



A paradigm shift in mathematical physics, Part 3: A mirror image of Feynman's quantum electrodynamics (QED)

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ABSTRACT

Richard Feynman's book *QED*, written for a lay audience, is a trusted source of information about Quantum Electrodynamics by a Nobel laureate. It is a mirror image of the Theory of Elementary Waves (TEW), discovered by Lewis E. Little. Recent work on TEW, published in this journal, shows that an elementary ray has the shape of a cylindrical helix traveling in Euclidean space, with a complex amplitude. This is an analog in physical nature of Feynman's mathematical concept of an amplitude, which is the core of QED. The only substantial difference is that an amplitude is assumed by Feynman to travel in the same direction as the particle, but in TEW they travel in opposite directions. There is almost no empirical data to resolve that disagreement. Such evidence as exists favors the idea they travel in opposite directions. If we modify Feynman's QED in this way we end up with a theory symmetrical to QED. We nickname it *QÆD*, using the letter Æ to symbolize an ælementary ray. *QÆD* is a fountain of information about the nature of elementary rays, and resolves some of the problems that Feynman said he found in QED.

Indexing terms/Keywords

Theory of Elementary Waves; TEW, Lewis E Little; local realism; Richard P Feynman; quantum electrodynamics; quantum amplitude; time reversal; double slit experiment

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This is the third in a series of articles on the mathematics of the Theory of Elementary Waves. Here we present Richard P. Feynman's concept of an amplitude in Quantum Electro-Dynamics. Feynman wrote of an amplitude $A = |A| e^{i\theta}$, being akin to the hand of a clock, spinning 14,000 times per centimeter for red light. The clock moves through Euclidean space from the photon source to the detector. This implies a cylindrical helix etched by the tip of the arrow. Such a cylindrical helix exactly fits the best available images of an elementary ray, although Feynman's amplitudes and elementary rays travel in opposite directions. The reversal of directions makes no difference mathematically. With this tiny modification of QED, it becomes a rich source of information about elementary rays.

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INTRODUCTION

This is the third in a series of articles introducing the mathematics of the Theory of Elementary Waves (TEW).[1-2] An elementary ray is the physical analog of a quantum amplitude,[3-8] which is the square root of a probability, and is the building block of all quantum math, including Quantum Electro-Dynamics (QED).

TEW is a new universe of notation and equations. An elementary ray is symbolized by \mathcal{A} . Any mathematician who ventures into TEW might as well be jumping down Alice's rabbit hole into Wonderland. That takes either blind courage or stupidity. Most mathematicians would prefer a step-wise development of the assumptions and logic. In this article we will develop a cautious and methodical entrance into the mathematics of TEW, by entering through a well-known, trusted, and fruitful area of quantum math.

Richard Feynman's tiny book *QED: the strange theory of light and matter*, presents a picture of Quantum Electro-Dynamics that is astonishingly close to TEW, although of course they are mirror images.[9] Our plan is simple. In part 1 of this article we will present a picture of how reality works according to Feynman. In part 2 we will swing an axe and remove from QED the assumption that waves and particles travel in the same direction. Then, may the chips fall where they may! Part 3 will discuss experiments for which QED and TEW predict different outcomes. Although the two theories have pervasive symmetry, there are some small differences that can be tested in the lab. We hope to inspire experimental physicists to resolve that disagreement about the direction of an amplitude vis-à-vis its particle.

Why would we modify QED in this way? Because of our allegiance to empirical data. There are no empirical data that support wave particle duality, as we showed in the second article of this series. The same is true of the dogma that waves and particles travel in the same direction. What little empirical data we have supports the idea that waves and particles travel in opposite directions. Therefore when we modify QED in Part 2 of this article, one of our goals is to bring QED into closer alignment with experimental data.

Feynman is not ultimately interested in a picture of nature and how it functions. His goal is to compute an amplitude that takes into account ALL the different ways something might happen. His approach is called the path integral approach, and is one of the three equivalent schools of mathematics used in quantum mathematics (QM). The Holy Grail of all schools of quantum math is computing an "observable." That is a complex number that magically pops out of quantum equations. That number predicts how an experiment or a new technology will function in the future. If you use a smart phone or a microchip, then you are benefiting from the harvest that has come from the use of QM observables. Our high tech economy has been built using such observables.

Feynman says, "It is to be emphasized that no matter how many arrows we draw, add, or multiply, our objective is to calculate a *single final arrow for the event*." That final composite arrow is so important because that is the total amplitude, which is the observable, which is the goal and purpose of quantum math.

We define QM as the science of observables. TEW seeks to be the corresponding science of physical nature independent of the observer. In our view QM and TEW complement and need each other, although we reluctantly note that they have some unavoidable areas of disagreement.

The unique peculiarity of all three schools of quantum math, compared to the math of all other sciences, is that QM is the only one based on amplitudes instead of probabilities. Prior to TEW no one had any idea why this was true. TEW says it is true because elementary rays and quantum amplitudes are two perspectives on the same thing. This "thing" is simultaneously the central focus of QM, QED, TEW and QÆD.

Part 1: Feynman's teaching

1.1 A complex amplitude, moving at the speed of light

Feynman's book is addressed to a lay audience that is math phobic. Therefore he breaks down concepts such as a complex vector into simplified ideas that will not spook his audience. He speaks of "little arrows" spinning rapidly like the hand of a one-handed clock. That is not the best way to present Feynman to an audience of mathematicians. Therefore we will present his thinking in a more abstract and elegant format.

Feynman wrote of an amplitude $\mathbf{A} = |\mathbf{A}| e^{i\theta}$ spinning 14,000 times per centimeter for red light. It moves out from the source at the speed of light. He pictured the vector \mathbf{A} as being the hand of a clock, while the clock face moves at light speed through Euclidean space, from the photon source and towards the detector. The tip of that hand inscribes a cylindrical helix (Figure 1). He tried to teach a lay audience about the properties of "little arrows" as he called them, each of which has a length $|\mathbf{A}|$ and an angle of rotation θ . A "little arrow" \mathbf{A} adds to another "little arrow" \mathbf{B} the way complex vectors add ($\mathbf{A} + \mathbf{B}$), and ditto for multiplying two "little arrows" ($\mathbf{A} \cdot \mathbf{B}$).

