International Journal of Pure and Applied Physics.
ISSN 0973-1776 Volume 21, Number 1 (2025), pp. 19-23

http://www.ripublication.com

The Light Propagation

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Abstract

This article presents experiments that determine whether light propagates at the speed of light relative to the receiver or the transmitter. To do this, light from a light source is projected onto two mirrors rotating around an axis, so that the mirrors have opposite velocity components relative to the light source. The light returning from the mirrors is directed to a common mirror and examined for interference shifts. The experiment is modeled on the Michelson-Morley experiment.

Keywords. Light Propagation.

1. The *Michelson-Morley* Experiment

I am based on the Michelson-Morley experiment. It is presented in books as follows: light from a horizontal light source falls onto a semi-transparent plate tilted at 45°. Part of the rays are transmitted vertically upwards to a horizontal plate and return from there, while another part of the rays pass straight through the inclined plate to a vertical plate and also return. The inclined plate is viewed from below. If the distance of the vertical plate is changed, the reflected rays travel different paths, so that they cancel each other out at a phase difference of half a wavelength. More precisely, if the inclined plate has the coordinates (x,x), $-d < x < d$, and the two other plates are at a distance h from its center, a ray arriving at x must travel a distance of $2(h - x)$ until it returns. If I move the vertical plate horizontally, differences in length of half a wavelength can occur and the light can be extinguished.

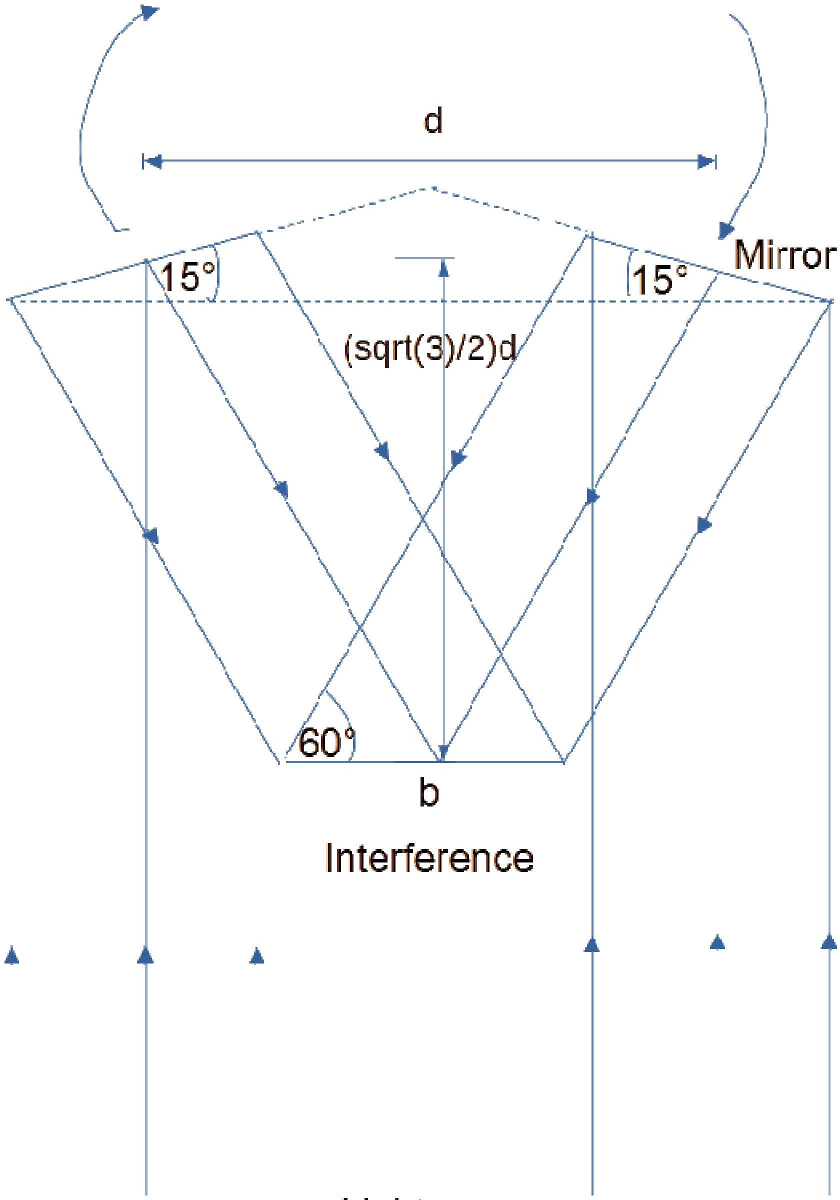
2. The Path of Rays in Stationary Mirrors with Figure Path of Rays

