the general science journal

Michelson's Repetition of the Fizeau Experiment:

A Review of the Derivation and Confirmation of Fresnel's Drag Coefficient

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***Abstract*:**

In this investigation, Michelson's *1886* repetition of the Fizeau experiment is briefly reviewed. And several derivations of the Fresnel's drag coefficient are presented and analyzed in detail. In addition, it's demonstrated that although the search for measurable changes, due to refraction, in the values of stellar aberration was the primary motivation for the original derivation of the Fresnel's drag coefficient, no effects of refraction on stellar aberration, in the related cases, are physically possible. And also, it's established that, contrary to the basic assumption of the derivation of Fresnel's drag coefficient by A. Michelson, a prism of glass moving in a straight line and water flowing inside stationary brass tubes are neither identical nor, kinematically, equivalent to each other; since the latter always exhibits variations in mass depending on the direction of incident light; while the former does not show any variations at all. And finally, it's pointed out, in the current investigation, that the Larmor-Lorentz theory, the special theory of relativity, and the new-source emission theory face theoretical difficulties in explaining away the reported result of the Fizeau experiment. And that is because the three physical theories, in question, must take it for granted that the speed of refracted

light, as measured in the reference frame of the flowing water, is equal to the speed of light in vacuum *c* divided by the refractive index of water *n*; i.e., *c/n*. Otherwise, the Fresnel drag coefficient cannot be derived on the basis of those three physical theories. That is on one hand. On the other hand, the assumption of *c/n* is clearly inconsistent with the experimental result reported by H. Fizeau and A. Michelson, which implies necessarily that the speed of refracted light, as measured in the reference frame of the flowing water, is always equal to $(c/n \pm v/n^2)$.

Keywords:

Fizeau experiment; Fresnel's drag coefficient; index of refraction; aether; Michelson's *1886* experiment; fringe displacement; moving refractive media; density ratio; inverse ratio; classical wave theory; Larmor-Lorentz theory; special relativity; new-source emission theory; elastic-impact emission theory.

Introduction:

The main objective of the original Fizeau water-tube experiment and its repetition by A. Michelson was to test and to verify experimentally the prediction of the Fresnel drag coefficient [***Ref. #3***].

Historically, the aether drag coefficient was initially derived by Augustin-Jean Fresnel in *1818*, on the basis of the classical wave theory of light, in an attempt to explain away, in a satisfactory manner, the negative result of Arago's experiment [***Ref. #10***].

The Arago experiment was based upon the supposition that a prism of glass on the surface of the moving earth should produce numerical values for light aberration noticeably different from those measured through the earth's atmosphere.

The very same supposition was, also, the stated rationale for the water-filled-telescope observations by G. B. Airy in *1870*; although this time around, the expected numerical values for light aberration, in the wake of L. Foucault's *1850* discovery [***Ref. #9***] that light travels through water at a considerably reduced speed and much less than that of light traveling through air, were more definitive. But once again, the experimental result was negative [***Ref. #7***].

In addition, the basic reasoning, behind carrying out the latter water-filled-telescope experiment, was much clearer and more solid, from theoretical viewpoint, than that of the former experiment by F. Arago, who really didn't know exactly what to expect, because he wasn't really sure whether light travels faster or slower in glass than it does in air:

The speed of light in water, according to L. Foucault, is c_w:

$$c_w = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

And, by using a telescope without water, light aberration $\Delta\beta$ is:

$$\sin \Delta\beta = \frac{v}{c} \sin \beta$$

where β is the angle between the apparent position of the light source and the orbital velocity vector of the earth v; and c is the speed of light in free space.

And therefore, G. B. Airy expected that, by using a telescope filled with water, the value of light aberration $\Delta\beta$ in free space should change to the much higher value of light aberration in water $\Delta\beta_w$:

$$\sin \Delta\beta_w = \frac{v}{c_w} \sin \beta = \frac{nv}{c} \sin \beta$$

where n is the refractive index.

However, a crucial requirement, for observing the predicted result, wasn't pointed out explicitly in the above calculations; and hence, the null result of Arago's experiment as well as the null result of Airy's experiment were officially deemed, at that time, unsuccessful.

The missing requirement was, of course, the sequencing order of the two effects of the process of refraction and the process of light aberration, in the case under discussion, on the incident light.

If the incident light is shifted by the process of light aberration, according to the law of light aberration, firstly; and then that shifted light is refracted by the process of refraction, according to Snell's law, secondly, then no changes in the values of light aberration, caused by refraction, can be observed.

That is because the process of refraction, in this particular case, takes the direction of incident light, which is already shifted by the process of light aberration, at the entrance point of the prism or the water-filled telescope, as its main input; and then refracts it in accordance with the Snell's law.

As a result, whenever the data reduction procedures, as mandated in experiments like these, are applied to the raw observational data, and the angle of refraction is taken out, the remaining directional angle is necessarily the apparent position of the star with respect to the line of sight, to which the telescope is pointed and set from the start along its direction in the first place.

By contrast, if the incident light is refracted by the process of refraction, according to the Snell's law, firstly; and then that refracted light is shifted by the process of light aberration, according to the law of light aberration, secondly, then the expected changes in the values of light aberration, as predicted by the calculations above, can be observed.

Now, what is the right astronomical setting, in which the computed prediction above can be obtained by using, for example, the Airy's water-filled telescope?

Believe it or not, the only astronomical setting, in which this predicted value for light aberration $\Delta\beta_w$:

$$\sin \Delta\beta_w = \frac{v}{c_w} \sin \beta = \frac{nv}{c} \sin \beta$$

can be measured, by using Airy's water-filled telescope, is a hypothetical galactic system, in which the entire earth and all of the distant stars, in question, are located completely immersed together inside one single galactic ocean of fresh water!

In such a highly unlikely setting, it's certainly possible for starlight to be refracted first by the fresh water of the galactic ocean; and then to be shifted second by the process of light aberration due to the orbital motion of the earth around the barycenter of the solar system.

Because of the incorrect and somewhat misleading way, in which light aberration was and is still interpreted in accordance with the classical wave theory, however, F. Arago and G. Airy were entirely justified in expecting to obtain positive results in their experiments.

Light aberration, and especially stellar aberration, on the basis of the classical wave theory, is assumed to be caused by the small displacement that the moving earth makes, during the very short interval of light travel time from the top to the bottom of the observational telescope; i.e., the incident light is firstly refracted and then shifted secondly by light aberration upon traversing the whole length of the measuring telescope.

But, of course, light aberration, in reality, is just the direction of the relative velocity resultant of the velocity vector of incident light and the orbital velocity vector of the earth, regardless of the distance between the objective lens and the eyepiece lens or the actual length of the telescope; and hence no positive results are expected to be obtained by Arago's experiment or by Airy's experiment.

1.   Michelson's Repetition of the Fizeau Experiment:

In this replication of the Fizeau experiment, by A Michelson, brass tubes of *2.8 cm* (internal diameter) are mounted on a wooden support; and the refractometer is mounted on brick piers.

Distilled water flows into the brass tubes, through a three inch pipe, from a filled tank placed about *23* meters above the apparatus.

A light beam from an electric lamp at a is divided to two parts by a half-silvered mirror at b, where one part traverses the path $b\ c\ d\ e\ f\ b\ g$ and the other parts traverses the path $b\ f\ e\ d\ c\ b\ g$.

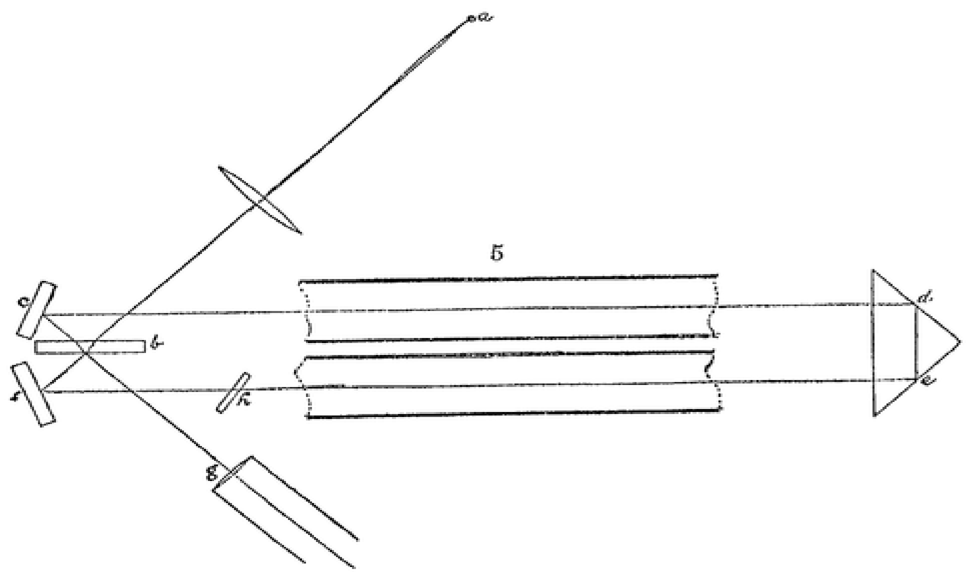

Figure #1: Refractometer

The two parts of the light beam, upon unification, form fringe patterns, which are observed through a telescope; where the following result is obtained:

$$\frac{n^2 - 1}{n^2} = 0.437$$

which is the result obtained in this experiment.

And therefore, A. Michelson has concluded that the result announced by H. Fizeau is essentially correct [***Ref. #1***].

2. Michelson's Derivation of the Fresnel Drag Coefficient:

According to A. Michelson, the Fresnel drag coefficient:

$$x = \frac{n^2 - 1}{n^2}$$

can be derived, on the basis of the aether wave theory, as follows:

Assume that the prism, *AC* in the *Figure #2*, is in motion relative to the aether in the direction *AB* with a uniform velocity *v*.

