial frames” [5] by Filipescu treats the wavefront of a ray of light or a photon, regarding their kinematics of mechanical nature, as a massless ball in their interactions with the matter of reflection and emission as well. Therefore, the velocity of light depends on the velocity of the source. This study is applied to “Observation of a star’s orbit based on the emission and propagation of light as mechanical phenomena” [6] and to the article presented here.

The emission and propagation of light as a mechanical phenomenon [5,6] means that in the vacuum of the frame at absolute rest, called the absolute frame, the light from a fixed or moving source is emitted with the universal speed $c \cong 3\times10^8$ m/s. If the source is fixed, the propagation velocity of light c_s

coincides with velocity c. If the source is in motion with the velocity v_s, then the velocity v_s drags the emitted velocity c, and the propagation velocity c_s is the vector sum of the velocities c and v_s. The dragging does not affect the direction or magnitude of the emitted velocity c.

The reflection of light as a mechanical phenomenon [2-5] means that, when engaged in reflection, the velocities c_s, c, v_s, and their reflected velocities have the same magnitude, respectively, in the frame of the mirror at the instance of collision, as can be observed from the drawings below. The incident and reflected angle of these velocities, all measured from the normal to the plane of the mirror at the point of collision, are equal, respectively, in the frame of the mirror and the absolute frame at the instance of the collision.

When the mirror and source are fixed in the absolute frame or at rest in an inertial frame, the reflection of light is as it is observed on the earth. Section 2 approaches a fixed mirror and a source in motion. Section 3 presents a mirror in motion and a fixed source applicable to the experiment performed by D. C. Miller [7]. Section 4 describes the mirror and source traveling with different velocities applicable to the experiment performed by R. Tomaschek [8].

Per the notations used in Sections 3 and 4, the points indicated by letters without an index correspond to points seen by an observer in the inertial frame of the mirror. The points indicated by letters with an index are instances of inertial frame points in the absolute frame. The points with the same index are associated with the same instance.

The drawings are at scale for the velocities c and v at the ratio of $c/v = 2$.

2. Reflection of light by a fixed mirror when light comes from a source in motion

This section derives the speed of the reflected wavefront of a ray of light c_{ra} in the vacuum of the absolute frame by a fixed mirror in the absolute frame when the coherent light comes from a source at rest in an inertial frame that travels with the velocity v_s.

For Sections 2 and 4, the propagation velocity c_s from the source in motion is the vector sum of the velocities v_s and the emitted velocity from the source c. There are two cases to study depending on the velocity of the source, v_s, whether it is engaged in reflection or not.

2.1. Velocity v_s is engaged in reflection

Figure 1 illustrates the case in which the velocity v_s and c are engaged in the reflection with the mirror. The speed c_{ra} is equal to the speed of light propagation c_s, $c_{ra} = c_s$.

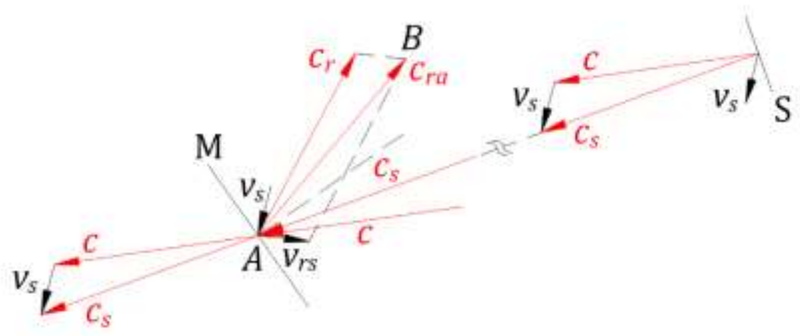

Figure 1. Velocity v_s is engaged in reflection.

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The result is the same if the reflection of velocities v_s and c are considered individually, so c_{ra} is the vector sum of the reflected velocities v_{rs} and c_r, respectively, as illustrated in Figure 1. The speeds $v_{rs} = v_s$ and $c_r = c$.