Based on this, I want to show that the propagation of light depends on the receiver, meaning that light moves at the speed of light relative to the receiver. To do this, I need to compare two light receivers moving at different speeds with the same light source. The simplest way is to let two plates rotate in a circle. When rotated counterclockwise in the vertical plane, the right plate moves up and the left plate down. If the light propagates according to the receiver, the rays from the right plate

follow it and arrive first. I then only need to reflect the rays from both plates onto a common plate where interference can occur. In the figure, this looks like this: The plates are at an angle of 15° to the dashed x-axis. The light hits the plates at the same angle to the vertical and reflects back at an angle of 30° to the incident ray. This then forms an angle of 90°-30° = 60° to the x-axis and to the horizontal plate below. The angles of the right and left plates behave symmetrical.
The rightmost rays of the light source hit the rightmost part of the right-hand inclined mirror and possess the shortest path to the horizontal mirror. They collide with rays coming from the upper right part of the left mirror, which possess the longest path. The entire setup is symmetrical about the vertical axis, corresponding to the y-axis. Likewise, the leftmost rays from the left part of the left mirror, with the shortest path, collide with the rays from the upper left part of the right mirror, with the longest path. As I move up the right mirror, the path difference between right and left becomes increasingly shorter until, in the middle of the inclined mirrors, the paths to the center of the horizontal mirror are equal. In this case, the rays simply add up. If I move even further up the right mirror, the right rays become longer than the left rays. At suitable distances, one would expect an intensity maximum in the center of the horizontal mirror, with the light decreasing symmetrically in both directions and, even after being extinguished, increasing again several times. I'll decide the details now.
The path from the light source to the horizontal, dashed line between the two outermost corners of the mirrors is given, and I only calculate the paths beyond that. I consider the lower right corner of the right mirror to be the origin of a horizontal line to the left. Then a ray that falls on the mirror offset by x to the left goes up over the horizontal line $y = x$ tan15° and s back to the horizontal line by means of y/s = sin60°, that is, $s = y$/sin60° = (2/sqrt 3)x tan15°. It travels a total distance of $y + s$ = (1 + 2/ sqrt 3)(tan15°)x. At the left mirror, the distance increases in exactly the opposite direction. If b is the component of the left mirror on the dashed line, the rays with the components on the right x and the left $b - x$, $0 \leq x \leq b$, come together. The paths from the dashed line to the horizontal mirror are then equal. Two rays meet there, together with the additional path of (1 + 2/sqrt 3)(tan15°)($x + b - x$) = (1 + 2/sqrt 3)(tan15°)b = constant. This means that with the experimental setup chosen as above, the sum of the rays is always constant. The difference leading to interference is then (1 + 2/sqrt 3)(tan 15°)($2x - b$). It is 0 for the rays from the center of the two mirrors, i.e., for $x = b/2$. They meet at the bottom of the plate at an angle of 60°. For the angles to the straight line connecting the two centers of the mirrors, for reasons of symmetry, only (180° - 60°)/2 = 60° remains. The triangle with the two mirror centers, approximately at a distance d, and the plate center forms an equilateral triangle, and the plate center, i.e., the plate, lies (sqrt(3)/2)d perpendicularly below the mirror centers. The following values now apply:
sqrt 3 = 1.732, sqrt(3)/2 = 0.866, 1/sqrt 3 = sqrt(3)/3 = 0.5773, 2/sqrt 3 = 1.155, tan15° = 0.2675, and thus (1 + 2/sqrt 3)tan15° = 2.155*0.2675 = 0.5765, 1/0.5765 = 1.7346. If 0.5765($2x - b$) is an odd multiple of half a wavelength λ, the rays cancel each other out. $2x - b$ = 1.7346($2n$ + 1)$\lambda/2$, x = 0.8673($2n$ + 1)$\lambda/2 + b/2$. Assuming a

sqrt 3 = 1.732, sqrt(3)/2 = 0.866, 1/sqrt 3 = sqrt(3)/3 = 0.5773, 2/sqrt 3 = 1.155, tan15° = 0.2675, and thus (1 + 2/sqrt 3)tan15° = 2.155*0.2675 = 0.5765, 1/0.5765 = 1.7346. If 0.5765(2x - b) is an odd multiple of half a wavelength λ, the rays cancel each other out. 2x - b = 1.7346(2n + 1)λ/2, x = 0.8673(2n + 1)λ/2 + b/2.

Figure Path of Rays



Assuming a mean wavelength of 0.5μ, we get x = 0.2168(2n + 1)μ + b/2. So I have to go left and right from the center of the plate in steps of approximately 0.4μ; n can also be negative. To see the interference lines, I have to use a telescope. The mirrors are to be positioned on a circle perpendicular to the circumference. Because both are tilted downwards at 15°, their angular separation is 180° - 2*15° = 150°. Because they are perpendicular to the circumference, they point in the direction of the radii. Their intersection point forms the center of the circle. The radii therefore intersect the line between the two mirror centers with length d at an angle of 15°. The perpendicular from the center of the circle to this secant bisects it in the middle at *d*/2 for reasons of symmetry. The relationship between the radius *r* and the secant is cos15° = (*d*/2)/*r* or *d* = 2(cos15°) *r* = 2*0.9659 *r* = 1.9318 *r*.

The corresponding length *s* of the inclined mirrors can also be calculated using the width of the plate *b*. The triangle with the inclined mirror and the dashed horizontal side *w* with the length of the plate b possesses a perpendicular to *w*, the height *h*. This divides *w* into the right half *wr* and the left half *wl*. The following relationships apply to the corresponding triangles with a right angle at h: *wr* = *s* cos15°, *wl* = *h*/tan60°, *h* = *s* sin15°. From this, *b* = *wr* + *wl* = *s* (cos15° + sin15°/tan60°).

