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A Unifying Theory for Quantum Physics, Part 1:

How to Motivate Students to Want to Study Quantum Technologies

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Abstract:

Is the quantum world as strange as they say? If this were an unsolved mathematics question, we might try a new angle of attack. We know quantum mechanics (QM) is the most accurate and productive science humans ever had, meaning its probability predictions are accurate. Every probability has two square roots. The Born rule says either would produce the same probability. Assume nature uses the negative of QM's equations. What could that mean? We'd need to revise Feynman's path-integrals and Schrödinger's equation. If waves travel in the opposite direction as what QM believes, that could produce the negative equations. No wave-particle duality. Free particles would follow backwards zero-energy waves coming from detectors. This, surprisingly, gets rid of quantum weirdness. Our proposal is that nature uses the negative of QM's equations because particles follow zero-energy waves backwards. Considerable evidence fits this model, including a neutron-interferometer and the Davisson-Germer experiments, a quantum-eraser experiment, Wheeler-*gedanken* and double-slit experiments, Bell-test experiments, Stern-Gerlach, and high-energy scattering experiments. Finally, we propose a plan for how to motivate students to want to study quantum technologies, thereby addressing the most prominent problem in QM today: the shortage of an educated workforce, the scarcity of aspiring students.

This is part 1 of a 2-part article. Both parts cover the same material in the same order. The second part is three times as long and gives all the details. This first part teaches our basic ideas, using a minimum of details. Part 2 is available in a peer-reviewed physics journal: https://rajpub.com/index.php/jap/article/view/9268

Mathematics Subject Classification (MSC2010): 81Q65 Alternative Quantum Mechanics

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I. Introduction

The spectacular success of Quantum Mechanics (QM) is based on the accuracy of its probability predictions. This article articulates the Theory of Elementary Waves (TEW) which proposes the following interpretation of the Born Rule: $\sqrt{Probability} = \pm\psi$, and although QM uses $+\psi$, nature uses $-\psi$. Both square roots ($\pm\psi$) are confirmed by the same lab data. Both could take credit for our high-tech economy. With one square root ($+\psi$) the waves and particles travel in the same direction, with the other ($-\psi$) they travel in opposite directions.

In this article we will derive wave-equations for how it is possible for a quantum particle to follow a zero-energy wave ($-\psi$) backwards. By "backwards" we mean they both move forwards in time but in opposite directions in Cartesian space. There is no time-reversal in this article. We will marshal substantial empirical evidence from experiments published over the last century, that confirm this unusual model. (1-29)

Astrophysicist Jason Lisle said, "Frankly, the way things behave at the smallest scale is simply not what we would expect." That summarizes the puzzle this article will solve.

Our thesis sounds odd: that nature uses $-\psi$, which means that particles follow zero-energy waves backwards. There are two reasons to temporarily suspend your disbelief and provisionally accept this as a fascinating idea. First, this view of quantum mathematics dispels all the enigmas and paradoxes from the quantum world. There is no more Schrödinger's-cat. No quantum eraser. No delayed-choice backwards-in-time cause-and-effect. No Wheeler's "thought experiment." No more riddles. Second, when we review many quantum experiments published in highly respected journals, as we are about to do, the weight of empirical evidence supports our TEW thesis (**−*ψ***) rather than the wave-particle duality thesis (**+*ψ***).

Sometimes people reject our ideas because they say, "It's metaphysics, not science." But wave-particle duality is metaphysics. We invite you to examine the empirical evidence, before you decide what is, and is not science.

1. The Quantum World Is Transparent: Easy to Picture

In the 1920s, QM was criticized because it rendered the quantum world "un-visualize-able." The German word "*Anschaulichkeit*" was used. Our approach restores visualize-ability and clarity to the quantum world as we will demonstrate by providing 34 colored illustrations in this article. How many-colored illustrations are found in QM articles? Zero, usually! Lay people (non-mathematicians) think in pictures, not in equations. With TEW the world of everyday experience blends imperceptibly into the quantum world, so when we look at nature, it is transparent, and we see the quantum world through it. Both the quantum and classical world obey the same rulebook.

