Skulls in the Stars

The intersection of physics, optics, history and pulp fiction

Fizeau's experiment: The original paper

Posted on March 31, 2008 by skullsinthestars

When I wrote my 'speed of light' post, I had to do a lot of searching to find Fizeau's original paper. Fizeau, as I mentioned, produced the first terrestrial measurement of the speed of light, using a rapidly rotating toothed wheel to break a light signal into continuous pulses whose speed could then be estimated. Since I've managed to find, after some effort, Fizeau's paper, I thought I'd do the physics community a service and post it in a more easy to find place: my blog!

Unless I'm very confused, it should be okay to reprint it here. The original paper dates from 1849, and the web archive where I eventually found it is publicly accessible.

Before I list the paper, a little boasting: I worked really hard to find it! Curiously, many books mention the Fizeau experiment but none of the books I had actually gave the journal reference. An internet search was quite unhelpful, as Fizeau did a more famous experiment in 1850 in which he tried to detect the motion of the aether: every entry I found on Google referred to this experiment.

So I knew only one thing: Fizeau did the experiment in 1849. Here's where my detective work came in: in those days, authors would usually publish most papers in the same journal. Fizeau's 1850 paper was published in the Comptes Rendus de l'Académie des Sciences, so it was a good guess that the 1849 paper appeared there as well. I went to the Académie's web page, and found an English translation of it.

For the earliest papers such as Fizeau's, however, that web page directed me to Gallica, apparently an online subsidiary of the National Library of France. This website is not in English, and there is no direct link to the journal. I wandered a bit and with my rusty French managed to figure out that the "Découverte" link was the one I wanted. From there, "périodiques" is the proper choice (periodicals), and then under "sciences" one clicks on "Comptes rendus hebdomadaires des séances de l'Académie des sciences". We have found the journal at last!

Now we have a new problem: there are two volumes in 1849 (volume 28 & 29), and the journal is not electronically searchable, being scanned pdfs of the original pages. In addition, each page is an individual pdf, resulting in a very slow read. However, I dusted off my memories of the "old days" of journal searches, when there wasn't this fancy "internets" to make life easy. All print journals publish an end of the year index, so I skimmed to the end of volume 29, and there it was, on page 855: Fizeau, "Note sur une expérience relative à la vitesse de propagation de la lumière," pages 90 & 132. Now it was an easy matter to skim to the appropriate pages, and find the following pages (pdfs):

title page, page 90, page 91, page 92, page 132

The complete reference is: H. Fizeau, Comp. Rend. Acad. Sci. (Paris) **29** (1849), 90-92. All that was left was the translation. Step 1 was to transcribe the scanned pages into electronic format, with all those pesky accents:

Sur une expérience relative à la vitesse de propagation de la lumière.

Je suis parvenu à rendre sensible la vitesse de propagation de la lumière par une méthode qui me paraît fournir un moyen nouveau d'étudier avec précision cet important phénomène. Cette méthode est fondée sur les principes suivants:

Lorsqu'un disque tourne dans son plan autour du centre de figure avec une grande rapidité, on peut considérer le temps employé par un point de la circonférence pour parcourir un espace angulaire très-petit, 1/1000 de la circonférence, par exemple.

Lorsque la vitesse de rotation est assez grande, ce temps est généralement très-court; pour dix et cent tours par seconde, il est seulement de 1/10000 et 1/100000 de seconde. Si le disque est divisé a sa circonférence, à la manière des roues dentées, en intervalles égaux alternativement vides et pleins, on aura, pour la durée du passage de chaque intervalle par un même point de l'espace, les mêmes fractions très-petites.

Pendant des temps aussi courts la lumière parcourt des espaces assez limités, 31 kilomètres pour la première fraction, 3 kilomètres pour la seconde.

En considérant les effets produits lorsqu'un rayon de lumière traverse les divisions d'un tel disque en movement, on arrive à cette conséquence, que si le rayon, après son passage, est réfléchi au moyen d'un miroir et renvoyé vers le disque, de manière qu'il le rencontre de nouveau dans le même point de l'espace, la vitesse de propagation de la lumière pourra intervenir de telle sorte, que le rayon traversera ou sera intercepté suivant la vitesse du disque et la distance à laquelle aura lieu la réflexion.