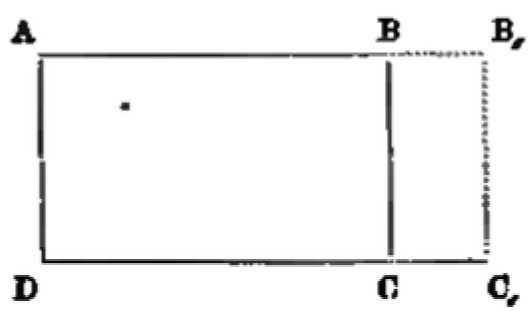

Figure #2: Prism

And assume that the density of the external aether is *1*; and the density of the aether, within the prism, is $1+\Delta$.

In the time *t*, the prism advances a distance:

$$vt = BB'$$

At the beginning of that time, the quantity of aether in the volume BC is:

$$Svt$$

where S is the surface area of the base of the prism.

And at the end of that time, the aether quantity is:

$$Svt(1+\Delta)$$

And hence, in this time, the quantity of aether introduced into this volume is:

$$Svt\Delta$$

Let the velocity of the aether contained in the prism be *xv;* and hence, the quantity of the aether is:

$$Sxvt(1+\Delta)$$

which is the same as:

$$Svt\Delta$$

and accordingly,

$$x = \frac{\Delta}{1+\Delta}$$

But the ratio of the velocity of light in the external ether to that within the prism is the index of refraction n, which is equal to the inverse ratio of the square root of the densities:

$$n = \sqrt{1+\Delta}$$

and therefore,

$$x = \frac{n^2 - 1}{n^2}$$

which is the Fresnel drag coefficient.

Undoubtedly, the above derivation of the Fresnel coefficient by A. Michelson, on the basis of the aether assumption, is very concise and simple.

Nonetheless, there are, obviously, significant differences between the moving prism, upon which Michelson's derivation of the Fresnel drag coefficient is based, and the flowing water inside stationary tubes of brass in his experimental setup, by which the reported result is obtained:

1. The refractive medium of flowing water, inside the stationary brass tubes, forms a continuous loop, in which a specific amount of water per unit time enters each brass tube through one end, and an equal amount of water per unit time exists each brass tube from the other end.

2. The refractive medium of glass inside the prism is moving as a single unit whose amount remains, at all times, constant and the same.

3. When the moving water, inside one of the stationary brass tubes, approaches light from a stationary light source, its actual amount, traversed by the incident light throughout the brass tube, increases linearly in direct proportion to the speed of its flow inside that brass tube.

4. When the moving prism approaches light from a stationary light source, the actual amount of its glass, traversed by the incident light throughout the prism, remains constant and exactly the same regardless of the speed of that prism.

5. When the moving water, inside one of the stationary brass tubes, recedes from light emitted by a stationary light source, its actual amount, traversed by the incident light throughout the brass tube, decreases linearly in inverse proportion to the speed of its flow inside that brass tube.

6. When the moving prism recedes from light emitted by a stationary light source, the actual amount of its glass, traversed by the incident light throughout the prism, remains constant and exactly the same regardless of the speed of that prism.

7. The only major shared characteristics that the moving prism and the flowing water, inside the stationary brass tubes, have in common, are the decrease in the length of the mean free path, upon approaching the stationary light source, in inverse proportion to the speed of approach;

and the increase in the length of the mean free path, upon receding from the stationary light source, in direct proportion to the speed of recession.

At first glance, therefore, it appears highly unlikely for the flowing water into the brass tubes of Michelson's experimental apparatus, and the moving prism of glass in his theoretical derivation, to have the same factor for the Fresnel drag coefficient, which is equal exactly to:

$$x = \frac{n^2 - 1}{n^2}$$

where n stands for the refractive index of water and the refractive index of glass, respectively.

And the main reason for that, evidently, is the variation in the amount of the flowing water inside the brass tubes, depending on the direction of incident light.

So, now, is Michelson's derivation of the Fresnel drag coefficient theoretically incorrect?

The answer to this question depends, entirely, on the physical mechanism behind the process of refraction in refracting media in general, and in the refracting medium of flowing water and the refracting medium of glass in particular.

But before any attempt at answering the above question, we have to make sure first and to demonstrate, quantitatively, that the amount of the flowing water, inside the stationary brass tubes, does vary, indeed, with the direction of its velocity vector with respect to incident light.

3. Water Mass Variations in Fizeau-Type Experiments:

Since in the above-described Michelson's experiment as well as in the original Fizeau experiment, water flows through stationary tubes relative to the laboratory, its mass varies necessarily with the direction of its velocity vector with respect to incident light.

To demonstrate that is indeed the case, let's assume that the length of the brass tube is L; and the area of its cross section is A.

When the experimental water is at rest relative to the laboratory, its total mass M_0, inside the brass tube, is given by the following equation:

$$M_0 = \rho L A$$

where ρ is the density of water.

But when the experimental water is moving relative to the laboratory at a velocity v, a certain amount of water per unit time continually exists the brass tube from one end; and at the same time, an equal amount of water per unit time continually enters the brass tube from the other end.

And therefore, if the travel time of incident light, through the brass tube, is t, then the amount of water that exists the brass tube, during that time, as well as the equal amount that enters it, can be obtained by using this equation:

$$\Delta M = \rho A v t$$

where ΔM is the variable amount of water.

Accordingly, incident light that takes an interval of time t to travel through the brass tube in the opposite direction of the approaching water, must encounter a total amount of water equal to M_A, before emerging from the other end of the brass tube:

$$M_A = M_0 + \Delta M = M_0 + \rho A v t$$

where A is the inner area of the cross section of the brass tube.

By contrast, incident light that takes an interval of time t to travel through the brass tube in the same direction as that of the receding water, must encounter a total amount of water equal to M_R, before exiting from the other end of the brass tube:

$$M_R = M_0 - \Delta M = M_0 - \rho A v t$$

where ρ stands for the density of water.

The similarity between the variations in the amount of flowing water, as computed here, and the variations in the amount of dragged aether, as calculated by A. Michelson in his aforementioned derivation of the Fresnel drag coefficient, from theoretical standpoint, is striking and intriguing.

Presumably, if the above variations in the amount of flowing water are used to obtain corresponding variations in the amount of free space inside each brass tube; and then the aether density is replaced with the space density, inside and outside the brass tubes, then an aether-free derivation of this factor of the Fresnel drag coefficient can be readily obtainable:

$$x = \frac{n^2 - 1}{n^2}$$

where n is the refractive index.

4. The Physical Mechanisms of Refraction:

In the published literature, there are two proposed physical mechanisms for determining the behavior of electromagnetic radiation traveling through refracting media:

I. The Absorption-Re-emission Mechanism:

According to this physical mechanism, incident light is absorbed and re-emitted continually by the particles of the refractive medium, in question.

Statistically, the free space, between each two adjacent particles of the refractive medium, is the mean optical path, through which light, from a stationary light source, always travels at its incident speed c.

It follows, therefore, that, through the refractive medium, the speed of light c':

$$c' = \frac{c}{n}$$

is entirely apparent and due mainly to the integrated time delay of absorption and re-emission of incident light throughout the refractive medium.

And subsequently, on the basis of this physical mechanism, the Fresnel drag coefficient:

$$x = \frac{n^2 - 1}{n^2}$$

is nothing more than the apparent speeding up and the apparent slowing down of incident light due to the total sum of the small displacements, each of which is made by every refractive particle during the short interval of time between the process of absorption and the process of re-emission of incident light.

And the question, once again, is this:

Is, in this case, the above-mentioned Michelson's derivation of the Fresnel drag coefficient incorrect?

Since the number of refractive particles, in the case of the moving glass prism, is constant, regardless of the direction of incident light; and since the number of refractive particles, in the case of the flowing water, is highly variable and dependent on the direction of the flowing water with respect to the incident light, then it should follow that the above Michelson's derivation of the Fresnel drag coefficient is definitely incorrect, on the basis of the absorption-re-emission mechanism.

By how much is the Fresnel drag coefficient for the moving glass prism x_g is quantitatively different from the experimentally obtained value of the Fresnel drag coefficient for the flowing water x?

The factor of the Fresnel drag coefficient for the moving glass prism x_g has, of course, to be obtained by experimental means.

However, based on the experimental result, obtained by Michelson and Fizeau, regarding the factor of the Fresnel drag coefficient for the flowing water x:

$$x = \frac{n^2 - 1}{n^2}$$

it can be deduced, to a reasonable degree of certainty, that, putting the different numerical values of n in these two cases aside, the factor of the Fresnel drag coefficient for the moving glass prism x_g ought to be less than that for the flowing water, if the absorption-re-emission mechanism is physically true; i.e.,

$$x_g < \frac{n^2 - 1}{n^2}$$

in the case of approach and in the case of recession, respectively, even though the refractive index of glass n_g is greater than the refractive index of water n_w.

Now, is there any practical way, by which the Michelson's moving prism of glass can be made equivalent kinematically to Fizeau's flowing water?

Certainly, if Michelson's moving prism of glass is transformed somehow into a rotating circular disc of glass, then the refracting medium of rotating glass, in this case, will be kinematically equivalent, in every respect, to the refracting medium of flowing water.

Also, if a brass tube filled with stationary water is moved in a straight line at a velocity v, then the refracting medium inside the moving prism, in this case, will be kinematically equivalent, in every respect, to the refracting medium inside the moving tube.

II. The Deposited-Momentum Mechanism:

According to this mechanism, incident light gives away a certain amount of its momentum to the refractive medium, upon entering; and takes it back upon existing that refractive medium.