The two square roots of probabilities (**±*ψ***) differ in terms of the timing of wave-function-collapse. We define below what we mean by "wave-function-collapse." QM says it happens when a quantum system is measured. We say it happens earlier. Consider a double-slit experiment. We say wave-function-collapse occurs when a particle is emitted, linked to an Elementary Wave that it follows backwards.

1.1 What Are Elementary Waves Like?

For a free particle, a zero-energy Elementary Wave originates at the detector (or target screen), travels to the particle source, whereupon wave-function-collapse occurs. After that the particle follows its wave in-reverse with a probability of one. An experiment therefore starts long before a particle begins to move. It starts when an Elementary Wave leaves the detector on a trip to the particle source, whereupon the particle is triggered to follow that specific wave backwards from the source to the detector from which that wave continues to emerge. TEW starts our stopwatch (to time the experiment) long before QM starts their stopwatch. This means that many phenomena that QM classifies as "nonlocal", we would classify as "local." In Bell test experiments our light cones are twice as large as QM's light cones.

Some people reject TEW because they say that all waves must carry energy. That's wrong. A Schrödinger wave for example carries none. It carries probability amplitudes, not energy. It cannot push or pull particles, nor do any work. It predicts what is likely to happen but does not push things to happen that way. Elementary waves and Schrödinger waves travel in opposite directions. Elementary Waves and energy flow in opposite directions.

Comparing our theory to garden-variety QM, what is the same, versus different? TEW will not significantly change bound particles, harmonic oscillators, the Periodic Table, nor chemical compounds, because if particles and waves gyrate around each other, it doesn't matter if they travel in the same or opposite directions. The Standard Model won't change, because in it there are no particles, just fields. But free particles will be dramatically different. They follow backwards zero-energy Elementary Waves coming from the detectors. Therefore, interferometer and double-slit experiments will be prominent in our discussion.

Thomas Kuhn, in the *Structure of Scientific Revolutions*, says that when a new scientific paradigm emerges, it makes no sense to scientists trained in the old paradigm. For example, Alfred Wegener proposed in 1912 that there had once been a supercontinent for which he coined the name Pangaea {from Ancient Greek pan (all, entire, whole) and Gaia or Gaea (Mother Earth, land)}. The supercontinent fragmented and drifted to become today's continents. In 1912 no one knew there were mountains on the seafloor. India slid north and slammed into Eurasia, uplifting the Himalayas. All scientists in 1912 agreed that Wegener's ideas were nonsense. There was no force strong enough to move continents. Therefore, Wegener's ideas were discarded from science until 1962. This article seeks to be for quantum physics what Pangaea was for geology. Pangaea led to plate-tectonics which today is the dominant paradigm in geology. (37,41,45)

1.2 How to Attract and Motivate Students to Study Quantum Technologies

Quantum technologies are blossoming everywhere, from quantum sensors to computers and communication. The greatest problem in QM today is that there are not enough workers. Students are not entering the quantum technologies in anything like the numbers that are needed.

When we listen to students reluctant to learn QM, they complain that they learn from pictures, but QM has no pictures, is not intuitive, and even STEM students cannot apprehend what the equations are referring to. And there are weird things like Schrödinger's cat. We propose a solution to all those complaints. At the end of this article, we will introduce a new variety of equations which we call eQM for "elementary QM" based on the following two proposals: That nature uses the negative of normal quantum equations because quantum particles follow zero-energy waves (called Elementary Waves) backwards in space (not backwards in time).

As a way to teach quantum math, eQM has many advantages:

a) It is intuitive,

b) provides pictures,

c) the equations refer to something tangible,

d) the equations are the same as those of QM except for a minus sign,

e) Schrödinger's cat is solved, and

f) eQM is controversial.

Students love crazy, revolutionary ideas. The opportunity to learn a new theory that encourages students to topple traditional QM would excite them, even if eQM is ultimately discredited, which we don't think will happen.

The field of mathematics called eQM does not yet exist. This article (at the end) will provide a blueprint for how to build it. It consists of using the pictures and ideas of TEW to teach quantum mathematics to students. We believe quantum math could be simplified, made tangible, and brought down-to-earth. Current quantum textbooks of 300 pages might be able to be simplified to 150 pages with dozens of color illustrations, by means of the plan described at the conclusion of this article.

