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The Theory of Elementary Waves (TEW) eliminates Wave Particle Duality

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ABSTRACT

Wave particle duality is a mistake. Another option was neither conceived nor debated, which is a better foundation for quantum mechanics. The Theory of Elementary Waves (TEW) is based on the idea that particles follow zero energy waves backwards. A particle cannot be identical with its wave if they travel in opposite directions. TEW is the only form of local realism that is consistent with the results of the experiment by Aspect, Dalibard and Roger (1982). Here we show that 1. although QM teaches that complementarity in a double slit experiment cannot be logically explained, TEW explains it logically, without wave function collapse, and 2. gives an unconventional explanation of the Davisson Germer experiment. 3. There is empirical evidence for countervailing waves and particles and 4. zero energy waves. 5. TEW clarifies our understanding of probability amplitudes and supports quantum math. 6. There is an untested experiment for which TEW and wave particle duality predict different outcomes. If TEW is valid, then wave particle duality is not necessary for quantum math, which is the most accurate and productive science ever. With a more solid foundation, new vistas of science open, such as the study of elementary waves.

Indexing terms/Keywords

Foundations of quantum mechanics; Wave particle duality; Theory of Elementary Waves

Academic Discipline And Sub-Disciplines

Physics, Quantum Physics, Foundations of quantum mechanics

SUBJECT CLASSIFICATION

Library of Congress Classification #'s for Quantum Theory are from QC173.96 to QC174.52

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TYPE (METHOD/APPROACH)

This article presents a provocative new theory of the relationship of waves and particles: a paradigm shift. It draws on published experiments in physics, and presents also the design of a proposed research study, never performed, which could answer fundamental questions about the direction of waves versus particles. The primary purpose is to stimulate new research.

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INTRODUCTION

The Theory of Elementary Waves (TEW) starts with the idea that particles follow zero energy waves in the opposite direction [1-5]. In the history of quantum mechanics (QM) many peculiar ideas have been discussed, including the idea that physical reality independent of the observer does not exist [6-8]. At first TEW sounds like another harebrained idea. From a commonsense point of view, TEW is worthy of attention: it is the only current theory that rescues the physical world from nonexistence, and can explain logically a long list of empirical data, weird ideas, and problems.

When the Aspect, Dalibard and Roger experiment was published in 1982 [9] it was thought to be the death knell for local realism, but that is not true. It was the death knell for Einstein's hidden variables [10-13], which were the only form of local realism possible if you assume that waves and particles travel in the same direction. Once that assumption is challenged, the evidence against it outweighs the evidence for it, as we will show. Collapse of that assumption leads to TEW which is the only local and realistic picture of the quantum world that is consistent with the results of the Aspect experiment [14]. But TEW still sounds harebrained compared with how physicists currently think, which is what a paradigm shift feels like. Refuse to consider dingbat ideas that explain so much of the physical world as we know it, and you will protect science from paradigm shifts [15].

A particle can only strike a detector if it is following backwards a zero energy elementary ray emanating from that detector, according to TEW. Particles carry all the momentum & energy. There is also an advanced level of TEW that explains the Bell test experiments such as that of Aspect 1982. Every elementary ray has a mate: a coaxial ray of the same frequency traveling in the opposite direction. Two "entangled" photons are each following the same bi-ray. Experimental support for these ideas will emerge.

1. COMPLEMENTARITY IN A DOUBLE SLIT EXPERIMENT

Quantum mechanics teaches that there is no logical explaination why we can see an interference fringe pattern on the screen of a double slit experiment, or know through which slit the particle went, but not both. TEW provides a logical explanation that was not previously considered. If you think of waves as traveling in the opposite direction as particles, then interference precedes the particle firing, and is located in the neighborhood of the particle source. In other words, scientists have been looking in the wrong place for the interference in Thomas Young's experiment. Young pictured the interference as being located on the wrong side of his double slit barrier.