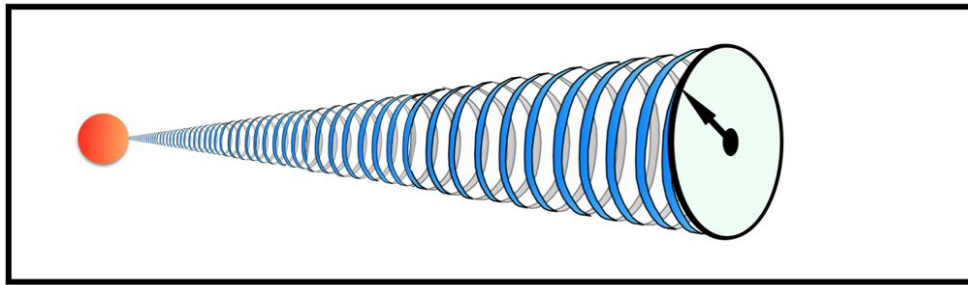


Fig 1. Feynman's amplitude: a little arrow spinning as the center of the clock moves at light speed

Figure 1 shows a Feynman clock face moving out from a red photon source. You can see a complex vector **A**, which is the hand of the clock, while the clock face moves at the speed of light.

Amplitudes follow the same kind of rules as do probabilities, even though amplitudes are not probabilities: they are the square roots of probabilities. If something can happen in two mutually exclusive ways, **A** or **B**, then you add the amplitude for one to the amplitude for the other: **(A + B)**. If there is a sequence of things that happens, first **A** then **B**, you multiply the amplitudes: **(A • B)** to calculate the overall amplitude. All the peculiarities of QM, all the weirdness, compared with other sciences, arise from this use of amplitudes. For example, if you square **(A + B)** you do NOT get the sum of two probabilities:

$$\text{Prob (A)} + \text{Prob (B)} \neq |(\text{A} + \text{B})|^2.$$

Since a two dimensional piece of paper is not intimidating to lay people, Feynman patiently explains addition and multiplication by means of how arrows look on a piece of paper. For addition of two amplitudes you hook the bottom of one arrow to the top of the next one, then figure out how long the resulting tangent would be. For multiplication he teaches a "shrink and turn" method that we won't describe here because it is confusing, and all it comes to in the end is the dot product of two complex vectors.

Chapter one of Feynman's book talks extensively of reflections off a piece of glass. If 4 % of incident light is reflected off the top of a piece of glass, that is an amplitude of $0.2 = \sqrt{4\%} = \sqrt{0.04}$. Similarly the amplitude for reflection off the bottom of the piece of glass is 0.2. When light reflects off glass, you must add together the amplitudes of the top and bottom reflections: **A+B**. So how do we add together an amplitude of 0.2 with another amplitude of 0.2? It depends on the phase θ_1 of the top vector **A** relative to the phase θ_2 of the bottom vector **B**. If they are completely in phase ($\theta_1 = \theta_2$) the answer is 0.4 derived thus in Feynman's book: $0.2 + 0.2 = 0.4$. If the phases differ by π , for example ($\theta_1 = \theta_2 \pm \pi$), then the answer is zero, derived thus: $0.2 - 0.2 = 0$. To avoid spooking his lay audience, Feynman always uses the geometric approach to vectors similar to the way the ancient Greek mathematicians reasoned. Addition consists of moving the second "little arrow" to start at the head of the first "little arrow." He avoids talking about Cartesian or polar coordinates lest his audience flee the auditorium.

If we conduct experiments on a series of pieces of glass of increasing thickness, then the percentage of light reflected will vary from 0 % to 16 % as a sinusoidal curve depending on the thickness of the glass. As the glass gets thicker the reflected light dies out to zero again, then with more thickness it climbs to 16 %, then sinks to zero, etc. This illustrates how much it matters whether the clock faces ("little arrows") from the top and bottom amplitudes are in sync with one another. What determines the direction of one clock arrow versus the other clock arrow is how much further light has traveled to get to the bottom of the glass, versus the top. Central to Feynman's thinking is the idea that clock faces are in sync, almost in sync, or out of sync. This is central to Feynman because if you add vectors that are out of sync then they cancel each other out, whereas if you add vectors in sync they will result in a substantial final vector, which is going to be your "observable."

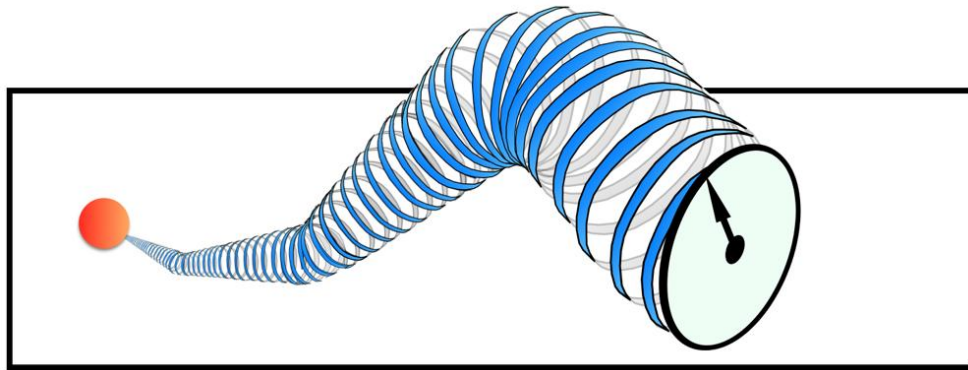


Fig 2. Light need not travel in a straight line, nor at a uniform velocity in Feynman’s world

Light often does not travel in a straight line (see Figure 2) in Feynman’s world. What makes nature appear to be so uniform, with light usually going in straight lines? The fundamental laws of nature are not geometric (such as straight lines) but probabilistic. If a photon can travel from the source S to a detector D by a variety of paths, you must add the amplitudes of all possible paths to determine the overall amplitude of its arrival at D. When amplitudes add, it requires vector addition of the hands from different clocks. The sum is greatly affected by the angle of the hands relative to neighboring clocks: whether they are in sync. If a set of clocks travel different distances their hands will be in disarray relative to each other, and vector addition ends up with a magnitude of about zero. But if a cluster of clocks has their hands pointing at a similar angle, almost in synchrony, then they will add together to a higher total. Since these clocks rotate so fast (14,000 revolutions per centimeter), only clocks that travel almost on straight lines and identical distances will meet that criterion. In other words, the physical world as you experience it is sculpted by and shaped by amplitudes, and the amplitudes only work when dozens of little clocks are in sync.

Feynman says: “It may surprise you that there is an amplitude for a photon to go speeds faster or slower than the conventional speed. The amplitudes for these possibilities are very small compared to the contribution from speed c ($c =$ speed of light); in fact they cancel out when light travels over long distances. However when the distances are short . . . these other possibilities become vitally important and must be considered.”