2. Agenda

We start with experiments that show neutrons travel in the opposite direction as neutron waves, that nature's path-integral equations are the negative of Feynman's, and that the Davisson-Germer experiment can be explained if electrons follow backwards waves of 1.67 Å coming from the detector. After this section, we'll solve some mysteries of QM: the quantum eraser, Wheeler's thought experiment, and Schrödinger's cat.

2.1 A Neutron-Interferometer

A neutron-interferometer experiment published by Helmut Kaiser, et.al. in *Physical Review* A shows that neutrons follow zero-energy waves backwards. (39)

In this experiment the amount of wave interference diminishes as more and more bismuth is added inside an interferometer (Figure 1). Bismuth, the 83^{rd} element, slows neutrons. With enough bismuth all interference abates. However, when a nearly perfect (NP) silicon Analyzer Crystal is inserted outside and downstream from the interferometer (red arrow), robust wave interference is restored upstream and inside the interferometer. That research team says QM cannot explain it. Reiterate: This is an experiment that QM cannot explain.

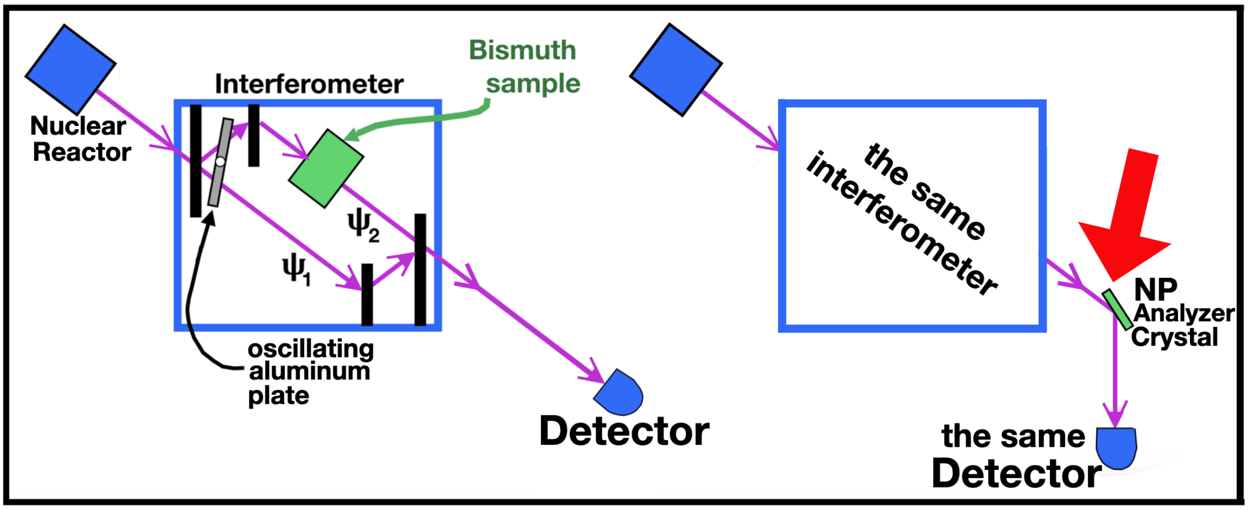

Fig. 1. A perfect-silicon-crystal Neutron Interferometer (NI) with two arrangements of the detector. Left: an incoming beam of neutrons is divided by silicon blades (black) inside the NI into two beams (ψ_1 and ψ_2 are purple arrows). An oscillating (±1°) aluminum plate induces a phase shift so when ψ_1 and ψ_2 are recombined, the ^3He detector records a sinusoidal curve. A sample of bismuth of varying thickness is inserted (green), slowing ψ_2 but not ψ_1. When they are recombined interference diminishes (flattening sine waves, measured as decreasing relative contrast). Right: A "nearly-perfect" (NP) silicon-crystal is inserted (red arrow) outside and downstream.