Elementary rays from the two different detectors behave differently as they pass backwards through the barrier and impinge on the particle source. One detector is the target screen, every point of which emanates elementary waves in all directions. Two parts of the same wave pass backwards through the two slits and interfere as they converge on the particle source, let's say it's an electron gun. An electron will only follow a ray whose frequency is $\nu = E / h$ (de Broglie's equation). The probability of an electron following such a ray backwards is proportional to the probability amplitude of the ray, squared. This is calculated using familiar math based on the difference in path length of the ray from the screen through slit B versus slit A, as compared to wavelength: the same math already used by QM, even though QM pictures the waves traveling in the opposite direction, and pictures interference as being located on the wrong side of the barrier.

If an electron is triggered, it follows its ray backwards with a probability of one, through one of the two slits, it doesn't matter which, and strikes the screen at that point from which its wave emanated. No interference after the electron is fired has any impact. Since each electron has a trajectory, there is no need for the concept of wave function collapse. Therefore Schrödinger's cat, Wigner's friend, parallel universes and other weird ideas vanish.

The other type of detector is a "which way" detector, so constructed that it can see only one of the two slits. An elementary ray from that detector passes backwards through slit A but has no twin through slit B and therefore no interference as it approaches the electron source. If an electron randomly chooses to follow that ray, the signal will contain no evidence of interference for the simple reason that there was no interference. Thus the use of two detectors (screen and "which way") means we conducted two unrelated experiments. The electron seen at the target screen is different than the electron seen by the which-way detector.

How can detectors, which radiate negligible energy, be the source of elementary rays? Everywhere in space, in all inertial frames there are rays of all wavelengths traveling in all directions at the speed of light. We will produce evidence that zero energy waves exist and have an impact.

More information about TEW

TEW is a probabilistic, local, realistic theory of the quantum world, unrelated to Einstein's hidden variables. There are no variables hidden inside particles; rather different particles are following different trajectories (elementrary rays). Clauser, Horne, Shimony and Holt (CHSH) published a version of the Bell inequalities, that provided the blueprint for the Aspect study. We showed in a previous publication that these Bell inequalities do not apply to TEW, because the local realism of TEW does not involve Einstein's hidden variables. TEW doesn't sneak through some loophole in Bell's Theorem. Rather TEW is not under the jurisdiction of Bell's Theorem. TEW is a type of local realism never envisioned by Einstein, Bell nor CHSH. TEW violates the CHSH inequality, yet is local and realistic!

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TEW is also unrelated to the Wheeler Feynman absorber theory [15], any theory involving backwards in time waves, or any interpretation of QM. Time always goes forwards in TEW.

Why do particles follow zero energy waves backwards? That is just the way nature is rigged up. The waves don't push or pull; they do no work. They are like pathways. If you are walking in the woods and come to a branch in the trail, would you choose the main trail, the path less travelled, or would you abandon both paths and bushwhack? Whichever you choose, the path contributes no energy to your decision. The trail analogy is passive, whereas elementary waves are dynamic: moving towards you at the speed of light. As environmental conditions change, the trail system changes. If the trailhead toward which you are hiking ceases to exist, the trail you are following might change or cease to exist.

Elementary rays do not move in a medium. They are the medium, somewhat like the canvas upon which reality is painted. Like any productive theory, TEW raises more questions than it answers, by a ratio of a hundred to one.

2. THE DAVISSON - GERMER EXPERIMENT

Clinton Davisson received a Nobel Prize in 1937 for the discovery of the diffraction of electrons by crystals, thereby proving wave particle duality [16-18]. He and Lester Germer fired electrons of different voltages at a nickel crystal lattice, and set a voltmeter at a variety of angles to detect the electron scatter. At most voltages and most detector angles, nothing remarkable was noted. However when the crystal was rotated to the A-azimuth and the electrons emitted at 54 volts, there was a spur in the output curve of data at detector angle $\theta = 50^o$ which is how XRays of wavelength $\lambda = 1.65$Å would refract: a Laue pattern. The data can only be explained if electrons are strongly influenced by such waves [15]. This was thought to confirm the de Broglie hypothesis [19].