2.2. *Velocity v_s is not engaged in reflection*

In this case, the emitted velocity c is reflected as depicted in Fig. 2. The speed $c_r = c$. The undisturbed velocity v_s drags the reflected velocity c_r, and the reflected velocity c_{ra} is the vector sum of velocities v_s and c_r. The speed $c_{ra} \neq c_s$.

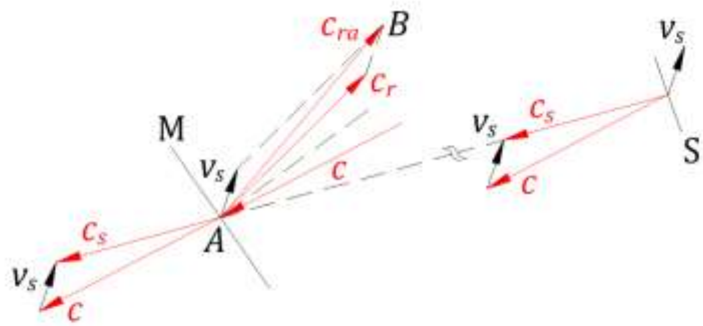

Figure 2. Velocity v_s is not engaged in reflection.

3. Reflection of light by a mirror in motion when light comes from a fixed source

This section derives the speed of the reflected wavefront of a ray of light c_{ra} in the vacuum of the absolute frame by a mirror at rest in an inertial frame that travels with the velocity v when the coherent light comes from a source fixed in the absolute frame.

3.1. *Reflection of the wavefront of a ray of light when its velocity from the source has an opposite direction to the velocity of the mirror*

Figure 3 shows a mirror M at rest in an inertial frame that is moving with velocity v. A coherent source of light S fixed in the absolute frame emits parallel rays of light with velocity c perpendicular to the mirror in the opposite direction of velocity v of the inertial frame. The wavefront of a ray of light from the source collides with the mirror at point A_1.

The speed of the incident wavefront to the mirror in the inertial frame $c_{ii} = c + v_i = c + v$, where $v_i = v$ is the speed of the mirror in the opposite direction of the incident wavefront.

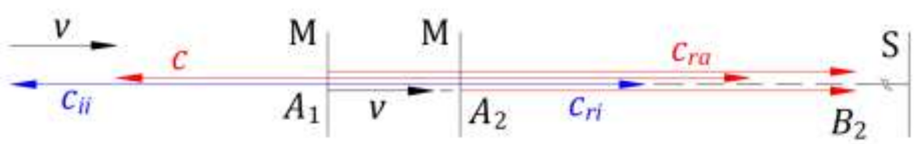

Figure 3. Reflection of the wavefront of a ray of light when its velocity from the source has an opposite direction to the velocity of the mirror.

Figure 3 displays the velocity vectors v, c, c_{ii}, c_{ri}, and c_{ra} at the point of collision A_1.

In the inertial frame of the mirror, the wavefront reflected as a mechanical phenomenon [2,3] has the velocity c_{ri} in the opposite direction to the velocity of the incident wavefront of light c_{ii}, and their magnitude are equal, $c_{ri} = c_{ii} = c + v_i = c + v$.

In the absolute frame, after a time t from the instance of the collision, the wavefront of light travels the path A_1B_2 with the speed c_{ra}, and the mirror travels the distance A_1A_2 with the speed $v_r = v$, where v_r is the speed of the mirror in the direction of the reflected wavefront. The distance $A_1B_2 = A_1A_2 + A_2B_2 \Rightarrow c_{ra}t = v_r t + c_{ri}t \Rightarrow c_{ra} = c_{ri} + v_r$ that yields the equation

$$c_{ra} = c + v_i + v_r \text{ [2,3].} \tag{1}$$

The solution of Equation (1) is $c_{ra} = c + v_i + v_r = c + v + v = c + 2v$.

In the absolute frame, the wavefront of the ray of light is observed along the paths A_1B_2 traveling in this particular case with the speed $c_{ra} = c + 2v$.