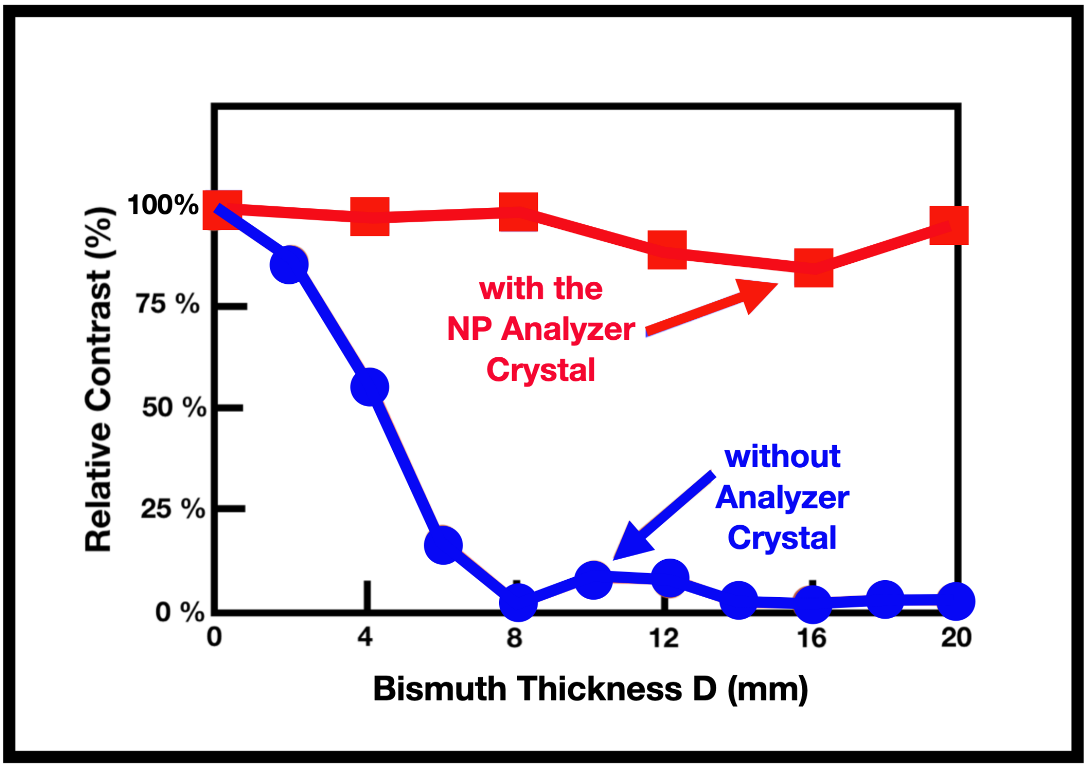

Fig. 2. This graph compares the height of wave interference if the NP Analyzer Crystal is absent versus present. The blue curve shows that with an increasing thickness (D) of bismuth across the horizontal axis, the sine waves representing wave interference flatten out (Relative Contrast decreases on the vertical axis). The red curve shows that when an NP Analyzer Crystal is inserted downstream, robust interference is restored. (Data from Figure 9 top and bottom, from p. 40 of the article by Kaiser, et.al.)(39)

Somehow the NP Analyzer Crystal reinstates full-bodied interference even though it is downstream! The researchers say neither they nor QM can explain this. The data in Table 1 says the same thing as Figure 2.

Table 1. Relative height of the interferogram **(% Relative Contrast)**

Bismuth width D	Without Analyzer Crystal	With NP Analyzer Crystal
$0.00\ mm$	100%	100%
$4.01\ mm$	$57.3 \pm 1.0\%$	$97.1 \pm 5.1\%$
$12.26\ mm$	$8.0 \pm 0.8\%$	$89.6 \pm 4.4\%$
$16.5\ mm$	$1.8 \pm 0.8\%$	$86.0 \pm 4.8\%$
$20.08\ mm$	$2.9 \pm 0.6\%$	$95.2 \pm 5.2\%$

(from Tables III & VI, pp.38-39)(39)

The NP Analyzer Crystal (Figure 3) is placed in the 111 anti-parallel position, Bragg angle θ_A = –22° full width at half maximum, mosaic width η_A = 0.00015 rad.