And therefore, the speed of light, through the refractive medium, c':

$$c' = \frac{c}{n}$$

is the actual speed of incident light throughout the refractive medium, which is necessarily reduced because of the reduced momentum of incident light inside the refractive medium.

And consequently, on the basis of this physical mechanism, the following Fresnel drag coefficient:

$$x = \frac{n^2 - 1}{n^2}$$

is merely the manifestation of the actual speeding up and the actual slowing down of incident light due to small variations in its momentum depending on the direction of its velocity vector with respect to the velocity vector of the refracting medium.

So, once again, is the above-mentioned Michelson's derivation of the Fresnel drag coefficient theoretically incorrect?

Since the variations in the speed of light, through the refractive medium, are collectively caused by variations in its momentum with respect to the velocity vector of the refractive medium, and completely independent of the actual number of the refracting particles, it follows that the above-mentioned Michelson's derivation of the Fresnel drag coefficient is definitely correct; and hence the flowing water and the moving glass prism should have the same factor of the Fresnel drag coefficient:

$$x = \frac{n^2 - 1}{n^2}$$

in accordance with the deposited-momentum mechanism.

5. Replacing the Aether with Vacuum in Michelson's Derivation:

The aforementioned variations, in the amount of water flowing through stationary tubes relative to the laboratory, with the direction of its velocity vector with respect to incident light, lead naturally to a simple modification of Michelson's derivation of the Fresnel drag coefficient.

Because the volume of the brass tubes remains constant, the variations in the quantity of flowing water, with the direction of incident light, imply, necessarily, that the amount of free space, covered by the incident light inside each brass tube, varies inversely with the variations in the amount of the flowing water. In other words, when the amount of flowing water increases, the amount of free space decreases. And, by contrast, when the amount of flowing water decreases, the amount of free space, inside each brass tube, increases; i.e.,

$$q_v \propto \frac{1}{q_w}$$

where q_w is the quantity of flowing water; and q_v is the quantity of free space.

It's, therefore, theoretically permissible, to replace the variations in the quantity of aether q_a, in the original Michelson's derivation of the Fresnel drag coefficient, with the variations in the quantity of free space q_v, in order to use the refractive index of vacuum in exactly the same way as A. Michelson used the refractive index of aether to derive the Fresnel drag coefficient.

Let's assume that L denotes the length of the stationary tube; A denotes the area of the cross section of the brass tube; v denotes the velocity of the flowing water; and ρ denotes the density of water.

When the flowing water is approaching directly the stationary light source, its total amount q_w is given by this equation:

$$q_w = q_0 + \Delta q_w$$

where q_0 is defined in accordance with this equation:

$$q_0 = \rho A L$$

and where Δq_w is calculated by using the following equation:

$$\Delta q_w = \rho A v t$$

and where t is the travel time of light through the brass tube.

And since the quantity of free space q_v varies with the quantity of water q_w in accordance with the following quantitative relation:

$$q_v \propto \frac{1}{q_w}$$

it follows, accordingly, that, when the flowing water approaches directly the stationary light source, the quantity of free space q_v inside the brass tube, decreases as given by this equation.

$$q_v = q_{v0} - \Delta q_v$$

where q_{v0} is the quantity of free space in a brass tube filled with stationary water.

And since the velocity ratio of light, according to the aforementioned Michelson's rule, is inversely proportional to the square root of the density ratio; i.e.,

$$x = \frac{\Delta}{1 + \Delta}$$

we can use, here, the quantity ratio of free space:

$$x_v = \frac{\Delta q_v}{q_{v0} - \Delta q_v}$$

to obtain the speed of light c'_n through the brass tube:

$$c_n' = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the flowing water; and n is the refractive index.

Likewise, when the flowing water is receding directly from the stationary light source, its total amount q_w with respect to the incident light is given by this equation:

$$q_w = q_0 - \Delta q_w$$

where q_0 is:

$$q_0 = \rho AL$$

and where Δq_w is:

$$\Delta q_w = \rho Avt$$

and where t is the travel time of light through the brass tube.

And since the quantity of free space q_v varies with the quantity of water q_w in accordance with this relation:

$$q_v \propto \frac{1}{q_w}$$

it follows that, when the flowing water recedes directly from the stationary light source, the quantity of free space q_v inside the brass tube, is given by this equation:

$$q_v = q_{v0} + \Delta q_v$$

where q_{v0} is the quantity of free space in a brass tube filled with stationary water.

And since, the velocity ratio of light in vacuum to that within the receding water is equal to the square root of the quantity ratio of free space:

$$x_v = \frac{\Delta q_v}{q_{v0} + \Delta q_v}$$

it's possible to obtain the speed of light c'_n in the receding refractive medium of flowing water, inside the brass tube:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the flowing water; and n is the refractive index.

Unlike the previous Michelson's derivation, however, this current derivation of the Fresnel drag coefficient is correct, if and only if the absorption-re-emission mechanism is true.

6. Theoretical Predictions:

Although the Fresnel drag coefficient applies only to the special case of refraction, in which the light source is at rest and the refractive medium is in motion, with respect to the stationary reference frame of the laboratory, a brief survey of other related cases of refraction is necessary for clarifying its kinematic and physical aspects in general, and for checking for whether or not its various interpretations, on the basis of several physical theories, are internally consistent.

I. The Predictions of the Classical Wave Theory:

Only these two predictions of the classical wave theory, with regard to the speed of light in refracting media, have been experimentally verified:

- The speed of light emitted by a stationary light source through a refracting medium at rest with respect to the stationary reference frame of the laboratory.

- And the speed of light emitted by a stationary light source through a refracting medium in motion with respect to the stationary reference frame of the laboratory.

1. The Light Source and the Refractive Medium at Rest:

If the light source, outside or inside a refractive medium at rest, is stationary in the reference frame of the laboratory, then the speed of its light inside that refractive medium c_n, as predicted by the classical wave theory, can be obtained through the use of this standard equation:

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

2. The Light Source in Motion and the Refractive Medium at Rest:

When the light source is in motion and the refractive medium is at rest, in the reference frame of the laboratory, the speed of light c_n through the stationary refractive medium, according to the classical wave theory, remains unchanged and the same as in the stationary case; i.e.,

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

That is because light, on the basis of this theory, does not inherit the velocity of its moving source.

3. The Light Source at Rest and the Refractive Medium in Motion:

When the light source is at rest and the refracting medium is in motion, the classical wave theory makes two different predictions, in the reference frame of the refracting medium and in the reference frame of the laboratory, respectively. However, only the latter prediction has been tested experimentally by the Fizeau experiment and its repetition by A. Michelson.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a stationary light source, through the moving refractive medium, according to the classical wave theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

for the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the stationary reference frame of the laboratory, when the light source is at rest and the refractive medium is in motion, the speed of its light c'_n through the refractive medium, according to the classical wave theory, is calculated, in the case of approach, by using this equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And likewise, the speed of light from a stationary light source c'_n inside a receding refractive medium is computed by using the following equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where n is refractive index.

4. The Light Source and the Refractive Medium Moving with the Same Velocity:

Although, in the surveyed literature, there is no mention of any specific equations for the special case of a light source and a refractive medium moving together with the same speed in the same direction relative to the laboratory, it's possible, from theoretical standpoint, to work out the details of computing the speed of light c'_n through the refractive medium, on the basis of the classical wave theory, in these two frames of reference, respectively:

In the Reference Frame of the Light Source and the Refractive Medium:

In the reference frame, in which the light source and the refractive medium are at rest, the speed of light c'_n through the refractive medium, can be calculated in accordance with the following equation:

$$c'_n = \frac{c}{n}$$

regardless of whether the light source is outside or inside the refractive medium.

And that is because the numerical value of the velocity of the refracting medium with respect to the light source, in this special case, is always equal to zero.

However, because the whole system, on the basis of this theory, is moving relative to the universal medium called '*Aether*', the second-order effects, which the Michelson-Morley experiment has been designed to look for, should be amplified further, in this particular case, by an additional factor equals to the refractive index n.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the classical wave theory, has to be calculated by using the standard equations of the Fresnel drag coefficient.

And that is clearly because the motion of the light source has no effect at all on the speed of light, within the framework of this theory.

Therefore, in the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the classical wave theory, is calculated by using this equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the refractive medium is trailing the light source.

And in accordance with this equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the light source is trailing the refractive medium.

5. The Light Source and the Refractive Medium in Motion:

Even though the published literature does not contain any mathematical formulas for the special case of a light source and a refractive medium in motion relative to each other as well as with respect to the laboratory, it's relatively easy, from theoretical viewpoint, to work out the details of calculating the speed of light c'_n through the refractive medium, in accordance with the classical wave theory.

Let's assume that v_s is the velocity of the light source; and v_m is the velocity of refractive medium, with respect to the stationary reference frame of the laboratory.

Since, within the framework of the classical wave theory, the velocity of the light source has no effect on the velocity of its light, we neglect the velocity of the source v_s completely, and take into consideration only the velocity of the refractive medium v_m, in computations done in the reference frame of the refractive medium and in the reference frame of the laboratory, correspondingly.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, whether the light source is at rest or in motion, through the refractive medium, according to the classical wave theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n} + \frac{v_m}{n^2}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n} - \frac{v_m}{n^2}$$

for the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, whether the light source is in motion or at rest, when the refractive medium is in motion, the speed of light c'_n through the refractive medium, according to the classical wave theory, is calculated, in the case of approach, by using the following equation:

$$c'_n = \frac{c}{n} - v_m\left(1 - \frac{1}{n^2}\right)$$

where v_m is the speed of the refractive medium with respect to the laboratory.

And in the same way, the speed of light c'_n inside a receding refractive medium is computed by using this equation:

$$c'_n = \frac{c}{n} + v_m\left(1 - \frac{1}{n^2}\right)$$

where n is refractive index.