D'une autre part, un système de deux lunettes dirigées l'une vers l'autre, de manière que l'image de l'objectif de chacune d'elles se forme au foyer de l'autre, possède des propriétés qui permettent de réaliser ces conditions d'une manière simple. Il suffit de placer un miroir au foyer de l'une, et de modifier le système oculaire de l'autre en interposant entre le foyer et l'oculaire une glace transparente inclinée sur l'axe de 45 degrés et pouvant recevoir lateralement la lumiere d'une lampe ou du soleil qu'elle réfléchit vers le foyer. Avec cette disposition, la lumière qui traverse le foyer dans l'étendue supposée très-petite de l'image qui représente l'objectif de la seconde lunette, est projetée vers celle-ci, se réfléchit à son foyer et revient en arrière en traversant le même espace pour passer de nouveau par le foyer de la première lunette, où elle peut être observée au moyen de l'oculaire et à travers la glace.

Cette disposition réussit très-bien, même en éloignant les lunettes à des distances considérables; avec des lunettes de 6 centimetres d'ouverture, la distance peut être de 8 kilomètres sans que la lumière soit trop affaiblie. On voit alors un point lumineux semblable à une étoile, et formé par de la lumière qui est partie de ce point, a traversé un espace de 16 kilomètres, puis est revenue passer exactement par le même point avant de parvenir à l'oeil.

C'est sur ce point même qu'il faut faire passer les dents d'un disque tournant pour produire les effets indiqués; l'expérience réussit très-bien, et l'on observe que, suivant la vitesse plus ou moins *grande de la rotation, le point lumineux brille avec éclat ou s'éclipse totalement. Dans les circonstances ou l'expérience a été faite, la première éclipse se produit vers 12,6 tours par seconde. Pour une vitesse double, le point brille de nouveau; pour une vitesse triple, il se produit une deuxième éclipse; pour une vitesse quadruple, le point brille de nouveau, et ainsi de suite.*

La première lunette était placée dans le belvédère d'une maison située à Suresnes, la seconde sur la hauteur de Montmartre, à une distance approximative de 8633 mètres.

Le disque portent sept cent vingt dents était monté sur un rouage mû par des poids et construit par M. Froment; un compteur permettait de mesurer la vitesse de rotation. La lumière était empruntée a une lampe disposée de manière à offrir une source de lumière très-vive.

Ces premiers essais fournissent une valeur de la vitesse de la lumière peu différente de celle qui est admise par les astronomes. La moyenne déduite des vingt-huit observations qui ont pu être faites jusqu'ici donne, pour cette valeur, 70948 lieues de 25 au degré.

Once that was done, I took the girlfriend's advice and went to babelfish for a translation:

On an experiment relating to the propagation velocity of the light.

I managed to make sensitive the propagation velocity of the light by a method which appears me to provide a new means to study with precision this important phenomenon. This method is founded on the following principles:

When a disc turns in its plan around the centre of face with a great speed, one can consider the time employed by a point of the circumference to traverse a very small angular space, 1/1000 of the circumference, for example.

When the number of revolutions is rather large, this time is generally very short; for ten and hundred turns a second, it is only 1/10000 and 1/100000 of second. If the disc is divided has its circumference, with the manner of the toothed wheels, in equal intervals alternatively empty and full, one will have, for the duration of the passage of each interval by the same point of space, the same very-small fractions.

During such short times the light traverses limited enough spaces, 31 kilometers for the first fraction, 3 kilometers for the second.

While considering the produced effects when a ray of light crosses divisions of such a disc in movement, one arrives at this consequence, that if the ray, after its passage, is considered by means of a mirror and returned towards the disc, in manner that it again meets it in the same point of space, the propagation velocity of the light will be able to intervene of such kind, that the ray will cross or will be intercepted according to the speed of the disc and the distance to which the reflection will take place.

