Interference Patterns Within a Circular Boundary

Aswan Korula (✉ vu2aeo@gmail.com)
https://orcid.org/0000-0002-8937-5137

Research Article

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Interference Patterns Within a Circular Boundary

Aswan Korula
vu2aeo@gmail.com
Kotagiri, TN 643217, India
ORCID ID: 0000-0002-8937-5137
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Abstract

In this paper we conduct a simple experiment within a circular ripple tank that conceals a paradox of unequal path lengths equivalent to the Michelson-Morley experiment of 1887. Leveraging on the equivalence of aqueous and optical interferometry, we analyse the outcome of our experiment to uncover a conflict between the predictions of general relativity and the symmetry of nature. Most astoundingly, it may be possible that this everyday phenomena and its analysis has somehow escaped the attention of rational thinkers from antiquity to the present day.

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1 Introduction

Science is a method of encouraging ideas to grow and evolve by winnowing them vigorously through a logical sieve for the purpose of generating simpler, more robust ideas. Sometimes the sieve manifests as a paradox: a contradiction of truths that provokes deeper introspection of a fundamental nature. To be effective, the paradox must be crafted so as to irrevocably demonstrate an existential conflict between theory and physical fact. Fundamental paradoxes are simple to sow, but spawn deep theoretical conflict.

2 Methodology

We begin with triangles; a most fundamental structure in the ordo cognoscendi of our understanding of the natural world. Then we conduct simple experiments involving a circular container filled with a fluid such as water. Finally we weigh the implications of these experiments against our current paradigm of waves travelling through space.

3 Euclidean Geometry

On a flat surface, we draw any angle $\theta$ at origin $Q$ bounded by two equal length line segments $QB = QB' = h$. We join points $B$ and $B'$ to points $A$ and $C$ such that the line segment $AC$ is perpendicular to $QB$ and centred at $Q$. We will restrict our arguments to the domain $x < h$. fig. [1] illustrates.
From fig. 1 we establish the following geometric truths:

1. If $x > 0$, physical measurements will verify the theoretical statement $AB + BC \neq AB' + B'C$ is true for all $\theta \neq 0, \pi, 2\pi$.

2. Since $h$ is constant, curve $BB'$ will take the form of a circle as $0 \leq \theta \leq 2\pi$.

4 The Experiment

Consider an ideal homogeneous flat surface capable of transporting a travelling wave and enclosed by a rigid boundary of geometrically circular shape.

4.1 Apparatus and Procedure

This experiment requires a medium sized, flat bottom, circular container of radius $h$ holding clean water about a centimetre deep. If we agree that the surface of the water is flat, we may from directly above, project fig. 1 onto it without distortion. The boundary of the container is defined by curve $BB'$, a physical circle of radius $h$ about point $Q$. Now let us agree that the water surface supports the geometry of fig. 1 over all $0 \leq \theta \leq 2\pi$ and $0 \leq x < h$. By gently touching the water surface just once at any point $A$, we disturb the equilibrium causing an isotropic sinusoidal wave (wavelength = $\lambda$) to emanate from that point. Each unique primary wave is encoded with a single unit of information namely the location of its origin. This primary wavefront will interact with the boundary of the container generating innumerable secondary waves as it does so. See fig. 2.
Figure 2: A single isotropic sinusoidal wave is emitted from point A. Each reflection event along curve $BB'$ generates its own isotropic wave. From physical measurements, we find that if $x \neq 0$ the statement $AB + BC \neq AB'_1 + B'_1C \neq AB'_2 + B'_2C \neq AB'_3 + B'_3C \ldots \neq AB'_i + B'_iC$ is true. We will observe the nature of the interference patterns for all $0 \leq x < h$ and debate whether the secondary waves re-focus at point $C$ or not.

5 Assumptions

Let us arbitrarily [4] assume the following theoretical truths within the confines of this experiment:

A1. The direction of travel of a sinusoidal wave is always perpendicular to its wavefront.

A2. If multiple secondary waves interfere constructively, then they have travelled equal wavelengths from the source.

A3. From the perspective of a stationary observer, the velocity of a wave is constant under reflection.