The Classical Wave Theory and the Result of the Fizeau Experiment:

In the case of a stationary light source and an approaching refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with this equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

Accordingly, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the approaching refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

where n is the index of refraction.

And likewise, in the case of a stationary light source and an receding refractive medium, the original Fizeau experiment as well as the Michelson's repetition have confirmed that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is according to this equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And so, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the receding refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

where n is the index of refraction.

The classical wave theory predicts that in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the moving refractive medium, is according to this equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

in the case, in which the refractive medium is approaching the stationary light source;
and in accordance with this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

in the case, in which the refractive medium is receding from the stationary light source.

And it follows, therefore, that the classical wave theory is consistent with the experimental result obtained by H. Fizeau and A. Michelson.

II. The Predictions of the Larmor-Lorentz Theory:

The Larmor-Lorentz theory makes several predictions, with regard to the speed of light in refractive media; but only these two predictions have been verified experimentally:

- The speed of light emitted by a stationary light source through a refractive medium at rest with respect to the stationary reference frame of the laboratory.
- And the speed of light emitted by a stationary light source through a refractive medium in motion with respect to the stationary reference frame of the laboratory.

1. The Light Source and the Refractive Medium at Rest:

If a light source, outside or inside a refractive medium at rest, is stationary in the reference frame of the laboratory, then the speed of its light inside that refractive medium c_n, as predicted by the Larmor-Lorentz theory, can be obtained through the use of this standard equation:

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

2. The Light Source in Motion and the Refractive Medium at Rest:

When the light source is in motion and the refractive medium is at rest, in the reference frame of the laboratory, the speed of light c_n through the refractive medium, on the basis of the Larmor-Lorentz theory, remains unchanged and the same as in the stationary case; i.e.,

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

That is because, according to the Larmor-Lorentz theory, the motion of the light source has no effect at all on the velocity of its light.

3. The Light Source at Rest and the Refractive Medium in Motion:

When the light source is at rest and the refracting medium is in motion, the Larmor-Lorentz theory makes two different predictions, in the reference frame of the refracting medium and in the reference frame of the laboratory, respectively; but, only the latter has been tested experimentally by the Fizeau experiment and its repetition by A. Michelson.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n through the refractive medium, according to the Larmor-Lorentz theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is receding from the light source.

That is because, within the framework of this theory, the speed of light, in the reference frame of the refracting medium, must be assumed first to be constant and exactly equal to:

$$c'_n = \frac{c}{n}$$

in those two cases, in order to derive the Fresnel drag coefficient for the experimentally verified case in the stationary reference frame of the laboratory.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, according to the Larmor-Lorentz theory, when the light source is at rest and the refractive medium is in motion, the speed of light c'_n through the moving refractive medium, is calculated, in the case of approach, by using the following equation:

$$c'_n = \frac{c}{n}\left(\frac{1 - v^2/c^2}{1 + v/nc}\right) \approx \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the approaching refractive medium with respect to the stationary light source in the reference frame of the laboratory; and n is the refractive index.

And, in the same way, the speed of light from a stationary light source c'_n inside a receding refractive medium is computed by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1-v^2/c^2}{1-v/nc}\right) \approx \frac{c}{n} + v\left(1-\frac{1}{n^2}\right)$$

where v is the velocity of the receding refractive medium with respect to the stationary light source in the reference frame of the laboratory; and n is the refractive index

4. The Light Source and the Refractive Medium Moving at the Same Velocity:

Although the published literature, concerning the Larmor-Lorentz theory, contains no specific equations for the special case of a light source and a refractive medium moving together with the same speed in the same direction relative to the laboratory, it's possible, theoretically, to work out the calculations of the speed of light c'_n through the refractive medium, on the basis of this theory, in these two frames of reference, correspondingly:

In the Reference Frame of the Light Source and the Refractive Medium:

According to the Larmor-Lorentz theory, in the reference frame, in which the light source and the refractive medium are at rest, the speed of light c'_n through the refractive medium, can be calculated in accordance with the following equation:

$$c'_n = \frac{c}{n}$$

regardless of whether the light source is inside or outside of the refractive medium.

Nonetheless, because the light source and the refractive medium, on the basis of the Larmor-Lorentz theory, are moving relative to the universal medium named '*Aether*', the second-order effects, which the Michelson-Morley experiment has been designed to measure, are expected to be magnified further, in this particular case, by an additional factor equals to the refractive index n. And as a result, the postulated length contraction, within the framework of this theory, may not be adequate, without further adjustments, for explaining away the null results of the Michelson-Morley experiment and similar experiments.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the Larmor-Lorentz theory, should be calculated through the use of the Fresnel drag coefficient. That is because the motion of the light source has no effect at all on the speed of light, within the framework of this theory.

And subsequently, in the reference frame of the laboratory, the speed of its light c'_n through the refractive medium, according to the Larmor-Lorentz theory, is calculated by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1-v^2/c^2}{1+v/nc}\right) \approx \frac{c}{n} - v\left(1-\frac{1}{n^2}\right)$$

in the case, in which the refracting medium is trailing the light source.

And in accordance with equation:

$$c'_n = \frac{c}{n}\left(\frac{1-v^2/c^2}{1-v/nc}\right) \approx \frac{c}{n} + v\left(1-\frac{1}{n^2}\right)$$

in the case, in which the light source is trailing the refracting medium.

5. The Light Source and the Refractive Medium in Motion:

In spite of the fact that, in the published literature, there is no mention of any specific equations for the special case of a light source and a refracting medium in motion relative to each other as well as relative to the laboratory, it's quite easy, from theoretical standpoint, to work out the details of computing the speed of light c'_n through the refractive medium, on the basis of the Larmor-Lorentz theory.

With respect to the stationary reference frame of the laboratory, let v_s denote the velocity of the light source; and v_m denote the velocity of refractive medium.

Since, within the framework of the Larmor-Lorentz theory, the velocity of the light source has no effect on the velocity of light, we neglect the velocity of the source v_s altogether, and take into account only the velocity of the refractive medium v_m, in calculations carried out in the reference frame of the refractive medium and the reference frame of the laboratory, respectively.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, through the refractive medium, according to the Larmor-Lorentz theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, whether the light source is in motion or at rest, when the refractive medium is in motion, the speed of light c'_n through the refractive medium, according to the Larmor-Lorentz theory, is calculated, in the case of approach, by using the following equation:

$$c'_n = \frac{c}{n}\left(\frac{1 - {v_m}^2/c^2}{1 + v_m/nc}\right) \approx \frac{c}{n} - v_m\left(1 - \frac{1}{n^2}\right)$$

where v_m is the speed of the refractive medium with respect to the laboratory.

And similarly, the speed of light c'_n inside a receding refractive medium is computed by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1 - v^2/c^2}{1 - v/nc}\right) \approx \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where n is refractive index.

<u>The Larmor-Lorentz Theory and the Result of the Fizeau Experiment:</u>

In the case of a stationary light source and an approaching refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is always in accordance with this equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the approaching refractive medium with respect to the stationary light source in the reference frame of the laboratory.

Accordingly, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

where n is the index of refraction.

And in a like manner, in the case of a stationary light source and a receding refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with this equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the receding refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And subsequently, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the approaching refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with the following equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

where n is the index of refraction.

The Larmor-Lorentz theory predicts that in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is according to this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is approaching the stationary light source;
and in accordance with this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is receding from the stationary light source.

And it follows, therefore, that the Larmor-Lorentz theory is inconsistent with the experimental result obtained by Fizeau and Michelson.

III. The Predictions of Einstein's Special Theory:

The special theory of relativity makes a number of predictions, with regard to the speed of light in refractive media; but only two predictions, of which, have been tested experimentally:

- The speed of light emitted by a stationary light source through a refractive medium at rest with respect to the stationary reference frame of the laboratory.

- And the speed of light emitted by a stationary light source through a refractive medium in motion with respect to the stationary reference frame of the laboratory.

1. The Light Source and the Refractive Medium at Rest:

If the light source, outside or inside a refractive medium at rest, is stationary in the reference frame of the laboratory, then the speed of its light through that refractive medium c_n, as predicted by Einstein's special theory, can be obtained by using the following standard equation:

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

2. The Light Source in Motion and the Refractive Medium at Rest:

When the light source is in motion and the refractive medium is at rest, in the reference frame of the laboratory, the speed of light c_n through the refractive medium, according to Einstein's theory of relativity, remains unchanged and the same as in the stationary case; i.e.,

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

And that is because, within the framework of the special theory of relativity, the motion of the light source has no effect whatsoever on the velocity of its light.

3. The Light Source at Rest and the Refractive Medium in Motion:

When the light source is at rest and the refracting medium is in motion, the special theory of relativity makes two different predictions, in the reference frame of the refracting medium and in the reference frame of the laboratory, respectively; but only the latter prediction has been confirmed experimentally by the Fizeau experiment and its replication by A. Michelson.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a stationary light source, through the refractive medium, according to the special theory of relativity, can be calculated by using the following equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is approaching the light source;

and by using this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is receding from the light source.

And that is because, within the framework of this theory, the speed of light, in the reference frame of the refractive medium, must be assumed first to be constant and exactly equal to:

$$c'_n = \frac{c}{n}$$

in those two secondary cases, in order to derive the Fresnel drag coefficient for the primary case in the stationary reference frame of the laboratory.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, in accordance with Einstein's special theory, when the light source is at rest and the refractive medium is in motion, the speed of its light c'_n through the refractive medium, is calculated, in the case of approach, by using the following equation:

$$c'_n = \frac{c}{n}\left(\frac{1 - nv/c}{1 - v/nc}\right) \approx \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the approaching refractive medium with respect to the stationary light source in the reference frame of the laboratory; and n is the refractive index.