In the absolute and inertial frame, the ray of light is observed along the paths A_2B_2 and AB, respectively, traveling with the speed $c_a = c_{ri} = c + v$; A_2B_2 is identical to AB in the inertial frame.

3.2. Reflection of the wavefront of a ray of light when the direction of velocities c_{ii} and c_{ri} make an angle a and b, respectively, measured from the direction of velocity v

In Figure 4, the direction of the velocities v_i and v_r make the angle a and b, respectively, measured from the direction of velocity v. Points A_1, A_2, A_3, B_1, B_2, and C_3 are instances in the absolute frame of points A, B, and C from the inertial frame of the mirror. Points X and Y belong to the fixed source in the absolute frame.

Figure 4 displays the velocity vectors v, v_i, v_r, c, c_{ii}, c_{ri}, c_{ra}, and c_a present at the point of collision A_1. The angle of the incident velocity c_{ii} and reflected velocity c_{ri}, both measured from normal to mirror at the point of collision A_1, are equal in the inertial and absolute frame. The speed $v_i = v\cos a$ and $v_r = v\cos b$. Substituting v_i and v_r in Equation (1), it is obtained Equation (2) applicable for any angle, both a and b.

$$c_{ra} = c + v\cos a + v\cos b \text{ [2,3].} \tag{2}$$

After one second from the instance of the collision, the wavefront of the ray of light travels the path A_1B_2 with velocity c_{ra}, and the mirror travels the distance A_1A_2 with velocity v.

The vector A_2B_2 is the velocity of the ray of light c_a observed in the absolute and inertial frame shown at the point of collision A_2 and A, respectively.

After a time t from the moment of the collision, the wavefront of the ray of light travels the path A_1C_3 with velocity c_{ra}, and the mirror travels the distance A_1A_3 with velocity v.

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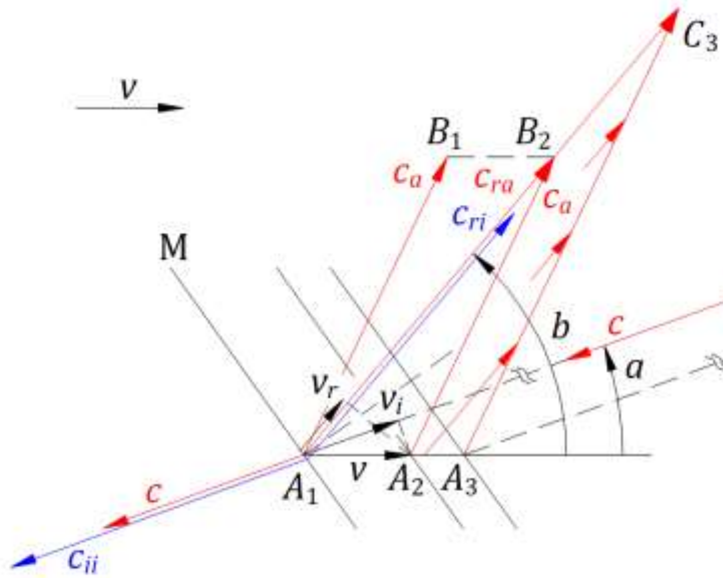

Figure 4. Reflection of the wavefront of a ray of light when the direction of the velocities v_i and v_r make the angle a and b, respectively, measured from the direction of velocity v.

In the absolute frame, the wavefront of the ray of light is observed along the paths A_1C_3 traveling with the speed c_{ra} given by Equation (2). The velocity c_{ra} has the same direction at and after the collision at point A_1.

In the absolute and inertial frame, the ray of light is observed along the path A_3C_3 and AC, respectively, traveling with the velocity c_a as a vector sum of the velocity c_{ra} and $-v_s$; A_3C_3 is identical to AC. The speed c_a can be calculated from the law of cosines $c_a^2 = c_{ra}^2 - 2\,c_{ra}v\cos b + v^2$.