5.1 Prediction

Before we commence the experiment, it is necessary to first predict the outcome in accordance with our existing paradigm. Let us do so considering an idealised situation by agreeing that:

1. The water surface is an ideal homogeneous lossless medium
2. The wave we generate is exactly one complete cycle of a sinusoidal travelling wave
3. $\lambda$ remains constant in accordance with the law of conservation of energy [5]
4. The container boundary is perfectly circular
5. Reflections are instantaneous and lossless

From the perspective of a stationary observer, we now combine the geometrical truths of section [3] and the assumptions of section [5] to pledge prediction P1:

In the special case of our geometrically circular container, the innumerable secondary wavefronts will re-combine to full intensity at a single point only in the special case that
the source is located at the geometric center of the container, point $Q$ ($x = 0$). In all other cases ($0 < x < h$), the ripples will interfere destructively with each other creating noise around point $C$.

6 Experimental Results

Now we turn to experiment. A video demonstration may be seen in [this YouTube video](#). If nature is impartial [6], then these results are repeatable in every circular container, anywhere in the universe. The reader is encouraged to perform this experiment for themselves and verify the result. All that is required is a circular platter of water and a steady hand.

We select point $A$ randomly within $BB'$ and gently disturb the surface of the water at that point to initiate a wave. The author claims that practical limitations aside, rather than result in noise and independent of the location of the origin ($0 \leq x < h$), the secondary waves must always recombine to full intensity at a point $C$ that is diametrically opposite ($AQ = QC$) from the source (See fig. 1). If $x \neq 0$, our physical measurements from section 3 have confirmed that $AB + BC \neq AB' + B'C$ and we arrive at the surprising conclusion that if the author’s claim is true, then the waves have travelled unequal distances in equal intervals of time. This difference in path lengths is particularly evident by setting $x \approx h$. In this case we have $AB + BC = 2\sqrt{2}h$ and by a direct route, $AB' + B'C = 2h$.

Let us refer to the author’s claim of constructive interference as the re-focusing of information between points $A$ and $C$ for all $0 \leq x < h$.

7 Discussion

7.1 Breakdown of Symmetry

While this experiment may appear trivial, the theoretical implications of the claim of re-focus over all $0 \leq x < h$ are devastating and lead directly to a breakdown of symmetry in nature. This breakdown is manifest in fundamental, yet most disquieting conundrums that immediately arise, but only in the domain of information flowing through space. Since our wave carries information (sec. 4.1), consider the following question with respect to our water wave experiment:

In the domain of information flowing through space, we have experimental evidence that confirms physical structure $BB'$ is a circle (sec. 3) but also encloses infinite pairs of foci (sec. 6). Now which of the following statements do we assign to be true: A circle is the special case of an ellipse with coincident foci or an ellipse is the special case of a circle having only one pair of foci? The set theory governing the conic sections has broken down.

7.2 On the Need for Skepticism

To suppress such seemingly un-unravelable arguments, we must be vigorously skeptical of claims of re-focus in our experiment and assert that even in a perfect world, the waves do not attain re-focus in a circular container of water for all $0 < x < h$. A thorough skeptic must even claim that prestige is at play and the re-focus claimed in the water wave (WW) experiment is simply a sophistry of light and shadow.

The author presents the arguments of section 8 to 12 to reject any assertion that re-focus does not occur at point $C$. 


8 Generalising Wave Theory

8.1 The Michelson-Morley Experiment

The wave equation,

\[
\frac{1}{c^2} \frac{\delta^2 y}{\delta t^2} = \frac{\delta^2 y}{\delta x^2}
\]  

(1)

governs not only the properties of ideal sinusoidal waves on water, but also that of optical waves travelling through homogeneous space [7]. A little introspection will reveal that the spatial geometry and sequence of events in our experiment is identical to that of a Michelson-Morley (MM) interferometer [8] moving through space under inertial rules. By fixing \( \angle B_1QB_2 = \pi/2 \), line segments \( QB_1' \) and \( QB_2' \) form the arms of the interferometer (see fig. 3). The arms are free to rotate about point \( Q \) and consequently each arm sub- tends its own angle \( \theta \) measured from a perpendicular to line segment \( AC \). The event cycle begins with the source at point \( A \) marking the emission of a pair of photons (wavelength=\( \lambda \)). As the entire apparatus moves with some constant \( AQ = QC \) velocity \( v \) along line segment \( AC \), the photons reflect from mirrors \( B_1 \) and \( B_2 \) to finally arrive simultaneously at point \( C \).