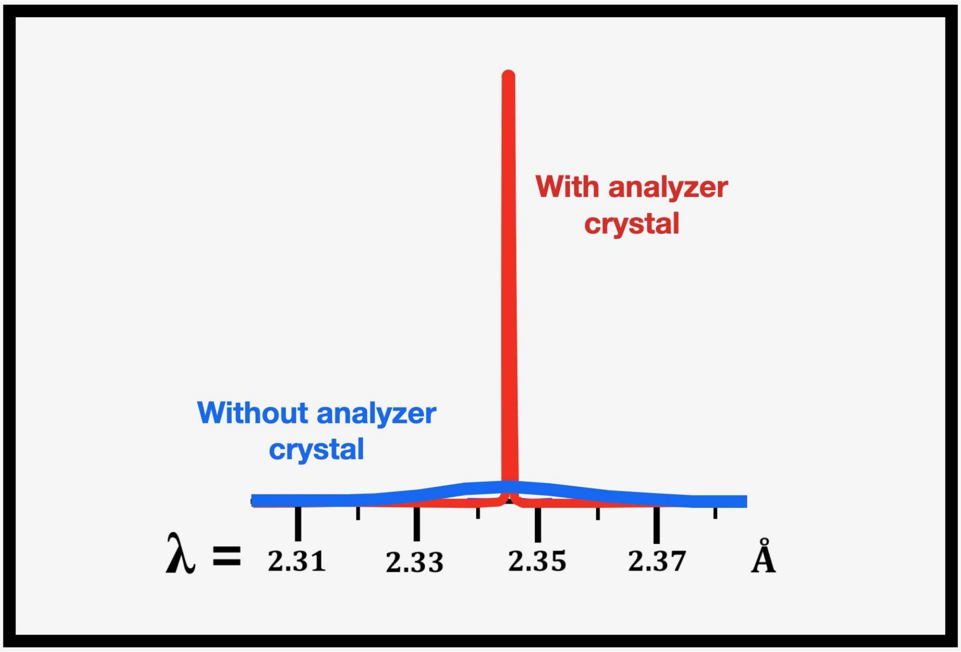

Fig. 3. The wavelength of the beam of neutrons is focused by the NP Analyzer Crystal. The variance narrows and Gaussian heightens (Data from Table 1 top and bottom rows, p. 36 of Kaiser)(39)

The only known explanation of this experiment is that zero-energy waves start at the detector, flow backwards through the interferometer into the nuclear reactor. Neutrons then follow the waves in-reverse to the detector.

If the waves are travelling in the opposite direction, it is obvious why the bismuth would appear to become almost invisible. The NP Analyzer Crystal increases the coherence length of a wave-packet from 86.2 Å to 3450 Å. A maximum sample of bismuth only delays a wave-packet by 435 Å.

For details, see Supplementary Materials which are available in the second part of this article in the *Journal of Advances in Physics* (2022).(3) https://rajpub.com/index.php/jap/article/view/9268

2.2. Feynman's Path-Integrals

QM has many illogical quirks, which we are calling "quantum strangeness or weirdness." In the case of Richard Feynman's path-integral equations, it's a dispute about how many paths a single photon simultaneously traverses. Feynman's answer is "an infinite number." His students say "one."

Feynman's path-integrals are powerful, but they require that you must accept an illogical idea, namely that every photon going from any point **a** to any other point **b** simultaneously travels across an infinite number of paths from **a** to **b** (**a** → **b**). Our theory, TEW, turns the mathematics around, so that before a photon takes one pathway **a** to **b**, a reverse path-integral has already integrated across an infinite number of pathways in the opposite direction, from **b** to **a** (**b** → **a**).

This means that Feynman calculates his path-integral K(b,a) but we calculate a "Reverse" path-integral K_R(a,b) which is the negative of Feynman's metric ($K_R = -K$). The Born rule says we square that to calculate the probability ($|K_R|^2 = |-K|^2 = P$robability) so our approach yields the same probability prediction as Feynman's approach. Our approach preserves all the accuracy, elegance, and finesse of Feynman's approach, but differs in that our approach is logical, because we agree with Feynman's students that one photon can only take one pathway.