The values are cos15° = 0.9659, sin15° = 0.2588, tan60° = sqrt(3) = 1.732, 1/tan60° = sqrt(3)/3 = 0.5773. This gives *b* = *s*(0.9650 + 0.1494) = *s* 1.1144 or *s* = 0.8973 *b*.

3. The Path of Rays with Rotating Mirrors

The ray path just described only applies to stationary mirrors. However, I want to demonstrate that the propagation of light changes with movement, specifically with respect to the receiver. To do this, I rotate the two inclined mirrors around their common suspension point, the center of the circle, while the horizontal interference mirror remains fixed and at rest. This causes everything to shake, and the mirrors only assume the position shown above for a single instant, which is the sole basis of my considerations. However, as an integral over everything, the result should be something that approximately corresponds to the stationary arrangement. Specifically, with a mathematically positive sense of rotation, the mirror rotates vertically upwards with the component of cos 15° = 0.9659, and the left mirror rotates downwards equally. This causes rays from the right and left mirrors, which are changed in opposite directions, to reach the horizontal stationary mirror and the difference is observed. I will now calculate how fast the mirror rotation must be to detect a change in the interference on the horizontal mirror. To do this, I will introduce the following abbreviations and, where possible, their suggested values.

r = distance of the mirrors from the rotation point = 0.5 m.

U = revolutions per second = *U* [s-1].

v = speed on the edge of the circle = 2*πr U*.

a = distance of the mirrors from the light source when horizontal = 10 m.

c = speed of light = 3 10^8 m/s.

t = time it takes for the light to travel from the light source to the mirrors = *a*/*c* = (*a*/3) 10^{-8} m/s = (3.3) 10^{-8} m/s

λ = wavelength of light = 0.5 µm = 5 10^{-7} m.

If the light propagation depends on the receiver, the right mirror, which is moved upwards, draws the light upwards at its vertical speed *v* cos15° = 0.9659 *v*, and the

other mirror downwards in the same way. The difference in the mirror speeds is 2 cos15° $v = 1.9318\, v$. With this difference in the time t that the rays need to travel from the light source to the mirrors, I have to reach approximately half the light wavelength $\lambda/2$ for a different interference to occur, i.e. $2\cos15°\, vt = \lambda/2$ or $v = (1/(4\cos15°))\, \lambda/t = (1/(4\cos15°))\ 5\ 10^{-7}\ 3\ 10^{7}$ m/s = 15/(4cos15°) m/s = 15/3.8636 m/s ≈ 4 m/s. For the number of revolutions, one then obtains with $r = 0.5$ m the value $U = v/\pi\ \text{m}^{-1} \approx 4/3\ \text{s}^{-1}$ using $v = 2\pi r\, U = \pi\, U$ m. The difference in the phases of the light waves at the center of the stationary mirror is 0 for stationary, inclined mirrors and $\lambda/2$ for the rotation value just given. The same applies to an integer multiple of $2n$ and a half-integer multiple of $2n + 1$ of the rotation speed. This means that the interference lines would have to be shifted by half a wavelength. The interference lines can only be shifted if the light propagation depends on the receiver; otherwise, not. The whole thing must be observed with a telescope. It should be noted that the distances beyond the rotating mirrors are small and do not matter compared to the large distance from the light source. However, the luminous intensities on the horizontal plate are quite uncertain and blurred for rapidly rotating mirrors. But one would expect that, despite the rotation, the light distribution will be noticeable for mirrors positioned exactly horizontally to each other and will change as multiples of the expression $2\cos15°\, vt = \lambda/2$. The light selection can be further improved by inserting fixed apertures between the two rotating mirrors and the plate. These apertures should allow only those rays arriving at an angle of 60° to the dashed horizontal line between the two mirrors at rest, or 30° to the rays from the light source arriving from below.
Remark: I know that a Doppler effect is observed in binary stars, which can actually only occur if the light propagates at the speed of light relative to the emitter, not the receiver.

4. The Light Propagation Relative to the Emitter

You can also check whether the light propagates relative to the emitter. To do this, you have to reverse the direction of the rays. The horizontal mirror then becomes the light source. Then you have to attach two inclined mirrors above it, which collide above the center of the horizontal mirror, so that the light falls, as usual, onto the moving mirrors and from there onto a horizontal plate where the emitter used to be. You just have to make sure that coherent rays reach the two moving mirrors.
In order for the rays to collide precisely there, the inclined, rotating mirrors must be tilted slightly more than 15° when at rest, so that the rays no longer point exactly vertically downwards, but rather slightly toward the center. If changes in the interference then occur on the lower mirror, when the other mirrors rotate faster, the light propagation depends on the emitter. The emitter is now the two rotating mirrors. It is assumed that the path from the new light source to them is short, so it plays no role compared to the long path from the two mirrors to the lower mirror, which now represents the receiver where the emitter was previously located