Of another share, a system of two glasses directed one towards the other, so that the image of the objective of each one of them is formed with the hearth of the other, has properties which make it

> *possible to carry out these conditions in a simple way. It is enough to place a mirror at the hearth of the one, and to modify the ocular system of the other while interposing between the hearth and the eyepiece a transparent ice tilted on the axis of 45 degrees and being able to laterally receive the light of a lamp or sun which it reflects towards the hearth. With this provision, the light which crosses the hearth in the presumedly very-small extent of the image which represents the objective of the second glasses, is projected towards this one, is thought of its hearth and returns in back while crossing same space to pass again by the hearth of the first glasses, where it can be observed with the means of the eyepiece and with through the ice.*
>
> *This provision succeeds very well, even while moving away the glasses at considerable distances; with glasses of 6 centimetres of opening, the distance can be 8 kilometers without the light being weakened too much. One then sees a luminous point similar to a star, and formed by light which started from this point, crossed a space of 16 kilometers, then returned to pass exactly by the same point before arriving at the eye.*
>
> *It is on this point even as it is necessary to make pass the teeth of a disc turning to produce the effects indicated; the experiment succeeds very well, and it is observed that, according to the more or less high speed of rotation, the luminous point shines with glare or eclipses completely. In the circumstances or the experiment was made, the first eclipse occurs towards 12,6 turns a second. For a double speed, the point shines again; for a triple speed, there are a second eclipse; for a quadruple speed, the point shines again, and so on.*
>
> *The first glasses were placed in the view-point of a house located at Suresnes, the second on the height of Montmartre, at an approximate distance of 8633 meters.*
>
> *The disc carry seven hundred and twenty teeth was assembled on a wheel mû by weights and was built by Mr. Froment; a meter made it possible to measure the number of revolutions. The light was borrowed has a lamp laid out so as to offer a source of very-sharp light.*
>
> *These first tests provide a value the speed of the light not very different from that which is allowed by the astronomers. The average deduced from the twenty-eight observations which could be made up to now gives, for this value, 70948 miles of 25 with the degree.*

And there it is! The translation is a little rough but clear enough to understand the gist of the research. You can, of course, read a clearer explanation of it at my earlier relativity post.

If anything, this post demonstrates how obsessed I get when I want to find an answer to a problem! I'm planning to do a bit more exploring of Gallica in the near future; now that I've figured it out, more or less, it is an excellent resource for early French scientific papers…

This entry was posted in Physics. Bookmark the permalink.

16 Responses to *Fizeau's experiment: The original paper*

Blake Stacey *says:*

April 1, 2008 at 8:04 am

You might consider joining up with the Blogging on Peer-Reviewed Research project and tagging posts like these.

Reply

skullsinthestars *says:*

April 1, 2008 at 2:07 pm

Blake: Thanks for the suggestion! I actually registered myself at the site a couple of weeks ago, but it didn't occur to me to tag this particular post: it didn't seem quite timely enough! 🙂

Reply

Subhendu Das *says:*

June 13, 2010 at 3:30 pm

I am wondering how this experiment proves that light speed is finite.

When there is an open slot in front of the light, the light will go and come back through the same slot at infinite speed.

But when there is a tooth in front of the light, there is no light going out and so no light will come back. This blocked part of the experiment does not prove anything. There is no light so there cannot be any measurements. Am I correct?

To setup the experiment correctly, the light must go through one slot and must come back through a different slot. And also when the light is returning from an open slot, at that very moment, the source of light must be blocked by a tooth.

Breaking the light into pulses does not prove its speed. The wheel must track a pulse. I do not see that happening in Fizeau's experiment. Do you?

Reply

skullsinthestars *says:*

June 15, 2010 at 9:08 pm

Experimentally, Fizeau showed that the amount of light returning through the system depends in a non-trivial way upon the speed of rotation. If the speed of light were infinite, the transmission of light would not really depend at all upon the speed: when the pathway is open, light would "instantaneously" go out and come back through the system.

Reply

Luis Garcia *says:*

November 13, 2018 at 1:58 pm

I understand that moving at 12,6 runs per second for a period of time there will be no any trace of light arriving to the eye of the observer.

Reply

Luis Garcia *says:*

November 13, 2018 at 1:59 pm

I understand that moving at 12,6 runs per second for a period of time there will be no any trace of light arriving to the eye of the observer.