In the first half of the twentieth century no one ever imagined, nor did they discuss the possibility of waves traveling in the opposite direction as particles. Their debates about wave particle duality never ruled out that possibility. Is it reasonable to dismiss TEW as preposterous when TEW is based on a thesis that was never even considered, nor was there any discussion of why this thesis was ignored? Davisson-Germer's data do not tell us which direction the waves are traveling. The data are consistent with the TEW thesis that rays of $\lambda = 1.65$Å from the detector refract through the crystal, impinge on the electron source, and electrons follow them backwards.

3. COUNTERVAILING WAVES AND PARTICLES

There are two interferometer experiments that yield results that are more consistent with TEW than with wave particle duality. One involves neutrons, the other is a *gedanken* ("thought") experiment designed by John Wheeler.

The first was published by Kaiser, Clothier, Werner, et. al. in 1992 [20]. They were part of Helmut Rauch's team establishing the foundations of neutron interferometry [21]. They stumbled upon the data below and chalked them up to Wheeler's smoky dragon because the phenomenon could not be explained by quantum mechanics.

A neutron beam of wavelength $\lambda = 2.35$Å enters the interferometer, is split into an upper and lower beam, which are recombined before leaving the interferometer. Downstream from the interferometer a ^{3}He detector records data. When the researchers place a sample of bismuth inside the interferometer, in the path of the upper beam, it slows that beam so it is no longer in phase with its twin. When the two beams recombine there is interference. The more millimeters of bismuth added, the more delayed is the upper neutron beam. With enough bismuth, say a sample of 10 or 20 mm, the delay is so long that the lower neutron wave packet leaves the interferometer before the upper wave packet arrives at the reunion site. So all interference vanishes. A wave packet is 86Å long whereas 20 mm of bismuth delays the wave packet by 435Å.

However, if a pressed silicon analyzer crystal is inserted in an {111} antiparallel configuration ($\theta_A = 22.0^o$) in front of the detector, robust interference inside the interferometer is restored, even with 20 mm of bismuth! The presence or absence of interference inside the interferometer is controlled by what happens downstream and outside the interferometer! The researchers say they cannot explain this.

The TEW explanation is that zero energy rays emanate from the ^{3}He detector and travel backwards through the interferometer. The analyzer crystal is upstream from the interference. A pressed silicon analyzer crystal increases the coherence length of a wave packet from $\Delta x = 86$Å to $\Delta x = 3450$Å which is more than enough to penetrate backwards through a full sample of bismuth that could only delay the beam by 435Å maximum. The two beams recombine, interfere, and exit through the front door of the interferometer. The ray then enters the nuclear reactor, connects with a disintegrating atom, and a neutron may at random choose that impinging ray to follow backwards. The neutron is then recorded by the ^{3}He detector, thereby making the interference visible. It is the ray that is subject to interference, not the neutron.

Wheeler's *gedanken* experiment

The second experiment that is more consistent with TEW than with wave particle duality is a 2007 publication by

Jacques, Wu, Grosshans, et. al.[22-23] which gives the results of a delayed-choice thought experiment designed by Wheeler [24]. Wave particle duality proposes that a quantum of energy behaves either as a wave or a particle, depending on how it is observed. Wheeler's idea was to put such a quantum into an interferometer, where it would choose at the beginning whether to traverse the interferometer on both paths (as a wave) or on only one of the paths as a particle would do.

There is delayed choice. When the quantum of energy enters the interferometer, it has yet to be decided how it will be observed. Then, while the quantum is traveling through the interferometer, it is randomly decided whether to test it as a wave or a particle when it reaches the exit of the interferometer.