There are a lot of wrinkles in physical reality at the atomic scale that get ironed out at the human scale, i.e. the scale of classical physics. Light is wiggly at the Angstrom scale, but straight on a centimeter scale. Also polarization: at the atomic scale there are four states of polarization of photons, of which the most important is time polarization. At the scale of classical physics there are only two such states: either horizontal and vertical, or circular polarization clockwise and counterclockwise.

Another Feynman rule is that it is not the shortness of the overall trajectory that dominates the calculation. It is the total amplitude. This principle is illustrated in Figure 3, which shows photons traveling from the source S, through a gap in a barrier, then hitting detectors P or detector Q.

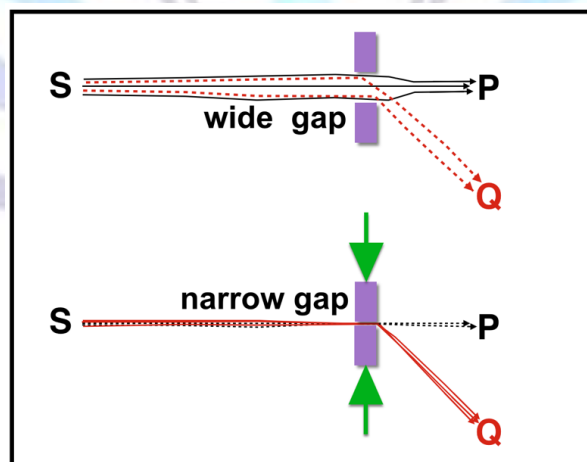


Fig 3. With a wide gap no photons go to Q. With a narrow gap Q clicks as often as P.

With a wide gap (Figure 3 top) most photon paths that arrive at P have gone almost the same distance, which means the clock faces of different rays will be almost synchronous. Therefore the amplitudes add up to a substantial total amplitude. With the same wide gap (Fig 3 top) the distance from the gap to detector Q varies considerably depending where the photon trajectory went through the gap. The top of the gap is further from Q. The bottom of the gap is closer. Therefore the clock faces are in disarray relative to one another when they arrive at Q. They add up to about zero. Therefore no photons arrive at detector Q. Photons are obedient to amplitudes.

If you narrow the gap (Figure 3 bottom) so that almost all photon trajectories go through the gap at the same point on the vertical axis, then detector Q clicks as often as P clicks. This means that as many photons go to Q as go to P. Why? Because the distance from the gap to Q is constant, so the clocks arrive at Q in sync, with a result that the amplitudes add up to a substantial overall amplitude. Since it is total amplitude and not distance that determines where the photons are detected, therefore Q clicks as often as P! Amplitudes, not geometry, shape the world we live in. Geometry such as straight lines becomes important only when it affects amplitudes. The world is sculpted and shaped by amplitudes.

Figure 4 displays another example of how the clock faces need to point in the same direction if photons from the source S can be seen at a detector P. On the left side of Figure 4 photons traveling from S to P make a sharp turn at the blue line called "M." Don't worry about why they make such a sharp turn. Since the distances from S to P vary depending on which route was used, when those amplitudes arrive at P the clock faces are in disarray and therefore the amplitude for a photon from S to arrive at P is small.

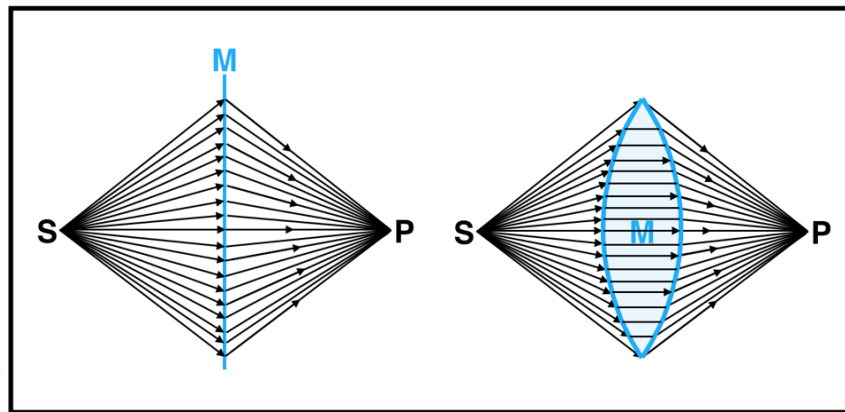


Fig 4. Photons arrive at P with different clock faces unless a lens is inserted (M on right)

However, we can trick nature. We know that photons travel slower in glass than in air. Suppose we calculate the amount of time it takes a photon to go from S to P along the top or bottom trajectory (i.e. the greatest distance), and we insert a piece of glass in the middle trajectories that exactly compensates for that delay. The piece of glass we need to insert has the blue shape shown in Figure 4–right, named "M." With that piece of glass in place, all trajectories take exactly the same amount of time, and therefore all the clock faces arriving at P are in sync. Therefore we obtain a large total amplitude, meaning a photon is very likely to be seen at P.

If you now look at the blue object in Figure 4–right you will discover that we have made a focusing lens!

1.2 Electrodynamics

Feynman claims that all of chemistry, biology, and solid state physics can be boiled down to three actions. The only parts of nature not encompassed by these three actions are nuclear forces and gravity. The three actions are:

- A. A photon goes from place to place.
- B. An electron goes from place to place.
- C. An electron emits or absorbs a photon.

What are the amplitudes for these three actions? When a photon travels from point 5 to point 6 that goes by the symbol $P(5 \text{ to } 6)$. When an electron does, the amplitude is symbolized by $E(5 \text{ to } 6)$. The amplitude for the third action, emission of absorption of a photon, goes by the symbol j meaning "junction," and j has an amplitude value about -0.1 .

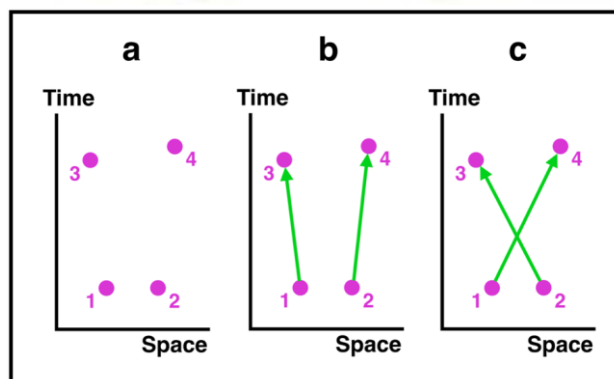


Fig 5 Electrons from 1 and 2 can go to points 3 and 4 in two different ways: 5-b and 5-c

Now let's develop a slightly more complex model that can be tested in a physics laboratory. Our research question is: "What is the total amplitude for two electrons traveling from points 1 and 2 to points 3 and 4?" The graph we will use is Figure 5-a, which is a Feynman diagram, meaning that time is plotted against space. Electrons will be graphed as straight green lines and photons as wavy red lines. Feynman diagrams are primarily a visual way to keep track of dozens of equations, as you will discover.