Reply

Subhendu Das *says:*

June 16, 2010 at 1:05 pm

The diagram of Fizeau's experiment can be found at the following webpage: http://en.wikipedia.org/wiki/Speed_of_light
Please look at it, if you do not remember, before reading my logic.

(a). When there is a slot in front of the detector, the figure shows that there is also a slot in front of the source. If the speed is infinite, then he saw the source light at that moment through the two open slots. That is he saw a continuous line from source to detector, via reflection in the mirror.
(b). The interruption of the light by a tooth has nothing to do with the experiment. The light vanished when interrupted, because the speed is infinity.

Thus the experiment is not conclusive. It does not prove that the speed of light is finite. Is my logic wrong?

Reply

skullsinthestars *says:*

June 22, 2010 at 12:10 pm

You seem to be neglecting the fact that the Fizeau wheel is moving! At certain speeds, all the light that is outgoing returns and is detected, while at other speeds, *no outgoing light returns*. That is the whole point of the experiment: if the speed of light were infinite, the rotation speed of the wheel would have no significant effect on the amount of light passing through the system. The fact that light doesn't reach the detector at certain speeds is an indication that the gap in the wheel has been replaced by a tooth by the time the light returns from the distant reflector.

Reply

Subhendu Das *says:*

June 22, 2010 at 12:40 pm

Thank you for your response.

The wheel is designed in such a way that you can see the light only when there is an open slot in front of the detector. It does not matter whether the wheel is rotating or not.

Also at that very moment, when you see the light, there is also an open slot in front of the source. Thus I can say that the light travelled at infinite speed through two open slots, directly from the source to the detector via mirror reflection.

Reply

Robert *says:*

March 11, 2011 at 10:51 am

If i understand your statement correctly, then you are neglecting that the wheel is moving. Imagine this setup: As opposed to having a mirror, you have only a straight path from the source to the detector. Between them, you have two wheels, with teeth every 10 degrees, perfectly in phase seperated a distance d and moving at an angular velocity of w. The light may hit the first wheel in a gap, allowing the light to continue. However, if w = (5*pi/180)/(d/c), then the light will be completely blocked at the second wheel, as the next tooth will have had time to move into place. Notice that if the speed of light is infinite, the wheel would need to move infinitley fast in order to block it. This setup should be equivalent to Fizeau's (his second wheel is imaged by the mirror). Notice that it is not necessary to have w = to the quantity shown above, which would cause all the light to be blocked. If w is less than this, some light will get through, but much less than that if the speed of light is infinite. This is enough to show that light's speed is finite. And i realize this post is half a year after, but i did not like the way it ended.

Reply

skullsinthestars *says:*

March 11, 2011 at 11:54 am

You've pretty much got it right. Somehow Subhendu seems to be neglecting the motion of the wheel, or presupposing that the speed of light is infinite and therefore the motion of the wheel doesn't matter.

mircea bujor *says:*

January 6, 2012 at 7:13 pm

Did such an experiment take place? And if yes can you provide more info?
Thank you!

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mircea bujor *says:*

January 6, 2012 at 5:19 pm

Thank you very much for your work. "If you take from one book, it's considered plagiarism. If you take from two books, it's research. Three books, it is deep research,.." David Irving.
It looks like everybody nowadays skipped the original paper when they were writing about this experiment.

Reply

skullsinthestars *says:*

January 9, 2012 at 12:07 pm

You're welcome!

Reply

Pingback: *Speed of Light | Chopping Light Beams | JAR Blog...*

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joshscandlen *says:*

November 25, 2022 at 12:57 pm

I thought this interesting...
"The first glasses were placed in the view-point of a house located at Suresnes, the second on the height of Montmartre, at an approximate distance of 8633 meters."

Suresnes is about 100 feet elevation, give or take. Montmarte is about 460 or so. 5.6 miles away. Thus light going towards the Montmarte is going UP, i.e., against the gravitational pull, light going from Montmarte towards Suresnes is going 'down'.

if light can bend because of gravity shouldn't there be a speed differential?

Interesting, no?
I wonder then if this experiment were done on a flat plane would the speed change at all?

Reply

Skulls in the Stars