Similarly, the speed of light from a stationary light source c'_n inside a receding refractive medium is computed by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1 + nv/c}{1 + v/nc}\right) \approx \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the receding refractive medium with respect to the stationary light source in the reference frame of the laboratory; and n is the refractive index.

4. The Light Source and the Refractive Medium Moving at the Same Velocity:

Even though, in the published literature, there are no specific mathematical formulas for the special case of light sources and refractive media moving together with the same speed in the same direction relative to the laboratory, it's possible, from theoretical standpoint, to work out the computations of the speed of light c'_n through any refractive medium, on the basis of the theory of special relativity, in these two frames of reference, respectively:

In the Reference Frame of the Light Source and the Refractive Medium:

According to the special theory of relativity, in the reference frame, in which the light source and the refractive medium are at rest, the speed of light c'_n through the refractive medium, can be calculated in accordance with the following equation:

$$c'_n = \frac{c}{n}$$

regardless of whether the light source is inside or outside the refractive medium.

Nevertheless, the second-order effects, which the Michelson-Morley experiment has been designed to detect, should be increased further, in this particular case, by an additional factor equals to the refractive index n. And as a result, it's highly likely that the Lorentz transformation, within the framework of this theory, may not, without further adjustments, be able to account for the null results of the Michelson-Morley experiment and similar experiments.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the theory of special relativity, should be calculated through the use of the Fresnel drag coefficient. And that is because the motion of the light source has no effect at all on the speed of light, within the framework of this theory.

And hence, in the reference frame of the laboratory, the speed of its light c'_n through the refractive medium, according to the theory of special relativity, is computed by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1 - nv/c}{1 - v/nc}\right) \approx \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the refractive medium is trailing the light source.

And in accordance with the following equation:

$$c_n' = \frac{c}{n}\left(\frac{1+nv/c}{1+v/nc}\right) \approx \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the light source is trailing the refractive medium.

5. The Light Source and the Refractive Medium in Motion:

Although, in the published literature, on this theory, there is no mention of any specific equations for the special case of a light source and a refractive medium in motion relative to the laboratory, it is not difficult, from theoretical standpoint, to work out the details of computing the speed of light c'_n through the refractive medium, on the basis of Einstein's special theory of relativity.

Let v_s stand for the velocity of the light source; and v_m stand for the velocity of refractive medium, with respect to the stationary reference frame of the laboratory.

Since, within the framework of the special theory of relativity, the velocity of the light source has no effect on the velocity of light, we ignore, here, the velocity of the source v_s entirely, and take into consideration only the velocity of the refractive medium v_m, in all calculations done in the reference frame of the refracting medium and the reference frame of the laboratory, correspondingly.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, through the refractive medium, according to special relativity, can be calculated by using the following equation:

$$c_n' = \frac{c}{n}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c_n' = \frac{c}{n}$$

for the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, whether the light source is in motion or at rest, when the refractive medium is in motion, the speed of light c'_n through the refractive medium, according to the the special theory of relativity, is calculated, in the case of approach, by using the following equation:

$$c'_n = \frac{c}{n}\left(\frac{1-nv_m/c}{1-v_m/nc}\right) \approx \frac{c}{n} - v_m\left(1-\frac{1}{n^2}\right)$$

where v_m is the velocity of the refractive medium with respect to the laboratory.

And likewise, the speed of light c'_n inside a receding refractive medium is computed by using this equation:

$$c'_n = \frac{c}{n}\left(\frac{1+nv_m/c}{1+v_m/nc}\right) \approx \frac{c}{n} + v_m\left(1-\frac{1}{n^2}\right)$$

where n is refractive index.

<u>The Special Theory of Relativity and the Result of the Fizeau Experiment:</u>

In the case of a stationary light source and an approaching refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with the following equation:

$$c'_n = \frac{c}{n} - v\left(1-\frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And therefore, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the approaching refractive medium, is in accordance with the following equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

where n is the index of refraction.

And similarly, in the case of a stationary light source and a receding refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with this equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And accordingly, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the receding refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

where n is the index of refraction.

But Einstein's special theory of relativity predicts that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is according to this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is approaching the stationary light source;
and in accordance with this equation:

$$c_n' = \frac{c}{n}$$

in the case, in which the refractive medium is receding from the stationary light source.

It follows, therefore, that the Einstein's special theory of relativity is inconsistent with the experimental result obtained by Fizeau and Michelson.

IV. The Predictions of the New-Source Emission Theory:

The new-source emission theory makes a number of predictions, with regard to the speed of light in refractive media; but only these two predictions have been tested experimentally:

- The speed of light emitted by a stationary light source through a refractive medium at rest with respect to the stationary reference frame of the laboratory.
- And the speed of light emitted by a stationary light source through a refractive medium in motion with respect to the stationary reference frame of the laboratory.

1. The Light Source and the Refractive Medium at Rest:

If the light source, outside or inside a refractive medium at rest, is stationary in the reference frame of the laboratory, then the speed of its light inside that refractive medium c_n, as predicted by the new-source emission theory, can be obtained through the use of this standard equation:

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

2. The Light Source in Motion and the Refractive Medium at Rest:

When the light source is in motion and the refractive medium is at rest, in the reference frame of the laboratory, the speed of light c_n through the refractive medium, according to the new-source emission theory, remains unchanged and the same as in the stationary case; i.e.,

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

That is because, according to this theory, the stationary refractive medium becomes, through the process of absorption and re-emission, a new source for all incident light regardless of its initial speed and direction.

3. The Light Source at Rest and the Refractive Medium in Motion:

When the light source is at rest and the refracting medium is in motion, the new-source emission theory makes two different predictions, in the reference frame of the refracting medium and in the reference frame of the laboratory, respectively. Nonetheless, only the latter prediction has been verified experimentally by the Fizeau experiment and its repetition by A. Michelson.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a stationary light source, through the refractive medium, according to the new-source emission theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, in accordance with the new-source emission theory, the incident light from a stationary light source is absorbed and dragged to the opposite direction of its propagation and then re-emitted by the approaching refractive medium at a combined speed c'_n:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the approaching refractive medium relative to the stationary light source in the reference frame of the laboratory; and n is the refractive index.

While the incident light from a stationary light source is absorbed and dragged in the same direction of its propagation and then re-emitted by the receding refractive medium at a combined speed c'_n:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the speed of the receding refractive medium relative to the stationary light source in the reference frame of the laboratory; and n is the refractive index.

4. The Light Source and the Refractive Medium Moving at the Same Velocity:

Despite the fact that the published literature, in this regard, contains no specific equations for the special case of a light source and a refractive medium moving together with the same speed in the same direction relative to the laboratory, it's certainly possible, from theoretical standpoint, to work out the details of computing the speed of light c'_n through the refractive medium, according to the new-source emission theory, in these two frames of reference, correspondingly:

In the Reference Frame of the Light Source and the Refractive Medium:

In the reference frame, in which the light source and the refractive medium are at rest, the speed of light c'_n through the refractive medium, can be calculated, on the basis of the new-source emission theory, in accordance with the following equation:

$$c'_n = \frac{c}{n}$$

regardless of whether the light source is inside or outside the refractive medium.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the new-source emission theory, should be calculated by using the Fresnel drag coefficient. And that is because the motion of the light source is neutralized through the process of absorption and re-emission of incident light by the refractive medium; and hence, it has no effect at all on the speed of light, within the framework of this theory.

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the new-source emission theory, is calculated by using this equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the refractive medium is trailing the light source.

And in accordance with the following equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

in the case, in which the light source is trailing the refractive medium.

5. The Light Source and the Refractive Medium in Motion:

Although, in the published literature, there are no mathematical formulas for the special case of a light source and a refractive medium in motion relative to each other and to the laboratory, it's possible, from theoretical viewpoint, to work out the details of calculating the speed of light c'_n through the refractive medium, on the basis of the new-source emission theory.

Let's assume that v_s is the velocity of the light source; and v_m is the velocity of refractive medium, with respect to the stationary reference frame of the laboratory.

Since, within the framework of the new-source emission theory, upon absorption and re-emission by the refractive medium, the velocity of the light source has no effect on the velocity of refracted light, we neglect the velocity of the source v_s completely, and take into consideration only the velocity of the refractive medium v_m in computations carried out in the reference frame of the refractive medium and in the reference frame of the laboratory, respectively:

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a moving light source, through the refractive medium, according to the new-source emission theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n}$$

for the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, whether the light source is in motion or at rest, when the refractive medium is in motion, the speed of light c'_n through the refractive medium, according to the new-source emission theory, is calculated, in the case of approach, by using this equation:

$$c'_n = \frac{c}{n} - v_m\left(1 - \frac{1}{n^2}\right)$$

where v_m is the velocity of the refractive medium with respect to the laboratory.

And likewise, the speed of light c'_n inside a receding refractive medium is computed by using the following equation:

$$c'_n = \frac{c}{n} + v_m\left(1 - \frac{1}{n^2}\right)$$

where n is refractive index.

<u>The New-Source Emission Theory and the Result of the Fizeau Experiment:</u>

In the case of a stationary light source and an approaching refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with the following equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And accordingly, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with the following equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

where n is the index of refraction.

While, in the case of a stationary light source and a receding refractive medium, the original Fizeau experiment as well as the Michelson's repetition have verified that the speed of its light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with this equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And consequently, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with the following equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

where n is the index of refraction.

However, the new-source source emission theory predicts that in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is according to this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is approaching the stationary light source;
and in accordance with this equation:

$$c'_n = \frac{c}{n}$$

in the case, in which the refractive medium is receding from the stationary light source.

And it follows, therefore, that the new-source emission theory is inconsistent with the experimental result obtained by Fizeau and Michelson.