There are two ways that the two electrons can travel from points 1 and 2 to points 3 and 4, and those are graphed in Figure 5-b and 5-c. Because the research question can be answered in those two ways, therefore we need to add together the two amplitudes:

$$E(1 \text{ to } 3) \bullet E(2 \text{ to } 4) + E(1 \text{ to } 4) \bullet E(2 \text{ to } 3) \tag{1}$$

However, there is a problem. When we compute equation 1 the results are way too low by comparison with laboratory data. Clearly something more is happening in nature than in our model. What?

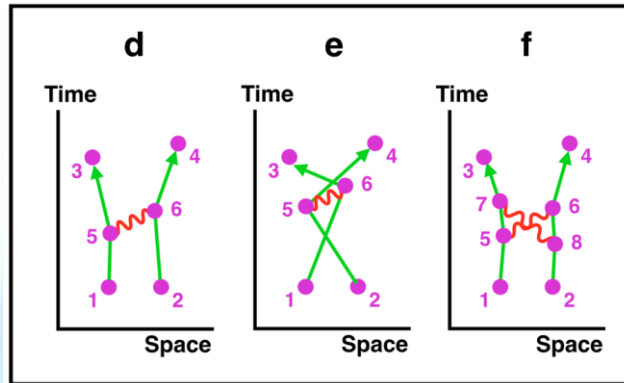


Fig 6 Electrons (green lines) from 1 & 2 can emit or absorb virtual photons (red wavy lines)

The term "virtual photon" means a hypothetical photon that we have not observed in the laboratory. In this case we will hypothesize photons that are emitted by electrons sometime after the experiment begins, and vanish back into electrons before the experiment ends. Therefore we don't see them with our equipment. But we know they must be there because the math says so. Figures 6-d and 6-e show an exchange of one photon between the electrons. Focusing on the amplitude for Figure 6-d it is the dot product:

$$E(1 \text{ to } 5) \bullet j \bullet E(5 \text{ to } 3) \bullet E(2 \text{ to } 6) \bullet j \bullet E(6 \text{ to } 4) \bullet P(5 \text{ to } 6) \tag{2}$$

Note that the absolute length of any of these vectors is less than one. Therefore the more terms we multiply together, the size of our total amplitude will shrink, and especially when the term *j* is included in our equation, because that has a value of -0.1. The more *j*'s the more diminished is the result. In equation 3 the two *j*'s mean we have multiplied everything else by 0.01.

But we still have a problem, even after we add equation 3 and the corresponding equation for Figure 6-e to the value we had from equation 2. This result is closer to the experimental data, but still too low. So then we will exchange two virtual photons: see Figure 6-f. The formula is getting more complex:

$$E(1 \text{ to } 5) \bullet j \bullet E(5 \text{ to } 7) \bullet j \bullet E(7 \text{ to } 3) \bullet E(2 \text{ to } 8) \bullet j \bullet E(8 \text{ to } 6) \bullet j \bullet E(6 \text{ to } 4) \bullet P(5 \text{ to } 6) \bullet P(7 \text{ to } 8) \tag{3}$$

In equation 3 we have four appearances of *j*'s meaning the value 0.0001 is multiplied into everything else. The total contribution of equation 3 is small. Now we remember the Feynman principle, which is that we must add together ALL the different ways something can happen. So our simple research question, "What is the total amplitude for two electrons traveling from points 1 and 2 to points 3 and 4?" requires that we add in the diminishing values of an infinite number of equations, reflecting an infinite number of ways the virtual photons can behave. We haven't even discussed some of the weird possibilities, such as one of the virtual photons abruptly turning into an electron and positron pair, and those rapidly annihilating each other and convert back into a photon before that photon is absorbed into one of the original electrons. That seems like a stupid thing to have a photon do. Nature does stupid things: erratic and unexpected behavior. Feynman diagrams are replete with many pictures of nature's zoo of unanticipated behaviors.

This gives you a flavor of what Feynman diagrams and QED are all about! It is only a brief taste.

1.3 The three schools of quantum math

As noted earlier, there are three mathematical ways to approach any problem in QM. The one we have been discussing was invented by Dirac and Feynman, and is called the path integral approach. Feynman's career was in high-energy particle physics. In that arena Feynman diagrams and the path integral approach prove useful. In particle physics you deal with a small number of particles: less than a hundred.



The second school of quantum math is the Schrödinger wave equation, with differential equations that are useful for gases and fluids that flow. The third school is the canonical approach invented by Heisenberg. It consists of operators, matrices, and linear algebra. All three approaches have been formally proved to be equivalent to one another. One approach can be more useful for one kind of problem solving, while a different one is more useful for a different kind of problem solving. Quantum physicists are practical people, willing to use any approach that gives them an answer: deriving an observable. Typical physicists!

In particle physics you don't run into a hundred interacting particles. When any form of QM deals with thousands of particles, you would not choose the path integral approach. The more particles involved in a problem, the closer the quantum math comes to classical physics. The equations of classical physics (such as Newton and Maxwell's equations) can be derived from quantum math, but not vice versa.

1.4 Problems with Feynman's QED

There are two flaws with Feynman's approach. He knew of the first, but not the second.

The first problem is that no one understands the relationship between QED and physical reality. Every step of the way QED was created in a dialog with experimental data, and the current correspondence between observables and physical nature is better than for any other scientific theory. Yet there is a migraine headache. No one knows what these "amplitudes" are in nature. Feynman says that the central machinery of QED has no apparent corresponding machinery in physical reality. Einstein was famous for his conviction that there should be a correspondence between the components of our equations and the components of physical reality.

Do you think that before any particle does anything it sends out octopus tentacles to assess the amplitude for any and every possible thing it could do, and then decides on a course of action based on rolling the dice to choose among the amplitude reports it receives from those tentacles? Sound unlikely. Feynman's view is that we have an elegant abstract theory that produces accurate observables, but we don't know why or how. He repeated that idea over and over, in many forums.

Feynman did not know about the second problem with his theory. He assumed, as did everyone else, that amplitudes and particles travel in the same direction. There had historically been a debate lasting centuries whether light consisted of waves or corpuscles, but everyone agreed that whatever it was, it traveled from source to detector, not the other direction. Therefore when Thomas Young and the founders of QM debated the wave versus particle question, it never crossed anyone's mind to ask whether the waves and particles traveled in opposite directions. That question did not enter human history until 1993. It entered history inside the skull of Lewis E. Little.