With our approach you need to get used to the idea that our reverse path-integral starts earlier than his path-integral. It starts at the detector **b** and integrates backwards across all pathways, arriving at the particle source **a**, where it triggers a photon to leave the source taking only one trajectory (we don't know which one) across to the detector **b**. All this is visible in Figure 4.

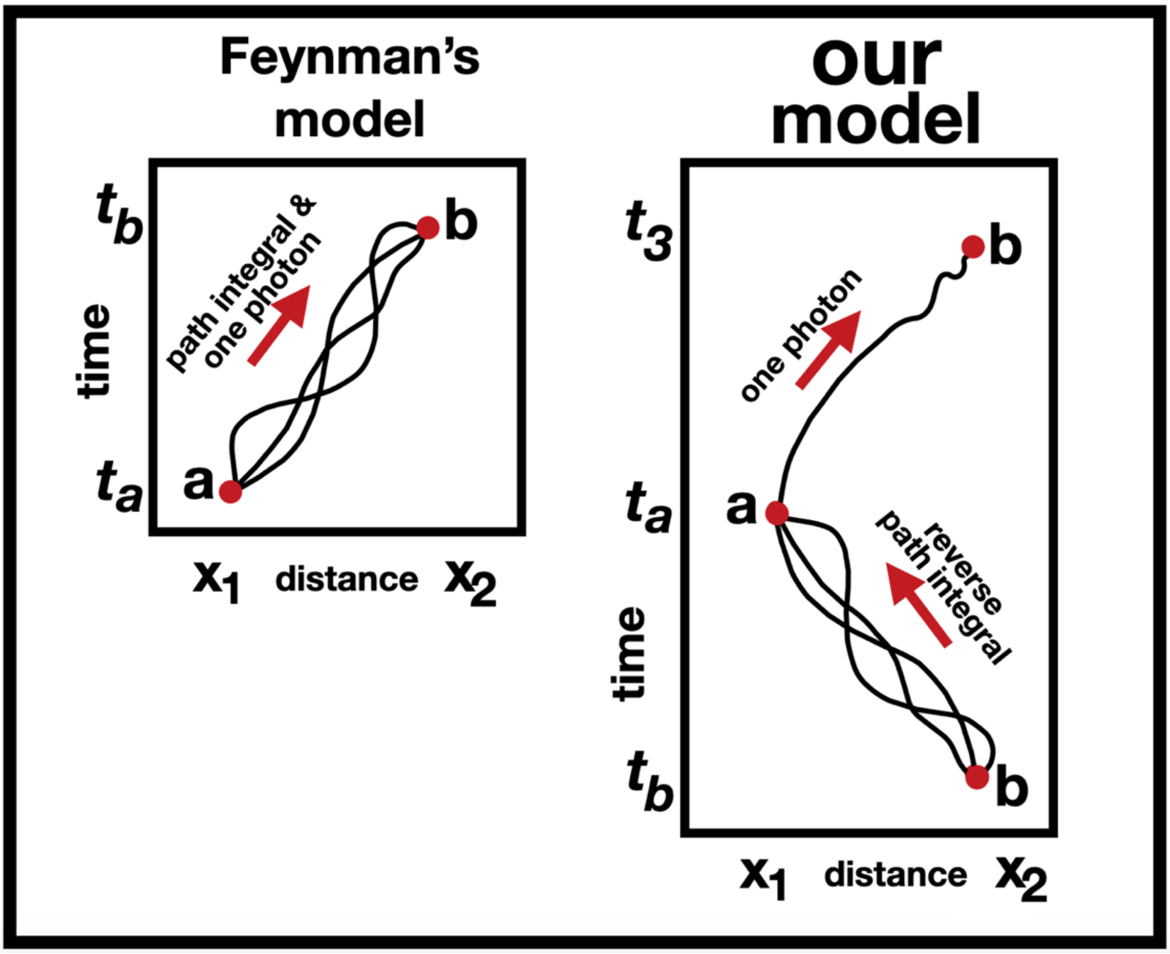

Fig. 4. Feynman's model (left) compared to ours's (right). Our reverse-path-integral K_R(a,b) starts earlier, integrates across all routes from **b** to **a** (**b** → **a**), then a single photon follows one path to the detector (**a** → **b**).