V. The Predictions of the Elastic-Impact Emission Theory:

The elastic-impact emission theory makes several predictions, with regard to the speed of light in refractive media; but only two of those predictions have been verified experimentally:

- The speed of light emitted by a stationary light source through a refractive medium at rest with respect to the stationary reference frame of the laboratory.

- And the speed of light emitted by a stationary light source through a refractive medium in motion with respect to the stationary reference frame of the laboratory.

1. The Light Source and the Refractive Medium at Rest:

If the light source, outside or inside a refractive medium at rest, is stationary in the reference frame of the laboratory, then the speed of its light inside that refractive medium c_n, as predicted by the elastic-impact emission theory, can be obtained through the use of this standard equation:

$$c_n = \frac{c}{n}$$

where n is the refractive index; and c is the speed of light in vacuum.

2. The Light Source in Motion and the Refractive Medium at Rest:

When the light source is in motion and the refractive medium is at rest, in the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the elastic-impact emission theory, in the case of an approaching light source, is calculated by using this equation:

$$c'_n = \frac{c+v}{n}$$

where v is the velocity of the approaching light source; and n is the refractive index.

And the speed of light from a receding light source c'_n through the stationary refractive medium is computed by using the following equation:

$$c'_n = \frac{c-v}{n}$$

where v is the velocity of the receding light source; and n is the refractive index.

Moreover, the speed of light from a moving light source c'_n through a stationary refractive medium, in the general case, can be calculated, in accordance with the elastic-impact emission theory, by using this general equation:

$$c'_n = \frac{c}{n}\left(1 + \frac{v^2}{c^2} + 2\frac{v}{c}\cos\theta\right)^{\frac{1}{2}}$$

where θ is the angle between the normal to the refractive medium and the velocity vector of the light source.

3. The Light Source at Rest and the Refractive Medium in Motion:

When the light source is at rest and the refracting medium is in motion, the elastic-impact emission theory makes two different predictions, in the reference frame of the refracting medium and in the reference frame of the laboratory, respectively. However, only the latter prediction has been tested experimentally by the Fizeau experiment and its repetition by A. Michelson.

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a stationary light source, through the refractive medium, according to the elastic-impact emission theory, can be calculated by using the following equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

in the case, in which the refractive medium is approaching the light source;
and by using this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

in the case, in which the refractive medium is receding from the light source.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, according to the elastic-impact emission theory, the incident light travels, inside the refracting medium, at the vector sum of its refracted velocity resultant with respect to the refracting medium and the velocity of the refracting medium with respect to the stationary reference frame of the laboratory.

If it's assumed, for instance, that the normal to the refractive medium coincides with its velocity vector, then the angle β, which the incident light makes with the velocity vector of the medium v, can be calculated by using this trigonometric relation:

$$\beta = 180^o - \phi$$

in the case of approach; and by using this trigonometric relation, in the case of recession:

$$\beta = 0^o + \phi$$

where ϕ is the angle of incidence as defined in accordance with Snell's law.

And hence, outside of the refractive medium, the relative velocity resultant of the incident light with respect to the refractive medium is c':

$$c' = c\left(1 + \frac{v^2}{c^2} - 2\frac{v}{c}\cos\beta\right)^{\frac{1}{2}}$$

in which the direction of the refracted velocity resultant β' is calculated by the following equation:

$$\sin\beta' = \frac{\sin\beta}{\sqrt{1 + \frac{v^2}{c^2} - 2\frac{v}{c}\cos\beta}}$$

where β is, as defined above, the direction of the velocity resultant of light.

And accordingly, the refracted velocity resultant c_n, with respect to the refractive medium, can be computed by using this equation:

$$c_n = c\left(1 + \left(\frac{v}{nc}\right)^2 - 2\frac{v}{nc}\cos\beta'\right)^{\frac{1}{2}}$$

where n is the refractive index.

Since β' is the actual angle of incidence, the angle of refraction β'' can be obtained from Snell's law:

$$n_0 \sin\beta' = n\sin\beta''$$

where n_0 is the refractive index in vacuum.

And it follows, therefore, that the vector sum of the refracted velocity resultant of light with respect to the refractive medium and the velocity of the refractive medium with respect to the stationary reference frame of the laboratory, c'_n, within the framework of the elastic-impact emission theory, can be computed by this equation:

$$c'_n = c_n \sqrt{1 + \frac{v^2}{c_n^2} - 2\frac{v}{c_n}\cos\beta''}$$

where c_n and β' are as defined by the two equations above; and the direction of c'_n can be obtained by inserting β' into the standard equation of Snell's law.

For an initial angle of incidence of:

$$\phi = 0^o$$

the general equation above is reduced to this standard Fresnel's equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

in the case of approach;
and to this Fresnel's equation, in the case of recession:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the laboratory; and n is the refractive index.

4. The Light Source and the Refractive Medium Moving at the Same Velocity:

If the light source and the refractive medium are moving together with the same speed in the same direction relative to the laboratory, then the speed of light c'_n through the refractive medium, according to the elastic-impact theory, can have two different values depending on the reference frame, in which the calculations are carried out:

In the Reference Frame of the Light Source and the Refractive Medium:

The relative velocity of incident light with respect to the refractive medium, in this case, is equal to c.

And therefore, in the reference frame, in which the light source and the refractive medium are at rest, the speed of light c'_n through the refractive medium, can be calculated in accordance with the following equation:

$$c'_n = \frac{c}{n}$$

regardless of whether the light source is located inside or outside the refractive medium.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n through the refractive medium, according to the elastic-impact emission theory, is calculated by using this equation:

$$c'_n = \frac{c}{n} - v$$

in the case, in which the refractive medium is trailing the light source.

And in accordance with the following equation:

$$c'_n = \frac{c}{n} + v$$

in the case, in which the light source is trailing the refractive medium.

And that is because, in the two cases, the relative velocity of incident light with respect to the refractive medium, is equal to c; and hence, Fresnel's factor is, in this case, nil:

$$\pm \frac{v}{n^2} = 0$$

in the case of approach and in the case of recession, correspondingly.

5. The Light Source and the Refractive Medium in Motion:

Although, in the published literature, on this subject, there is no reference to any mathematical formulas for the special case of a light source and a refractive medium in motion relative to the laboratory, it's possible, from theoretical perspective, to work out the details of calculating the speed of light c'_n through the refractive medium, on the basis of the elastic-impact emission theory.

Let's assume that, with respect to the stationary reference frame of the laboratory, v_s is the velocity of the light source; and v_m is the velocity of refractive medium.

Since, within the framework of the elastic-impact emission theory, the velocity of the light source and the velocity of the refractive medium v_m have effects on the velocity of light, we have to take both into consideration, in any computations done in the reference frame of the refractive medium and in the reference frame of the laboratory, respectively:

In the Reference Frame of the Refractive Medium:

In the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from a moving light source, through the refractive medium, according to the elastic-impact emission theory, can be calculated as in the following cases:

- If the refractive medium and the light source are approaching each other, then, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n from the approaching light source, through the approaching refractive medium, according to the elastic-impact emission theory, can be obtained by using this equation:

$$c'_n = \frac{c + v_s}{n} + \frac{v_m}{n^2}$$

  where v_s is the velocity of the approaching light source; v_m is the velocity of the approaching refractive medium; and n is the refractive index.

- If the light source is receding from the approaching refractive medium, then, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n from the receding light source, through the approaching refractive medium, according to the elastic-impact emission theory, can be computed by using this equation:

$$c'_n = \frac{c - v_s}{n} + \frac{v_m}{n^2}$$

where v_s is the velocity of the receding light source; v_m is the velocity of the approaching refractive medium; and n is the index of refraction.

- If the refractive medium and the light source are receding from each other, then, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n from the receding light source, through the receding refractive medium, according to the elastic-impact emission theory, can be calculated by using the following equation:

$$c'_n = \frac{c - v_s}{n} - \frac{v_m}{n^2}$$

where v_s is the velocity of the receding light source; v_m is the velocity of the receding refractive medium; and n is the refractive index.

- And if the light source is approaching the receding refractive medium, then, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n from the approaching light source, through the receding refractive medium, according to the elastic-impact emission theory, can be obtained by using this equation:

$$c'_n = \frac{c + v_s}{n} - \frac{v_m}{n^2}$$

where v_s is the velocity of the approaching light source; v_m is the velocity of the receding refractive medium; and n is the refractive index.

In the Reference Frame of the Laboratory:

In the reference frame of the laboratory, the speed of light c'_n, from a moving light source, through the refractive medium, according to the elastic-impact emission theory, can be calculated as follows:

- If the refractive medium and the light source are approaching each other, then, in the reference frame of the laboratory, the speed of light c'_n from the approaching light source, through the approaching refractive medium, according to the elastic-impact emission theory, can be obtained by using this equation:

$$c_n' = \frac{c+v_s}{n} - v_m\left(1-\frac{1}{n^2}\right)$$

where v_s is the velocity of the light source; v_m is the velocity of the refractive medium; and n is the index of refraction.

- If the light source is receding from the approaching refractive medium, then, in the reference frame of the laboratory, the speed of light c'_n from the receding light source, through the approaching refractive medium, according to the elastic-impact emission theory, can be obtained by using the following equation:

$$c_n' = \frac{c-v_s}{n} - v_m\left(1-\frac{1}{n^2}\right)$$

where v_s is the velocity of the receding light source; v_m is the velocity of the approaching refractive medium; and n is the index of refraction.