Thus Feynman was simply adopting the same erroneous concept that all physicists had adopted, when he assumed without proof that amplitudes and particles travel in the same direction. Throughout this article we assume that Feynman's amplitudes are synonymous with what others call waves. We take the two words to be synonyms. There are few experiments that test whether waves and particles travel in the same versus opposite directions. We showed in the second article in this series that such empirical data as exists is compatible with the idea that they travel in opposite directions.

Part 2: Modifying QED: creating QÆD

2.1 We remove that tiny part of QED that contradicts nature

Let us now play a simple mathematical game. We will take Feynman's QED, keep it almost entirely intact, making only one small change: we will assume that waves and particles travel in opposite directions. We will call the new arrangement QÆD, for Quantum Ælectro-Dynamics. In a previous article we explained why we have chosen the letter Æ to symbolize an elementary ray.

QÆD instantly solves some problems and creates others. No longer is each particle like an octopus sending out amplitude arms to feel out the environment. Instead we reverse the direction of those octopus arms. They start at the periphery and move centripetally. When a particle decides at random which amplitude to follow, all that amplitude information is available to the particle locally. It is like each particle is surrounded by dots in all directions, like stars in the night sky. The radius of each dot is proportional to the amplitude of that option. A particle is more likely to choose a larger dot than a smaller one.

The amplitudes are unchanged in magnitude and phase when the octopus arms are reversed in direction. An equation such as # 2 can be reversed. Instead of

$$E(1 \text{ to } 5) \bullet j \bullet E(5 \text{ to } 3) \bullet E(2 \text{ to } 6) \bullet j \bullet E(6 \text{ to } 4) \bullet P(5 \text{ to } 6) \quad (2)$$

we write:
$$P(6 \text{ to } 5) \bullet E(4 \text{ to } 6) \bullet j \bullet E(6 \text{ to } 2) \bullet E(3 \text{ to } 5) \bullet j \bullet E(5 \text{ to } 1) \quad (4)$$

To reiterate: the mathematics of computing amplitudes is unchanged. All that changes is the picture of where this information is located in Euclidean space. Aside from that, the math of QÆD is identical to the math of QED. The previous sentence implies that the impressive accomplishments of QED can also be claimed as accomplishments of QÆD.

Another way of saying the same thing is that QED works the same if time goes backwards, as Feynman delights in telling us over and over and over again. Throughout his professional life Feynman was always talking about the possibility of time going backwards.[10] Therefore QED equations work the same if the waves go backwards while time goes forward. We

claim that time reversal is a proxy for the real issue, which is wave direction reversal. We will return to this issue in the final conjecture of this article.

These amplitudes can be called “rays” and they convey zero energy in either QED or QÆD. Since zero energy amplitudes cause no conceptual problems in QED, they should be the same in reverse. At scholarly conventions some mathematicians refuse to talk with this author simply because they consider it preposterous to speak about a zero energy wave! The idea of zero energy might be more palatable if we speak of amplitudes rather than waves.

Perhaps we should change the name from TEW to the Elementary Theory of Amplitudes (TEA). For historical continuity we will continue to call our science “TEW.”

The QÆD arrangement means that we live in an ocean of such amplitudes or rays, traveling in all directions, located everywhere in space and in all inertial frames. When we speak of such things vis-à-vis TEW, our audience gets perturbed as if they dislike being immersed or drowned in such an ocean. Well guess what? Exactly the same issue is implicit in QED. You and I live in an ocean of amplitudes, according to Feynman. No one objects when Feynman says it. They should not object when we say it. Mathematicians should cease and desist from treating this ocean as if it were a problem.

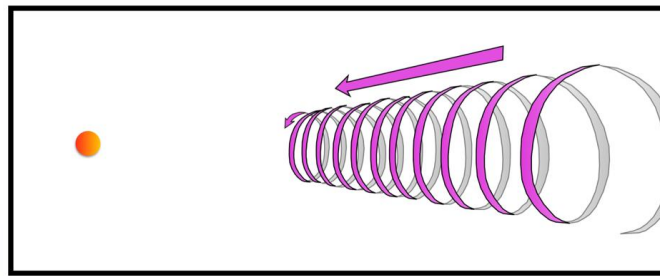


Fig 7. An elementary ray impinging on a particle source

We learn from Feynman what a ray (i.e. amplitude) looks like (Figure 1), namely a cylindrical helix traveling through Euclidean space, but having embedded in the center of its clock face a complex vector. Figure 8 is a mirror image of Figure 1, with the colors changed to remind us that we are speaking about an amplitude, not a photon or electron. This moving corkscrew is active prior to the emission of a particle.

2.2 The relationship of QED and QÆD

Feynman would say that we made the same mistake as beginning physics students: looking at one Feynman diagram and believing we have a picture of reality. Feynman is not ultimately interested in reality. Realism is not his goal. He is by profession a practitioner of QM, which is a science of observables. Feynman’s goal is the computation of a total amplitude, called “an observable” which is arrived at by adding together ALL the little arrows.

Although QED is a science of observables, QÆD seeks to be a science of physical nature independent of the observer. We agree with the beginning physics students that reality is what we are interested in. We are willing to receive an “F” in Feynman’s course on QED.

In everyday nature things are always idiosyncratic, peculiar and particular. We humans have no experience of “ALL the different ways something can happen.” Can you imagine what 20th century history would be like if we had to take into account BOTH the idea that Hitler lost AND the idea that Hitler won World War II? Try to integrate human history across both possibilities and see what happens to your brain.

In real life things only happen one way or the other. Sometimes it is a rare event or a common event. It doesn’t bother us to say that we have arrived at one specific detailed picture of physical nature. It doesn’t bother this author to say that Hitler lost WWII. Our goal and Feynman’s goal diverge.

A divergence of goals is only one of several conflicts between QED and QÆD. A second conflict is a territorial dispute. We claim that QM is incompetent at describing physical nature independent of the observer. If you doubt what we say, try contemplating Schrödinger’s cat, or parallel universes, or any number of other stupid ideas for which QM is famous. We draw a boundary line and say that QM should have the humility to observe that boundary. We say that QM is a science of observables and should avoid making any further comments about nature independent of the observer.

In exchange for such an agreement, TEW and QÆD propose that WE are the experts on physical reality independent of the observer, but are incompetent in the physics lab: unable to generate observables.

There is one other area of conflict between Feynman’s QED and our ideas. Feynman never explicitly discusses the speed at which his amplitudes travel through Euclidean space. For example he never clarifies whether an electron amplitude moves at the speed of the electron, the speed of light, or at infinite speed. For TEW this issue needs to be clarified. We claim that elementary rays always travel at the speed of light, not at the speed of electrons nor infinitely fast. This is necessary so that the rays transform properly into different inertial frames.