There is a rule in calculus that when you swap the bounds of integration (i.e., integrate in the opposite direction), you get the negative of the original integral. This knits together our two themes: 1. nature uses negative quantum equations; 2. waves and quantum particles travel in opposite directions in TEW.

$$\int_{b}^{a} f(x)dx \equiv - \int_{a}^{b} f(x)dx \qquad \forall f$$

Fig. 5. A law of calculus: if you reverse the bounds of integration, you get the negative of the integral.

$$\textbf{Reverse path integral} \equiv \mathbf{K}_R(a,b) \equiv \int_{b}^{a} e^{(i/\hbar)S_R(a,b)}\mathcal{D}[x(t)]$$

$$\textbf{Feynman's path integral} \equiv \mathbf{K}(b,a) \equiv \int_{a}^{b} e^{(i/\hbar)S(b,a)}\mathcal{D}[x(t)]$$

$$\textbf{R-path integral} \equiv \mathbf{K}_R(a,b) = -\textbf{Feynman's-path integral} \equiv -\mathbf{K}(b,a)$$

Fig. 6. Our reverse-path-integral K_R(a,b). integrates in the opposite direction and is therefore the negative of Feynman's path-integral: $K_R = -K$.

We turn now to the details of deriving a reverse path-integral to fit Figure 4.

As we said, we will integrate Feynman's path integral in the opposite direction as Feynman. We will model our equations on Feynman and Hibbs' equations 2.17-2.25, by **swapping the bounds of integration.** (33)

For a trajectory **x(t)** we define the reverse-action S_R as follows:

$$S_R = \int_{t_b}^{t_a} \mathcal{L}_R(\dot{x}, x, t)dt \tag{1}$$

where $\mathcal{L}_R$ is the reverse-lagrangian for the system. For a particle of mass m subject to a potential energy $V(x,t)$, which is a function of position and time, the reverse-lagrangian is

$$\mathcal{L}_R = \frac{m}{2}\dot{x}^2 - V(x,t) \tag{2}$$

We call the trajectory $\bar{x}(t)$ that goes from b to a with a minimum of action "S_R."
If we keep the endpoints fixed, but otherwise displace the path away from $\bar{x}(t)$ by an increment of $\delta(t)$, then we have defined

$$\delta x(t_b) = \delta x(t_a) = 0 \tag{3}$$

The fact that $\overline{x}(t)$ is an extremum of S_R implies that, to the first order in $\delta x(t)$

$$\delta S_R = S_R[\overline{x} + \delta x] - S_R[\overline{x}] = 0 \tag{4}$$

So, plugging in Equation 1, we can say:

$$S_R[x+\delta x] = \int_{t_b}^{t_a} \mathcal{L}_R(\dot{x}+\delta\dot{x}, x+\delta x, t)dt \tag{5}$$

$$= \int_{t_b}^{t_a} \left[\mathcal{L}_R(\dot{x}, x, t) + \delta\dot{x}\frac{\partial \mathcal{L}_R}{\partial \dot{x}} + \delta x \frac{\partial \mathcal{L}_R}{\partial x}\right] dt \tag{6}$$

$$= S_R[x] + \int_{t_b}^{t_a} \left[\delta\dot{x}\frac{\partial \mathcal{L}_R}{\partial \dot{x}} + \delta x \frac{\partial \mathcal{L}_R}{\partial x}\right] dt \tag{7}$$

Upon integration by parts the variation in S_R becomes

$$\delta S_R = \left[\delta x \frac{\partial \mathcal{L}_R}{\partial \dot{x}}\right]_{t_b}^{t_a} - \int_{t_b}^{t_a} \delta x \left[\frac{d}{dt}\left(\frac{\partial \mathcal{L}_R}{\partial \dot{x}}\right) - \frac{\partial \mathcal{L}_R}{\partial x}\right] dt \tag{8}$$

Since $\delta S_R(t)$ is zero at the end points, the first term on the right-hand side of the equation is zero. Between the end points $\delta S_R(t)$ can take on any arbitrary value. Thus the extremum is that curve along which the following condition is always satisfied.