Wheeler's prediction was a paradoxical one: that the usual rule would apply. If you test it as a wave it will be a wave, if you test it as a particle, it will be a particle. This is paradoxical because it implies backwards in time cause and effect: when a quantum of energy enters the interferometer it will make the "correct" decision about how to behave based on accurate anticipation of whether it will later be tested as a particle or wave.

Jacques, Wu, Grosshans, et. al. built the interferometer that Wheeler described, and confirmed Wheeler's prediction. They built an elongated Mach-Zehnder interferometer 48 meters wide. It took a quantum of energy 160 ns to traverse. A switch called the "EOM" randomly switched every 40 ns between measuring the quantum as a wave or a particle. When the experiment was conducted, the data showed that if you look for a wave you find a wave, and if you look for a particle you find a particle, as Wheeler predicted.

The TEW interpretation is simple. The data indicate that both waves and particles (two different things) are simultaneously present. There is no evidence that one is changing into the other. Since the photon particles account for all the energy, the waves must carry no energy. This is a simple and obvious interpretation of the data. Any other interpretation fails to stick to the data.

How do the researchers explain the results? They say, "Our realization of Wheeler's delayed-choice *gedanken* experiment demonstrates that the behavior of the photon in the interferometer depends on the choice of the observable that is measured, even when that choice is made later in time." They endorse Wheeler's idea of backwards in time cause and effect. "Once more, we find that nature behaves in agreement with the predictions of quantum mechanics even in surprising situations."

When we compare the TEW explanation to the explanation by Jacques et. al., the first is a straightforward description of what the data say, whereas the latter is convoluted and far fetched even by their own standards.

4. ZERO ENERGY WAVES

Einstein pondered zero energy waves, which he called "ghost fields" (German: *Gespensterfelderi*) [25]. What bothered Einstein was that zero energy waves could never be seen because they have no energy to make a detector "click." TEW solves that problem because particles carry all the energy and momentum to make detectors "click," but particles always follow one ray or another backwards. There are rays without particles but never particles without a ray.

Consider the Purcell effect [25-27]. When an excited Rydberg atom is placed in a resonant cavity, the rate of decay can be 500 times the rate of decay in free space, if the diameter of the cavity is a multiple of λ, where λ is the wavelength of a photon emitted when the outer electron falls to a lower energy orbit [28]. A mode of the cavity conveys no energy. Yet this thing of zero energy affects the decay of an atom! How does an atom know that it's surrounded by a cavity, much less a cavity of the right diameter? In TEW, elementary rays from the cavity, with wavelength λ impinge on an electron, offering it pathways that could be used at random to fall to a lower energy orbit and emit a photon following the ray backwards. What physicists call a "mode of the cavity," TEW calls an elementary ray.

Franco Selleri (1936-2013) wrote more about zero energy waves than anyone else. He called them "empty waves."[29] Two lasers were arranged by Pfleegor and Mandel so their beams crossed [30-33]. An interference fringe pattern appeared on a photographic plate at the intersection. The intensity of the lasers was turned down until only one photon (from one laser or the other) was emitted at a time, and then a pause before another photon was emitted. The interference fringe pattern at the intersection continued to be visible if the photographic film remained there long enough. The photons made the interference visible. Empty waves explained how there could be interference when no photon or only one photon was present. Particles carried all energy and momentum in Selleri's model [34]. It never dawned on him that waves and particles might travel in opposite directions.

5. TEW AND QUANTUM MATH

In TEW math has a foundation in physical reality. Consider a probability amplitude $\mathbf{A} = |\mathbf{A}|\, \mathbf{e}^{i\theta}$. Picture an elementary ray as a helix that twists like a corkscrew as it moves forwards. The physical analog of the modulus $|\mathbf{A}|$ would be the square root of the probability of a particle following that ray. The phase θ would be the angle of rotation of the corkscrew.

Helical probability amplitudes come from Feynman's book *QED*, but Feynman pictured them traveling in diametrically the wrong direction [35].