2.3 What QED teaches us about the elementary rays of TEW

QED is a fountain of many valuable ideas about how elementary rays behave. For example we learn from QED that elementary rays need not go in straight line, or they can fork and bifurcate, as shown in Figure 8.

Figure 8 is an elementary ray picture of Figure 6–d. Let’s start with the target named “3” which is located in the lower left corner of Figure 8. An elementary ray emanates from that target and merges at point 5 with a photon elementary ray. Then from 5 to 1 the elementary ray has a higher frequency than it previously had. The higher frequency means it could latch onto a higher energy electron.

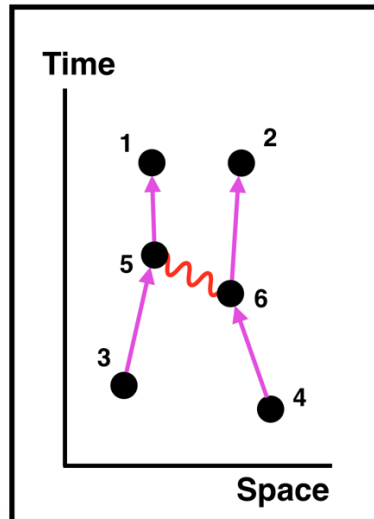


Fig 8. This is the Figure 6–d flipped vertically vis-à-vis dots, but arrows moving forward with time

The point is that elementary rays for electrons can merge with a photon elementary ray, forming an electron elementary ray of higher frequency. This enriches our knowledge of how elementary rays behave. The Feynman diagrams help us to see that there could be an infinite number of forks and mergers and lots of complexity. It is as if elementary rays have now acquired beards, that protrude in one direction or another in unpredictable ways.

This gives us a profound insight into micro–determinism. Previously we had said that no probabilistic decisions are made at the detector, therefore there is no wavefunction collapse at the detector. We still say that. We had also said that probabilistic decisions were made at the particle source, and we still say that, except that the word “probabilistic” should be replaced with “amplitudistic,” which is a word we just coined. “Amplitudistic” is the square root of “probabilistic.”

The question is, what happens to an electron after it has made its amplitudistic decision at the electron gun? Is that trajectory deterministic until the electron reaches a detector? The answer is “No,” at least not in the setting of high energy particle physics such as Feynman specialized in. Once the particle has committed to following one of the impinging elementary rays, at any point it can make a different decision. For example a high energy electron can abruptly disintegrate into a photon and a lower energy electron, as we learned from Figure 8. The original electron makes that amplitudistic decision during interaction with a field of other elementary rays in the vicinity. It would be like making a marriage commitment at the beginning, then you discover there are a lot of other partners flirting with you and inviting you to stray, and sometimes you do.

2.4 Error correction

In the first of this series of three articles this author proposed a mathematical model for the cylindrical helix of an elementary ray. Upon further consideration, he wishes to simplify that model by removing the variable β from the final line of Equation 3. Instead of $z = c\beta t$, the final line of Equation 3 should read $z = ct$. With this correction, that paragraph in “Paradigm shift, Part 1” should read:

“We define θ as the angle of rotation of the corkscrew at the (x, y) plane. θ is a function of time: it spins at incredible speeds. \mathbb{R} can be described as follows: The energy of \mathbb{R} is zero:

$$E(\mathbb{R})=0.$$

$$x = |A| \cos(\theta)$$

$$y = |A| i \sin(\theta)$$

$$z = ct$$

where c is the speed of light along axis Z . ω is the angular frequency and ν is the frequency, so:



$\theta = \omega t = 2\pi\nu t$ and $\nu = \frac{\theta}{2\pi t} = \frac{\omega}{2\pi}$. The wavelength is $\lambda = \frac{c}{\nu}$ and the wave number is $k = \frac{2\pi}{\lambda}$.

Although this helical object travels at the speed of light up the Z axis, we are primarily interested in a cross section at the electron gun. In that plane $A = |A|e^{i\theta}$.

Part 3: Design of Experiments

3.1 Conflict between QED and QÆD

One of the unavoidable conflicts between QED and QÆD is that either amplitudes travel in the same direction as particles, or in the opposite direction. There is no middle ground. Feynman didn't discuss this issue. He simply assumed, as did all QM experts, that amplitudes and particles travel in the same direction. We have said that the small amount of experimental evidence investigating this has favored the idea that amplitudes and particles travel in opposite directions. This is especially true of a neutron interferometer experiment published by Kaiser, Clothier, Werner, Rauch and Wölwitsch in 1992, which we reviewed in a previous article.

3.2 Three experiments, never performed, to distinguish QED versus QÆD

When does interference occur relative to the firing of an electron? TEW says interference occurs prior to or during electron firing; QM says it occurs after electron firing, actually after the electron wave-particle penetrates through the double slit barrier. TEW says there is no interference after an electron is fired; QM says the opposite. Therefore if we divide time at the point when a single electron is fired, we should be able to design experiments for which the theories predict different outcomes.

Here are three experiments that have never been conducted. To conduct these experiments we need to limit emission to one electron at a time, with a delay for the equipment to be reset before the next electron is fired. Figure 10 shows the first experiment. At first, ignore the pattern on the target screen.

The equipment in Figure 10 is designed so both slits are open until that nanosecond when an electron is fired. At that instant a powerful laser fires straight down, blocking the right slit. QM says only one slit is open so therefore there will be no interference fringe pattern on the target screen: just one vertical line (a narrow Gaussian line) behind the left slit. TEW says there will be an interference fringe pattern (as shown in Figure 10) skewed toward the left side of the target screen.

The TEW prediction is based on when interference is thought to occur, namely before, or during the electron emission. At that time both slits are open. Therefore there will be interference between elementary rays coming through the slits and interfering as they impinge on the electron gun. That pattern of interference will be encoded in the pattern of electrons emitted. Since the right slit is closed when an electron gets there, only the left slit will be open for electrons to inscribe that pattern on the target screen.

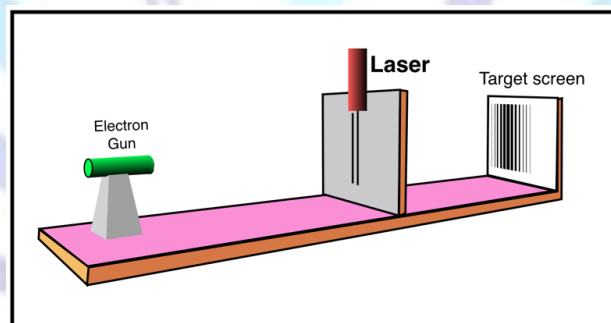


Fig 9: The right slit of a double slit experiment closes at the nanosecond an electron is fired.