Figure 3: Geometry of the Michelson-Morley experiment depicting the general case \( x \neq 0 \) and \( \theta_2 \neq 0, \pi/2, \pi.. \) Equivalent to our WW experiment, when physically measured we find \( AB_1' + B_1'C \neq AB_2' + B_2'C \) but yet we agree that the outcome is a null result at point \( C \). From the diagram it is evident that \( x, h \) in the WW experiment are equivalent to \( v, c \) in the optical domain.

As is true in our experiment, it is straightforward to recognise that in one informational cycle of an MM interferometer and for all \( 0 \leq v < c \), the locus of all points in space where a reflection event can occur is a circle of radius \( h \) about origin \( Q \). In terms of scope, our simple WW experiment is equivalent to one cycle of an MM interferometer having infinite arms (See fig. 2).

It is also a well established fact of modern science [9] that re-focus of optical information (a null result in interferometry) occurs perfectly in an MM interferometer for all \( 0 \leq v < c \), where \( c \) represents the velocity of light. Let us note here that equivalent to our experiment, a null result in the MM interferometer can only be obtained by invoking the ideal conditions of section 5.1.
Now we reason: If nature is impartial, and all transverse waves are governed by identical equations, then given identical physical interactions within identical spatial geometries, logic dictates that all transverse waves must behave in the same way. Therefore it is illogical to claim re-focus occurs with optical waves in the MM experiment and that it does not for all $0 < x < h$ in an ideal circular container of water.

8.2 Relativity

A skeptic unwilling to concede that perfect re-focus occurs for all $0 < x < h$ must at least stipulate that re-focus occurs perfectly if $x = 0$ and that for all $0 < x < h$, the spatial extent of the disturbance around point $C$ is some function of $x$. If this is true, an observer moving from $A$ to $C$ under inertial rules may measure the extent of this disturbance (commonly referred to in interferometry as the fringe width) around point $C$ and using a stopwatch, estimate their own velocity - thereby violating the principle of relativity [10]. Therefore if we are to respect the principle of relativity, the assertion that re-focus does not occur in our experiment for all $0 < x < h$ must be declared false. This line of reasoning equivalently justifies the null interferometric result of the MM experiment over all $0 < v < c$.

9 Reflection Geometry

The equivalence of these two experiments is also manifest in the peculiarities of the reflection event if $\theta \neq 0, \pi/2, \pi...$ As is true in the case of the MM interferometer, the angles of incidence ($\angle ABQ$) and reflection ($\angle BQC$) are unequal in our experiment as well. On an astronomical scale, this relativistic effect is known as stellar aberration [11] in the optical domain and is proportional to $v/c (x/h$ in our experiment) and $\sin 2\theta$.

10 Relativity of Simultaneity

Another relativistic effect, that of distant simultaneity [12] is also readily discernible in the conduct of our experiment. Consider the spatial and temporal perspectives of two observers separated in the velocity domain. In the MM experiment, the perspective of the moving observer is revealed by setting $v = 0$ ($x = 0$ in our experiment) and that of the stationary observer by setting $0 < v < c$ ($0 < x < h$ in our experiment).

Recall from fig. 1 that if $\theta \neq 0, 2\pi, 3\pi...$ then points $B$ and $B'$ are separated in space from the perspective of both observers. In both experiments, (i) from the perspective of the moving observer ($v = 0$ or $x = 0$), the reflection events from $B$ and $B'$ occur at the same instant in time and (ii) from the stationary observer’s perspective ($v > 0$ or $x > 0$), the reflection events are separated in time as a function of $v$ ($x$ in our experiment) and $\sin \theta$.