TEW also explains the Born rule. Consider a bi-ray in advanced TEW. The probability of a photon following the bi-ray is the probability amplitude |**A**| of one ray multiplied by that of its mate. They both have the same probability amplitudes. So the product is $\mathbf{P} = |\mathbf{A}|^2$.

In the introductory level of TEW the waves travel in the opposite direction as what is commonly thought. Schrödinger, Klein Gordon, electromagnetic and other wave equations would be the same, since wave equations don't change if the direction of the waves is reversed. Even equations describing irreversible processes because of a loss of energy or increased entropy would be the same because energy is carried by particles, not waves, in TEW. Particles in TEW travel in the same direction as particles in QM.

6. A PROPOSED EXPERIMENT

Since TEW and QM almost always predict the same outcome from experiments, it is hard to design an experiment for which they predict different outcomes. Here is one, never conducted. In a double slit experiment QM says no interference exists prior to electron emission. TEW says no interference that occurs after electron emission has any relevance. Therefore we will divide time: before versus after electron emission. This experiment is easy to imagine but hard to design. We need some way to obstruct slit B at about that nanosecond when an electron is fired. Therefore, prior to electron firing there are two slits, but by the time the electrons reach the barrier, only slit A is open. There is a pause between electrons, during which slit B is re-opened. Outcome data consist of what appears on the screen.

Prior to electron emission, when both slits are open, TEW says that each point of the target screen radiates waves independent of the waves from each other point. There is no such thing as a plane wave. Two parts of the same wave penetrate backwards through the two slits, and those two rays interfere as they converge on the electron source. At random an electron chooses one ray to latch onto. Then slit B closes. An electron will carry the pattern of that interference whether it travels towards slit A or B. The electrons heading for slit B are blocked. But the interference fringe pattern is still carried by the electrons going through slit A. The pattern is not carried as hidden variables inside the electrons, but consists of the different pathways that the different electrons are following. Therefore there will be ½ an interference pattern (ripples) on the target screen, skewed toward the slit A. Thus there is a way to see an interference fringe pattern AND also to simultaneously know through which slit the electron penetrated, contrary to what complementarity says is possible.

According to QM interference will not occur because no electrons penetrate slit B. Therefore only a vertical line will appear on the target screen.

Trying to design equipment such that slit B could close before an electron gets there, is tricky. One could for example place a laser above slit B pointing down, but given the delay time in firing a laser, and the brief number of nanoseconds between an electron firing and its arrival at the barrier screen, the timing of the experiment is the key to this experiment's success.

CONCLUSION

This article presents a snapshot of TEW, a theory that is consistent with quantum math but inconsistent with wave particle duality. We have presented experimental results that support TEW, plus one experiment never performed which would produce different outcomes depending on which way waves travel. If there is validity to TEW, then wave particle duality is not necessary for quantum math. It is akin to a railroad tie that no longer supports any weight and needs to be replaced.

It is likely that many readers continue to feel that this article presents harebrained ideas. Every paradigm shift appeared harebrained at the time. Whether TEW is harebrained is irrelevant. The question is whether it corresponds to empirical data, and most of those data do not yet exist. Even if this article is 99 % baloney, it will have served a purpose if it stimulates new research.

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Some ideas in this article are based on my interpretation of Lewis E. Little's TEW theory as of 2012 conversations he and I had.

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Dr. Boyd was born in 1943 in New Jersey, USA. Boyd's undergraduate degree in mathematics was from Brown University. He has advanced degrees from Harvard, Yale and Case Western Reserve Universities, served on the faculty of the National Institutes of Health for 7 years, and has been on the faculty of the Yale Medical School. His day job is as a physician, which is fortunate because he need not fear he is risking a career in physics by speaking in public about these controversial ideas. Boyd retired after a quarter century at Waterbury Hospital, Waterbury CT, a Yale teaching hospital. He has published in the New England Journal of Medicine and Physics Essays.