- If the refractive medium and the light source are receding from each other, then, in the reference frame of the laboratory, the speed of light c'_n from the receding light source, through the receding refractive medium, according to the elastic-impact emission theory, can be computed by using this equation:

$$c_n' = \frac{c-v_s}{n} + v_m\left(1-\frac{1}{n^2}\right)$$

where v_s is the velocity of the receding light source; v_m is the velocity of the receding refractive medium; and n is the index of refraction

- And finally, if the light source is approaching the receding refractive medium, then, in the reference frame of the laboratory, the speed of light c'_n from the approaching light source, through the receding refractive medium, according to the elastic-impact emission theory, can be calculated by using this equation:

$$c_n' = \frac{c+v_s}{n} + v_m\left(1-\frac{1}{n^2}\right)$$

where v_s is the velocity of the approaching light source; v_m is the velocity of the receding refractive medium; and n is the index of refraction.

<u>The Elastic Impact Emission Theory and the Result of the Fizeau Experiment:</u>

In the case of a stationary light source and an approaching refractive medium, the original Fizeau experiment as well as the Michelson's repetition have confirmed that the speed of light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with the following equation:

$$c'_n = \frac{c}{n} - v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

Accordingly, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

where n is the index of refraction.

And likewise, in the case of a stationary light source and a receding refractive medium, the original Fizeau experiment as well as the Michelson's repetition have confirmed that the speed of its light c'_n through the refractive medium, as measured in the stationary reference frame of the laboratory, is in accordance with the following equation:

$$c'_n = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right)$$

where v is the velocity of the refractive medium with respect to the stationary light source in the reference frame of the laboratory.

And consequently, this experimental result implies, necessarily and independently of any physical theory, that, in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is in accordance with this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

where n is the index of refraction.

The elastic-impact emission theory predicts that in the reference frame, in which the refractive medium is at rest, the speed of light c'_n, from the same stationary light source, through the refractive medium, is according to the following equation:

$$c'_n = \frac{c}{n} + \frac{v}{n^2}$$

in the case, in which the refractive medium is approaching the stationary light source;
and in accordance with this equation:

$$c'_n = \frac{c}{n} - \frac{v}{n^2}$$

in the case, in which the refractive medium is receding from the stationary light source.

And it follows, therefore, that the elastic-impact emission theory is consistent with the experimental result obtained by Fizeau and Michelson.

7. The Momentum of Light in Refracting Media:

It should be mentioned, within this context, that calculations of electromagnetic momentum of refracted light, in the reference frame of the refracting medium and in the reference frame of the laboratory, depend upon the kinematic arrangement of the light source and the refracting medium and upon the choice of physical theories as well.

The momentum of refracted light, inside stationary refracting media, and regardless of whether the emitting light source is at rest or in motion, is governed, according to the classical wave theory, the Larmor-Lorentz theory, the special theory of relativity, and the new-source emission theory, either by this Abraham's equation:

$$p_A = \frac{p_0}{n}$$

or it's governed by this Minkowski's equation:

$$p_M = np_0$$

where p_A is the momentum of light in the refracting medium as given by Abraham's equation; p_M is the momentum of light as given by Minkowski's equation; and p_0 is the momentum of light, from a stationary light source, in vacuum.

Although, presumably, it is not possible, within the framework of those four theories, to decide between the above two conflicting equations for computing the momentum of light traveling through refracting media, it's almost certain that Abraham's equation is the correct one, in the case of light sources and refractive media at rest. And that is, obviously, because if the speed of light is reduced, in stationary refracting media, by a factor of n from c to c_n:

$$c_n = \frac{c}{n}$$

then, by definition, its momentum should be reduced by a factor of n as well from p_0 to p_r:

$$p_r = \frac{p_0}{n}$$

where p_r is the momentum of light, emitted by a stationary light source, through a refracting medium at rest in the reference frame of the laboratory.

As for the Minkowski's momentum equation, it may, well, turn out that it's the correct mathematical formula for computing electromagnetic momentum, on the basis of those four physical theories, in a significant number of cases, in which the Doppler effect is involved.

The quantitative treatment of electromagnetic momentum, in refracting media, however, is somewhat lengthy and more complicated, within the framework of the elastic-impact emission theory; because the calculations, here, require necessarily that the state of motion for the light source, outside as well as inside the refracting medium, has to be taken into account.

In order to make those lengthy computations as short and simple as possible, therefore, we shall treat in detail, here, only the cases, in which the light source is in motion and the refracting medium is at rest; and the cases, in which, the light source is at rest, and the refracting medium is in motion.

A. The Refracting Medium at Rest:

Let p_0 stand for the momentum of light, from a stationary light, in vacuum; and let v_s stand for the velocity of the light source.

The Stationary Case:

If the velocity of the light source v_s is nil, then the momentum of light p throughout the stationary refracting medium, and regardless of whether the stationary light source is located outside or inside that refracting medium, can be calculated, in the reference frame of the refracting medium and in the reference frame of the laboratory as well, on the basis of the elastic-impact emission theory, by using the following equation:

$$p = \frac{p_0}{n}$$

where n is the index of refraction.

The Case of a Moving Light Source Outside a Stationary Refracting Medium:

If a light source, located outside a stationary refracting medium, approaches directly that refracting medium, then, according to the elastic-impact emission theory, the momentum of its light p, through the stationary refracting medium, can be obtained, in the reference frame of the refracting medium as well as in the reference frame of the laboratory, by using this equation:

$$p = \frac{p_0}{n}\left(1 + \frac{v_s}{c}\right)^2$$

where is v_s is the velocity of the approaching light source.

The momentum of refracted light increases, in this case, because of its higher velocity, in addition to the increase in its frequency, due to the Doppler effect, in accordance with this equation:

$$f' = f\left(1 + \frac{v_s}{c}\right)$$

where f' is the received frequency; and f is the emitted frequency.

Likewise, if a light source, located outside of a stationary refracting medium, recedes directly from that stationary refracting medium, then the momentum of its light p, inside the stationary refracting medium, can be computed, in the reference frame of the refracting medium and in the reference frame of the laboratory as well, by using this equation:

$$p = \frac{p_0}{n}\left(1 - \frac{v_s}{c}\right)^2$$

where is v_s is the velocity of the receding light source.

The main reason behind the decrease in the momentum of refracted light, in this case, is its lower velocity, in addition to the decrease in its frequency, due to the Doppler effect, as calculated ed through the use of the following equation:

$$f' = f\left(1 - \frac{v_s}{c}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

The Case of a Moving Light Source Inside a Stationary Refracting Medium:

If a light source, located inside a stationary refracting medium, is approaching the observer directly, then, according to the elastic-impact emission theory, the momentum of its light p, through the stationary refracting medium, can be obtained, in the reference frame of the refracting medium and in the reference frame of the laboratory, by using this equation:

$$p = \frac{p_0}{n}\left(1 + \frac{nv_s}{c}\right)\left(1 + \frac{nv_s}{c - v_s(n-1)}\right)$$

where v_s is the velocity of the approaching light source.

The primary reason for the increase in the momentum of refracted light, in this particular case, is the increase in its frequency, due to the Doppler effect, in accordance with the following equation:

$$f' = f\left(1 + \frac{nv_s}{c - v(n-1)}\right)$$

where f' is the received frequency; and f is the emitted frequency.

And similarly, if a light source, located inside a stationary refracting medium, is receding directly from the observer, then the momentum of its light p, through the stationary refracting medium, can be calculated, in the reference frame of the refracting medium and in the reference frame of the laboratory as well, by using the following equation:

$$p = \frac{p_0}{n}\left(1 - \frac{nv_s}{c}\right)\left(1 - \frac{nv_s}{c + v_s(n-1)}\right)$$

where is v_s is the velocity of the receding light source.

The main reason for the decrease in the momentum of refracted light, in this case, is the decrease in its frequency, due to the Doppler effect, in accordance with this equation:

$$f' = f\left(1 - \frac{nv_s}{c + v_s(n-1)}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

It should be noted, in this regard, that all Doppler shifts, caused by the motion of the light source inside a refracting medium, remain persistent and observable in all frames of reference and the same, even after the shifted light emerges from that refracting medium and restores its initial velocity in vacuum.

B. The Light Source at Rest:

Let's assume that p_0 denotes the momentum of light in vacuum, from a stationary light; and v_m denotes the velocity of the refracting medium.

1. The Case of Approach:

In the case of a refracting medium approaching a light source at rest, the calculations, on the basis of the elastic-impact emission theory, must be carried out, in the reference frame of the refracting medium and in the reference of the the laboratory, separately, and regardless of whether the stationary light source is located outside or inside the approaching refracting medium.

The Light Source Outside of the Refracting Medium:

If the refracting medium approaches a light source outside of it and at rest with respect to the stationary laboratory, then the momentum of refracted light, in the reference frame of the refracting medium, can be computed, on the basis of the elastic-impact emission theory, by using this equation:

$$p = \frac{p_0}{n}\left(1 + \frac{v_m}{nc}\right)\left(1 + \frac{v_m}{c}\right)$$

where v_m is the velocity of the approaching refracting medium; and n is the index of refraction.

In addition to a higher velocity, the increase in the momentum of refracted light, in this particular case, is due to the increase in its frequency, because of the Doppler effect, in accordance with the following equation:

$$f' = f\left(1 + \frac{v_m}{c}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

And in the stationary reference frame of the laboratory, the momentum of refracted light can be calculated, in accordance with this equation:

$$p = \frac{p_0}{n}\left[1 - \frac{v_m}{c}\left(\frac{n^2 - 1}{n}\right)\right]\left(1 + \frac{v_m}{c}\right)$$

where v_m is the velocity of the approaching refracting medium; and n is the index of refraction.

The increase in the momentum of refracted light, in this particular case, is due only to the increase in its frequency, because of the Doppler effect, as obtained by using the following equation:

$$f' = f\left(1 + \frac{v_m}{c}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

The Light Source Inside the Refracting Medium:

If the refracting medium approaches a light source located inside of it and at rest with respect to the stationary laboratory, then the momentum of refracted light, in the reference frame of the refracting medium, can be computed, on the basis of the elastic-impact emission theory, by using the following equation:

$$p = \frac{p_0}{n}\left(1 + \frac{v_m}{nc}\right)\left(1 + \frac{n^2 v_m}{nc + v_m}\right)$$

where v_m is the velocity of the approaching refracting medium; and n is the index of refraction.