11 Dispersion

As the demonstration video clearly shows, the author’s claim that re-focus occurs in the WW experiment over all $0 \leq x < h$ is particularly hard to digest in any situation other than if $x \approx 0$. It is well established that in practice, water waves are far from ideal and among other imperfections, exhibit the property of dispersion. The author presents the following arguments to assert that it is illegal to invoke dispersion to reject the claim of re-focus.
1. It is unscientific to definitively claim that dispersion does not equivalently occur in optical waves. The logical skeptic must always allow for the possibility that we have simply not been able to measure/ theorise it so far. It is possible that nature has equivalently implemented dispersion in the optical plane but the magnitude of this dispersion is too small for our instruments to detect as yet.

2. When we physically measure the dispersion of aqueous waves, we are limited to doing so only through a play of light and shadow. In effect, by being able to measure the changes in wavelength of an aqueous wave seemingly without affecting its properties, we have broken the rules of measurement [13]. In truth, like optical waves, any attempt to directly measure the properties of aqueous waves would result in irrevocable changes to their properties.

3. The equivalence of aqueous and optical interferometry is well established in history and is leveraged in schools [14] and universities [15] all over the world to teach wave theory. Practical effects such as dispersion are never invoked to falsify the ideal conclusions from these experiments, therefore I contend it is illegal to invoke these effects here simply because we are uncomfortable with the ideal outcome.

12 Domain of Testing

In our WW experiment, it is elementary to reject the phenomena of re-focusing over all $0 \leq x < h$ by simply shifting the origin point away from point $Q$ and calling attention to the large extent of disturbance around point $C$. Recall however, that in optical interferometry, the MM result has at best only been tested in the order of $v \leq c/10^3$ i.e. relative to the CMB rest frame. Yet we have accepted the MM result over all $0 \leq v < c$. A fair testing of re-focus in the WW experiment therefore must be equivalently limited to the order of $x \leq h/10^3$.

13 General Relativity vs the Symmetry of Nature

In optical interferometry, this paradox of unequal path lengths is traditionally resolved by the application of GR [2]. A theory that under inertial rules and for all $0 < v/c < 1$, predicts the existence of measurable effects on space and time known as lorentz contraction and time dilation. In the optical domain, both these relativistic effects are widely acknowledged to physically exist[10] [17].

However as far as aqueous interferometry is concerned, and for all $0 \leq x/h < 1$, it is elementary to establish with only a marketplace stopwatch that (i) the time interval $t$ taken from emission to re-focus is a constant showing that an aqueous equivalent of time dilation does not exist and (ii) An aqueous equivalent of lorentz contraction is also demonstrably absent.

At this juncture the conflict between the results of our experiment, the predictions of GR and the symmetry of nature becomes self evident. Given,

1. Identical governing equations and identical sequences of events within identical spatial geometries,
2. Equivalent and readily measurable everyday effects such as reflection, refraction, diffraction and interference,
3. Equivalent and readily measurable relativistic effects of sections 9 and 10,

we must ask ourselves, has nature abandoned her impartiality and preferred not to equivalently implement the relativistic effects known as lorentz contraction and time dilation in the aqueous domain?
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Should the reader remain adamantly skeptical of the claims presented so far, they must contend with the following argument:

If (i) there exists an equivalence between optical and aqueous interferometry and (ii) the form and premise of any assertion to reject re-focus in the WW experiment is true, then *reductio ad absurdum*, this assertion may be equivalently applied in the optical domain to reject the null interferometric result of the MM experiment.

Therefore if the theoretical arguments of sections [8] [9] and [10] remain unfalsified and we acknowledge that practical limitations (secs. [5.1] and [11] read in conjunction with sec. [12] will equivalently degrade the ideal outcome of both these experiments, we are faced with a choice:

1. Accept that re-focus occurs equivalently in both WW and MM experiments or
2. Equivalently reject the null result claimed in both experiments

To arbitrarily declare that a null result occurs in MM experiment and not in the WW experiment simply because we are unable to theorise the latter would represent a gross violation of impartiality on our part.

15 Conclusion

Finally, we are left a curious new question, how do we resolve the paradox of unequal path lengths in our water wave experiment? Perhaps there exists a general solution that is compatible with both aqueous and optical waves?

16 Statements and Declarations

The author has no competing interests to declare that are relevant to the content of this article. There are no data associated with this article.

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