The instances of point A from A_1 to A_3 reflect only one wavefront from each ray of light coming from points X through Y of the fixed source in the absolute frame. This multitude of wavefronts travels in the direction of velocity c_{ra} and generates the ray of light observed along the line A_3C_3 traveling with the velocity c_a. When the velocity of light is considered independent of the velocity of the source, and the source is at rest in the inertial frame of the mirror [2,3], the ray along the line A_3C_3 is generated by the same ray from the source.

This section is presented with more details in “Reflection of Light as a Mechanical Phenomenon Applied to a Particular Michelson Interferometer” [2] and in “Opposing hypotheses of the reflection of light applied to the Michelson interferometer with a particular geometry” [3].

3.3. Discussions

The physics phenomena are observed in the inertial frame of the Sun as in the absolute frame, or in other words, the inertial frame of the Sun is a frame at relative rest [5] for the inertial frame of the Earth that travels with the velocity v. The absolute frame can be replaced with the frame at relative rest of the Sun for the studies in the inertial frame of the Earth. Therefore, the Sun can be considered a fixed source for the Earth’s inertial frame.

Equation (2) applies to sunlight that has the velocity c and to the mirror at rest in the inertial frame of the Earth that travels with the velocity v; both speeds are in the inertial frame at relative rest of the Sun, not in the absolute frame. Thus, the study of Section 3 applies to the experiment performed in 1925 by D. C. Miller [7] that used sunlight.

4. Reflection of light by a mirror in motion when light comes from a source in motion

This section derives the speed of the reflected wavefront of a ray of light c_{ra} in the vacuum of the absolute frame by a mirror at rest in an inertial frame that travels with the velocity v when the coherent light comes from a source at rest in an inertial frame that travels with the velocity v_s.

4.1. Velocity v_s is engaged in reflection

Figure 5 illustrates the case in which the velocities v_s and c are engaged in reflection with the mirror in motion. The speed of light propagation c_s is the vector sum of the velocities v_s and c. The speeds $v_i = v\cos a$, $v_r = v\cos b$, $c_{ri} = c_{ii} = c_s + v_i$, then $c_{ra} = c_{ri} + v_r = c_s + v_i + v_r$ yields the equation

$$c_{ra} = c_s + v\cos a + v\cos b\,. \tag{3}$$

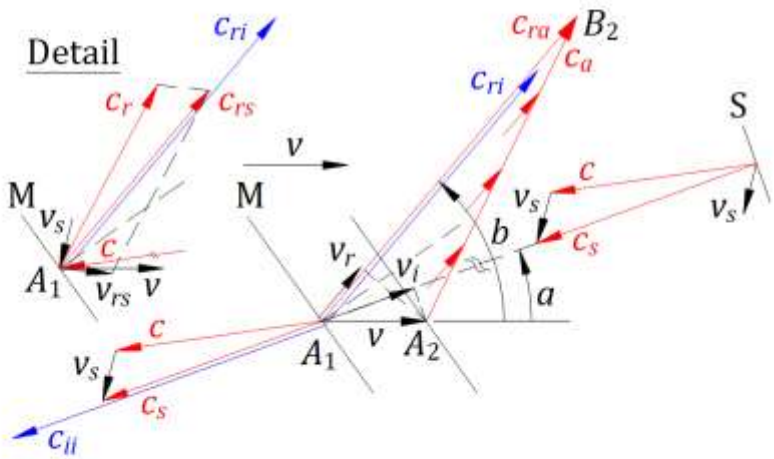

Figure 5. Velocity v_s is engaged in reflection.

The result is the same if the velocity v_s and c are considered individually in reflection and the reflected velocity c_{rs} is the vector sum of the reflected velocities v_{rs} and c_r, as shown in the detail of Figure 5. The speeds $v_{rs} = v_s$ and $c_r = c$. The speed $c_{ri} = c_{rs} + v_i = c_s + v_i$, then $c_{ra} = c_{ri} + v_r = c_s + v_i + v_r$ gives Equation (3).