In addition to its higher velocity, the increase in the momentum of refracted light, in this special case, is due to the increase in its frequency, because of the Doppler effect, as calculated by using the following equation:

$$f' = f\left(1 + \frac{n^2 v_m}{nc + v_m}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

And the momentum of refracted light, in the stationary reference frame of the laboratory, can be calculated, in accordance with this equation:

$$p = \frac{p_0}{n}\left[1 - \frac{v_m}{c}\left(\frac{n^2 - 1}{n}\right)\right]\left(1 + \frac{n^2 v_m}{nc + v_m}\right)$$

where v_m is the velocity of the approaching refracting medium; and n is the index of refraction.

The increase in the momentum of refracted light, in this particular case, is due primarily to the increase in its frequency, because of the Doppler effect, as given by the following equation:

$$f' = f\left(1 + \frac{n^2 v_m}{nc + v_m}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

2. The Case of Recession:

In the case of a refracting medium receding from a light source at rest, the calculations, within the framework of the elastic-impact emission theory, have to be carried out, in the reference frame of the refracting medium and in the reference of the the laboratory, separately, and regardless of whether the stationary light source is located outside or inside the receding refracting medium.

The Light Source Outside of the Refracting Medium:

If the refracting medium is receding from an outside light source at rest with respect to the stationary laboratory, then the momentum of refracted light, in the reference frame of the refracting medium, can be obtained, according to the elastic-impact emission theory, by using this equation:

$$p = \frac{p_0}{n}\left(1 - \frac{v_m}{nc}\right)\left(1 - \frac{v_m}{c}\right)$$

where v_m is the velocity of the receding refracting medium; and n is the index of refraction.

In addition to its lower velocity, the decrease in the momentum of refracted light, in this case, is due to the decrease in its frequency, because of the Doppler effect, as computed by using this equation:

$$f' = f\left(1 - \frac{v_m}{c}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

And the momentum of the same refracted light, in the stationary reference frame of the laboratory, can be calculated, in accordance with the following equation:

$$p = \frac{p_0}{n}\left[1 + \frac{v_m}{c}\left(\frac{n^2 - 1}{n}\right)\right]\left(1 - \frac{v_m}{c}\right)$$

where v_m is the velocity of the receding refracting medium; and n is the index of refraction.

The decrease in momentum of refracted light, in this special case, is due mainly to the decrease in its frequency, because of the Doppler effect, as obtained from the following equation:

$$f' = f\left(1 - \frac{v_m}{c}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

The Light Source Inside the Refracting Medium:

If the refracting medium recedes from a light source located inside of it and at rest with respect to the stationary laboratory, then the momentum of refracted light, in the reference frame of the refracting medium, can be computed, on the basis of the elastic-impact emission theory, through the use of the following equation:

$$p = \frac{p_0}{n}\left(1 - \frac{v_m}{nc}\right)\left(1 - \frac{n^2 v_m}{nc - v_m}\right)$$

where v_m is the velocity of the receding refracting medium; and n is the index of refraction.

In addition to its lower velocity, the decrease in the momentum of refracted light, in this special case, is due to the decrease in its frequency, because of the Doppler effect, in accordance with the following equation:

$$f' = f\left(1 - \frac{n^2 v_m}{nc - v_m}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

And the momentum of refracted light, in the stationary reference frame of the laboratory, can be calculated, in accordance with this equation:

$$p = \frac{p_0}{n}\left[1 + \frac{v_m}{c}\left(\frac{n^2 - 1}{n}\right)\right]\left(1 - \frac{n^2 v_m}{nc - v_m}\right)$$

where v_m is the velocity of the receding refracting medium; and n is the index of refraction.

The decrease in the momentum of refracted light, in this case, is due to the decrease in its frequency, because of the Doppler effect, in accordance with the following equation:

$$f' = f\left(1 - \frac{n^2 v_m}{nc - v_m}\right)$$

where f' is the observed frequency; and f is the emitted frequency.

It should be noted, in this regard, that all Doppler shifts, caused by the motion of the refracting medium, remain observable and the same in all frames of reference, even after the shifted light emerges from that refracting medium and restores its initial velocity in vacuum.

8. Concluding Remarks:

As pointed out earlier in this investigation, theoretical predictions, related to refraction, within the framework of every physical theory, vary considerably, mainly because it's possible, kinematically, to arrange the light source and the refractive medium in a variety of different ways:

1. The light source and the refractive medium are at rest relative to each other as well as with respect to the reference frame of the laboratory.
2. The light source is stationary; and the refractive medium is in motion, relative to each other as well as with respect to the reference frame of the laboratory.
3. The light source is in motion; and the refractive medium is at rest, relative to each other as well as with respect to the reference frame of the laboratory.
4. The light source and the refractive medium are at rest, relative to each other; and both are moving with the same speed in the same direction with respect to the reference frame of the laboratory.
5. The light source and the refractive medium are in motion, relative to each other as well as with respect to the reference frame of the laboratory.
6. The light source, the refractive medium, and the laboratory are at rest relative to each other; but, at the same time, all the three are moving with the same speed in the same direction with respect to an external frame of reference.
7. The light source is stationary; and the refractive medium is in motion, with respect to each other as well as relative to the laboratory; but, at the same time, all the three are moving with the same speed in the same direction with respect to an external frame of reference.
8. The light source is in motion; and the refractive medium is at rest, with respect to each other

as well as relative to the laboratory; but, at the same time, all the three are moving with the same speed in the same direction with respect to an external frame of reference.

9. The light source and the refractive medium are at rest with respect to each other; and both are moving with the same speed in the same direction relative to the laboratory; but, at the same time, all the three are moving with the same speed in the same direction with respect to an external frame of reference.

10. The light source and the refractive medium are in motion with respect to each other as well as relative to the laboratory; but, at the same time, all the three are moving with the same speed in the same direction with respect to an external frame of reference.

In the list of the ten kinematic arrangements above, only the first and the second arrangements between the light source and the refractive medium have been tested in the laboratory, and the related theoretical predictions, in this regard, have been experimentally verified to a sufficient degree of certainty.

The main reason why eight of the above ten arrangements have never been examined in the laboratory or tested experimentally in any way, during the last two hundred years since the days of Fresnel and Fizeau, is partly theoretical and partly practical.

Clearly, the third kinematic arrangement has not been tested experimentally, not because of any practical difficulty; but because the dominant physical theories, throughout those two hundred years or so, have taken it for granted that the speed of light, in this specific case, must be:

$$c_n' = \frac{c}{n}$$

whether the light source is inside or outside the refractive medium.

By contrast, the fourth and the fifth kinematic arrangements have not been tested experimentally, because of practical difficulties in using the primary experimental method of interferometry to test both in the laboratory.

Consequently, predictions related to the speed of light, in all of the last eight kinematic arrangements above, have been, so far, only deduced from theoretical considerations, which lead to different results depending, by definition, upon the choice of physical theories, in this regard.

And finally, it should be pointed out, at the end of this discussion, that, in spite of suggestive analogies, the Fresnel drag coefficient has never been searched for or experimentally tested in any other type of wave phenomena beside light.

Consider the outstanding case of sound, for example.

In the aforementioned repetition of the Fizeau experiment by A. Michelson, if the stationary light source is replaced with a stationary sound source, and the interferometer for measuring the speed of light is replaced with a similar instrument for measuring the speed of sound, then should we expect, in this case too, that incident sound, in the latter experiment, is going to be dragged by the Fresnel drag coefficient, in the same way incident light is dragged by the same coefficient in the former experiment?

Intuitively, one expects, at the face of it, that sound will not be just partially dragged, by the flowing water as in the case of light; but it will be fully dragged by the flowing water in both directions in accordance with these two equations:

$$c'_A = c_w - v$$

where c'_A is the speed of sound in the case of directly approaching water;
and:

$$c'_R = c_w + v$$

where c'_R is the speed of sound in the case of directly receding water; and v is the speed of the flowing water; and c_w is the speed of sound in the stationary water.

However, because sound, from the stationary sound source, encounters, during its travel inside the same tube, more amount of approaching water and less amount of receding water than that of stationary water, its effective speed should be slightly higher than predicted, by the above equations, in the case of approaching water, and slightly lower in the case of receding water.

By how much?

That can, of course, be determined only by experimental means.

What will happen, in this particular case, if the Fizeau flowing water is replaced with Michelson's moving prism of glass?

The amount of glass, in this case, is constant; and hence, it has no effect on the speed of sound, as computed from the two equations above, in both directions.

Nonetheless, in the reference frame, in which the glass prism is at rest, sound, from the stationary sound source, is necessarily shifted by the Doppler effect towards the blue in the case of approaching prism, and towards the red in the case of receding prism.

And since, in the case of sound, blue Doppler shifts imply that the glass particles are effectively closer to each other than in the stationary case; and red Doppler shifts imply that the glass particles are effectively farther apart from each other than in the stationary case, the predicted values for the speed of sound, by the two equations above, should be higher than predicted in the case of approaching prism, and lower than predicted in the case of receding prism.

And that is clearly because, in the case of sound, farther-apart refractive particles lead to smaller values of pressure, and hence to lower speeds; while closer refractive particles lead to larger values of pressure, and as a result to higher speeds of sound.

Also, because sound is a purely wave phenomenon, its quantitative treatment, within the framework of the classical wave theory, the Larmor-Lorentz theory, the special theory of relativity, the new-source emission theory, and the elastic-impact emission theory, leads to the same numerical prediction, even though the basic assumptions of these physical theories are vastly different.

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