If this proves to be true, it will refute something Feynman repeatedly said: that it is impossible to both see an interference fringe pattern and know which slit an electron used. One of the axioms of complementarity would be proved wrong.

The next two experiments are based on the apparatus shown in Figure 11. This is another modified double slit experiment. The author learned Figure 11 from Lewis E. Little. This time both slits are always open. A "vanishing screen" is inserted in front of the target screen. The "vanishing screen" needs to be designed so it is opaque to electrons until the nanosecond that an electron is fired, and then it becomes transparent. Alternatively it needs to be transparent to electrons until one is fired, and then it becomes instantly opaque. Electrons are fired one at a time, with a pause in between.

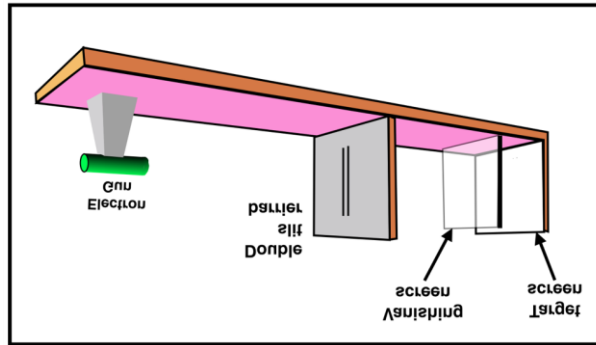


Fig 10. A screen that switches opaque ↔ transparent is inserted into a double slit experiment

The reason for the unusual predictions by TEW is again because of the timing of the interference. Starting with an opaque “vanishing screen,” elementary rays emanating from all points of that screen will interfere near the electron gun prior to the gun firing. The amplitude of an electron choosing that ray as opposed to the other competitor rays is proportional to the strength of its amplitude. The amplitude reflects the pattern of interference, which we can indirectly see from the blue curve on the home screen (Figure 12). If an electron chooses to follow one elementary ray backwards, it is programmed to strike the home screen (the opaque “vanishing screen”) in the familiar aqua-blue pattern. But we tricked nature. The home screen is nowhere to be found, having become transparent.

Those electrons are travelling on the green lines in Figure 12. The electrons continue on a straight line until they hit the “target screen” where they inscribe the pattern diagrammed in orange. This is a screwy pattern: not what we expected. For example, in the center of the screen there is a valley (a white area), where we had expected the tallest mountain.

The equipment is designed so nature can vote for one theory or the other. Figure 12 is what will happen if TEW is correct and QM is wrong. If QM is correct and TEW is wrong, then the orange curve will have a familiar shape similar to the blue curve, with the tallest mountain in the center of the screen.

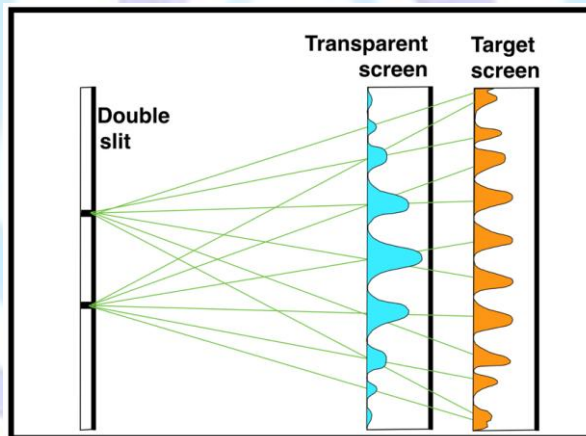


Fig 11. When the screen starts opaque then becomes transparent, the orange appears like this

In the next experiment (Figure 12) the “vanishing screen” starts out transparent. Elementary rays start at the target screen (blue-aqua curves) on the far right, pass right through the transparent “vanishing screen” and interfere between the double slit barrier and the electron gun. The electrons that follow these rays backwards are programmed to make the blue curve on the target screen. But once again we have tricked nature. We abruptly insert a barrier that wasn’t there before: the vanishing screen is now opaque. When the electrons hit that screen they inscribe a different screwy pattern, as shown in orange in Figure 13. But only if TEW is correct and QM wrong.

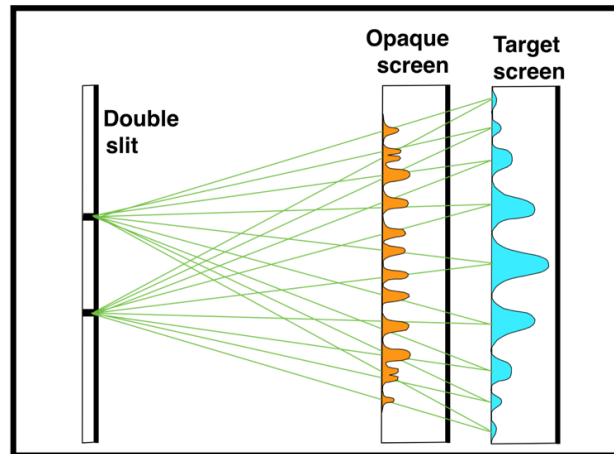


Fig 12. When the screen starts transparent then becomes opaque, the orange appears like this

If on the other hand QM is correct and TEW is wrong, then the pattern of the orange curve will look familiar, similar to the blue curve, with the largest mountain in the center of the screen. Thus nature can vote for one theory or the other.

As previously noted, we assume that what QM means by the word “waves” is the same as what Feynman means by the word “amplitudes.” Therefore the experiments just described should allow us to choose whether QED or TEW is closer to nature.





4. Summary

4.1 Comments on the cross-fertilization of QED and QÆD

QED is a powerhouse of science that has been productive for more than five decades. There are no glaring problems with it, except that it doesn't make sense. The particular style of it being nonsensical is so familiar from elsewhere in QM that scientists are numb to it and don't see nonsensicality as being a problem. After all, QED is a fountain of information that is essential to the design and implementation of high tech equipment, and that is worth trillions of dollars. Therefore anyone who declares that QED doesn't make sense should expect to be treated as a pariah.

What exactly do we mean by the words, "doesn't make sense"? We mean that Feynman himself said that QED ultimately doesn't make sense, that no one understands QM, as exemplified by the fact that we are unable to discover which slit an electron uses in a double slit experiment. That type of weirdness infects Quantum Chromo-Dynamics (QCD) also, Feynman says. QCD concerns quarks. Feynman could not explain what an amplitude refers to in nature. There is nothing controversial about amplitudes: they have been proved to be a valid concept in experiments ever since WWII. But what in nature corresponds to an amplitude is an impenetrable mystery, according to Feynman. He repeatedly apologized to his lay audience about how QED would not make nature comprehensible to them. He declared that when the audience accepts the "incomprehensibility" of QED, then they will be accepting reality. He insisted: incomprehensibility = reality. He also insisted on the corollary: quantum reality = incomprehensible.