4.2. Velocity v_s is not engaged in reflection

In this case, the emitted velocity c is reflected as depicted in Fig. 6.
The speeds $v_i = v\cos a$, $v_r = v\cos b$, $c_{ri} = c_{ii} = c + v_i$, then $c_r = c_{ri} + v_r = c + v_i + v_r$ yields the equation

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$$c_r = c + v\cos a + v\cos b. \tag{4}$$

The undisturbed velocity v_s drags the reflected velocity c_r, and their vector sum gives the velocity c_{ra}.

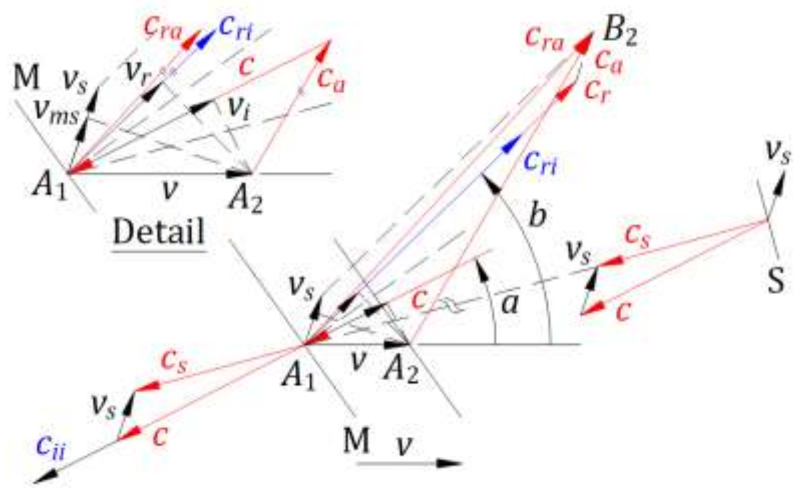

Figure 6. Velocity v_s is not engaged in reflection.

The detail of Figure 6 is an enlarged view at point A_1. The velocity of the mirror along the direction of velocity v_s is v_{ms}. Vector $v_{ms} < v_s$, therefore, v_s is not engage in reflection.

4.3. Discussions

The cases of this section apply to the experiment performed in 1924 by R. Tomaschek [8]. The relative speed of the Sun with the Earth to a star as a source of light is unknown. Therefore, the fringe shift within the modified Michelson interferometer is not derivable, so unpredictable. If still the star is considered a fixed source, then the modified Michelson interferometer may display a fringe shift more or less of 0.40×10^{-4} [2-4].

"Emission, propagation, and reflection of light as mechanical phenomena in inertial frames" [5] is the particular case in which both the mirror and source are at rest in an inertial frame that travels with the velocity v and the velocity v_s is not engage in reflection.

5. Conclusions

Formula/Equation (2) $c_{ra} = c + v\cos a + v\cos b$ is derived, as well, when the source is at rest in the inertial frame of the mirror, the velocity of light is considered independent of the velocity of the source, and the reflection of light is a mechanical phenomenon [2,3]. This formula applied to the Michelson interferometer with a particular geometry [2,3], where the beam splitter makes an angle of $45°$ with the direction of the rays from the source and one mirror is perpendicular and another parallel to this direction, predicts zero fringe shift, and applied to the Michelson interferometer, as presented in the Michelson-Morley experiment [1], predicts a fringe shift of 0.40×10^{-4} [4].

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Here, formula/Equation (2) is derived based on "Emission, propagation, and reflection of light as mechanical phenomena in inertial frames" [5] that concludes that light behaves in inertial frames as in the absolute frame. Therefore, the Michelson-Morley experiment yields zero fringe shift for any geometry.

The studies on the reflection of light as mechanical phenomena [2-5] are based on the behavior of balls with and without mass. Therefore, these studies apply to the elastic collision of massless balls with a wall (photons with a mirror) and approximately to the balls with mass assuming that the mass of the rigid wall is much higher than the mass of the balls.

The incident angle and reflected angle of the emitted velocity c are equal in each figure above. This property of reflection of light impacts our visual observations because our eyes are sensitive to the electromagnetic nature of light, therefore, to the direction of the emitted velocity c.

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