In this article we suggest that a TEW elementary ray is a physical analog of a QED amplitude. They both travel as cylindrical helices along the long axis of the helix. Only the smallest adjustment is required in the QED starting assumptions, namely that amplitudes precede the emission of particles, and particles follow them backwards. That in turn means that amplitudistic decisions are located at the particle source, so we need to discard the idea of wave function collapse at the detector.

When we make such an assumption we discover that we have a mirror image of QED that apparently carries with it all the power and usefulness of the original QED. This mirror image is so startlingly similar to TEW that we assume they are two names for the same thing. Backwards QED, which we have called QÆD, provides a mountain of useful empirical information to make TEW more robust than TEW had been previously. This changes TEW from a theoretical enterprise to an empirical science with well-known practical applications.

The symmetry of QED and QÆD is so extreme that we need to ask whether they are two versions of the same thing. However, they cannot be simply mirror images. Amplitudes in nature must travel in the same direction as, or the opposite direction as the particles. There is no middle ground. There is unavoidable conflict. Very little empirical research has been done to illuminate this dispute. The little that exists is consistent with the idea that they travel in opposite directions, and inconsistent with the idea that they travel in the same direction. Feynman never thought about that.

This problem of paucity of empirical information inspired us to design new experiments, never conducted, that would provide a clear answer. We presented three such experiments in this article. Neither Lewis E. Little nor this author is an experimental physicist. We are old men who have lived our lives outside the ivory tower of academia. If you ask leading mathematicians what they think of us, you will get a blank stare. To design and build the experiments described above might be simple enough for any physics student who has access to a sophisticated lab. The scientists who do so will be the next generation, not us.

4.2 Four main points

1. The "amplitudes" which lie at the heart of QED and all other forms of QM are physically real and are what TEW calls "elementary rays";
2. Particles follow amplitudes backwards;
3. Amplitudes constitute a guidance system emanating from our detectors (and from everywhere else also, but the ones we detect come from our detectors);
4. Particles can neither exist nor move without these amplitudes.

4.3 Nature's hairstyle and Feynman's time reversal

Feynman speaks often of "Nature," using female pronouns and never referring to her as "Mother Nature." Our interpretation of Feynman's book *QED* is that she prefers a curly hairstyle (Figure 13).



Fig 13. Nature prefers curls, especially in the form of cylindrical helices

Conjectures are respectable in mathematics. I will make a conjecture: that Richard Feynman was preoccupied with, seduced by, and in love with the idea of time reversal, BECAUSE he was a brilliant guy who was on the brink of discovering amplitude direction reversal, even though time goes in the conventional direction. Backwards time is a proxy for the real issue: backwards amplitudes.

Acknowledgment

Two experiments in this article were suggested to me by Lewis E. Little.

Bibliography

- [1] J. H. Boyd, A paradigm shift in mathematical physics, Part 1: The Theory of Elementary Rays (TEW), *Journal of Advances in Mathematics*, **11**, #3, (July 2015).
- [2] J. H. Boyd, A paradigm shift in mathematical physics, Part 2: A new local realism explains Bell test & other experiments, *Journal of Advances in Mathematics*, **11**, #4, (July 2015).
- [2] J. H. Boyd, A new variety of local realism explains a Bell test experiment: the Theory of Elementary Waves (TEW) with no hidden variables, *Journal of Advances in Physics* **8**, 2051-58 (Mar 2015).
- [3] J. H. Boyd, The Theory of Elementary Waves eliminates Wave Particle Duality, *Journal of Advances in Physics* **7**, 1916-1922 (Feb 2015).
- [4] J. H. Boyd, Re-thinking Alain Aspect's 1982 Bell test experiment with delayed choice, *Physics Essays* **26** (4) 582-591 (2013).
- [5] J. H. Boyd, Re-thinking a delayed choice quantum eraser experiment: a simple baseball model, *Physics Essays* **26**, 100-109 (March 2013), (doi: 10.4006/0836-1398-26.1.100).
- [6] J. H. Boyd, Rethinking a Wheeler delayed choice gedanken experiment, *Physics Essays* **25**, (3) pp. 390-396, 2012. doi: <http://dx.doi.org/10.4006/0836-1398-25.3.390>
- [7] L. E. Little, Theory of Elementary Waves, *Physics Essays* **9** (1), 100-134 (1996).
- [8] L. E. Little, *Theory of Elementary Waves*, (New Classics Library, New York, 2009).
- [9] R. P. Feynman, *QED* (Oxford University Press and Princeton U. Press, 1985).
- [10] J. A. Wheeler and R. P. Feynman, "Interaction with the absorber as the mechanism of radiation," *Reviews of Modern Physics* **17**, 157-181 (1945).



Author's biography with Photo



Jeffrey H. Boyd

Dr. Boyd was born in 1943 in northern New Jersey, USA, the son of a factory worker family in which no one had ever been to college. In high school he helped his father dig a basement by hand, using a pick, shovel and wheelbarrow. Boyd chose which college to apply to based on which one had the best applied math department. Boyd's undergraduate degree in mathematics was from Brown University in 1965. Following Dr. Martin Luther King in the Civil Rights movement, Boyd was in Mississippi in 1965, where he learned that being denounced as an outside agitator did not mean one was doing the wrong thing. Boyd has post-graduate degrees from Harvard, Yale and Case Western Reserve Universities, has served on the research faculty of the National Institutes of Health for seven years, and has been on the faculty of the Yale Medical School. His day job is as a physician: a psychiatrist. Boyd retired after a quarter century at Waterbury Hospital, Waterbury CT, a Yale teaching hospital at which he served as chairman of behavioral health and chairman of ethics. Almost half a century ago Boyd abandoned his first love (mathematics) because of his belief that no mathematician over the age of 25 ever discovered anything important, and he was rapidly approaching that age. He wanted to be in a field where age and experience counted for you, not against you. A rewarding career in medicine followed. Then Andrew Wiles proved Fermat's last theorem at age forty and Lewis Little discovered elementary waves at age fifty-two. With this series of articles in *JAP* the author discovered, to his astonishment, that even this old dog can learn some new tricks. Boyd has published in the *New England Journal of Medicine*, *Journal of Advances in Physics*, *Journal of Advances in Mathematics* and *Physics Essays*. He is currently working on videos to present his ideas via YouTube and Facebook.