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}_R}{\partial \dot{x}}\right) = \frac{\partial \mathcal{L}_R}{\partial x} \tag{9}$$

The **path of least action** $\overline{x}(t)$ always satisfies the following condition:

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}_R}{\partial \dot{x}}\right) - \frac{\partial \mathcal{L}_R}{\partial x} = 0 \tag{10}$$

which is the Euler-Lagrange equation of motion.

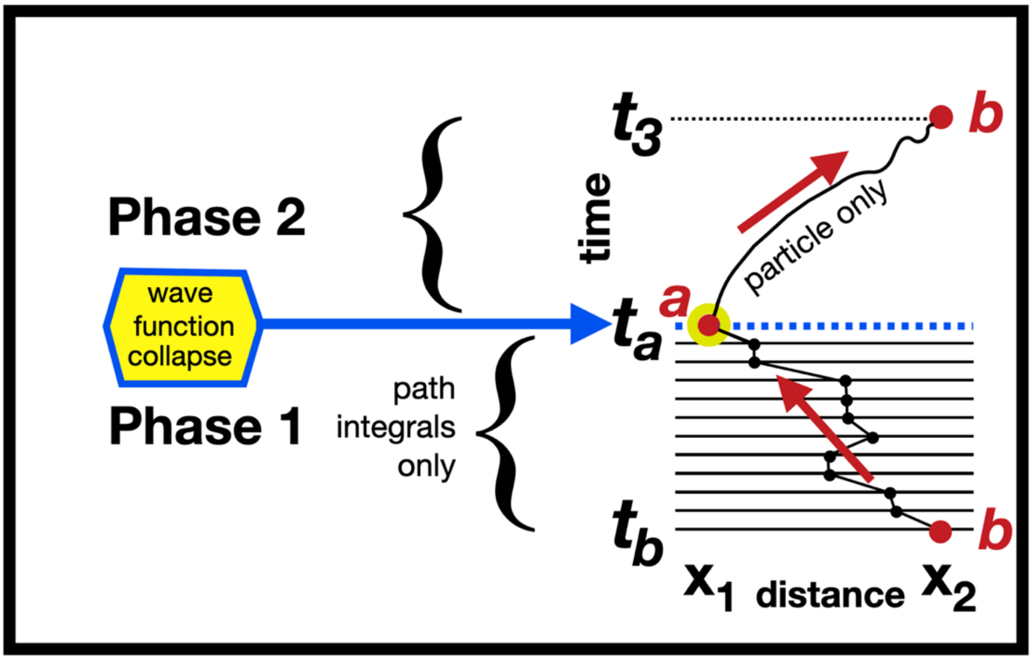

Fig. 7. Compared to the right side of the previous Figure, we have sliced the time in Phase 1 into increments of duration **ε**. Only one path (named "$\mathbf{x_n}$") is diagrammed here. It consists of dots connected by straight lines crossing a stack of time slices. As **ε** diminishes towards zero, this choppy path approaches a smooth path $\mathbf{x_n}$.

When we sum across all the paths $\mathbf{x}_n$ from **b** to **a**, we arrive at a first approximation of the R-path integral:

$$K_R(a,b) = \sum_{\text{All paths from } b \text{ to } a} \phi_R[x(t)] \tag{11}$$

where $\phi_R[x(t)]$ is the phase of a path. In Feynman's work it is the **phase** of the path that is the most important variable in deriving the total path-integral. The contribution of a path to the total phase is proportional to the exponent of its reverse-action S_R:

$$\phi_R[x(t)] = \text{constant } e^{(i/\hbar)S_R[x(t)]} \tag{12}$$

where the reverse-action (here we repeat Equation # 1):

$$S_R(a,b) = \int_{t_b}^{t_a} \mathcal{L}_R(\dot{x}, x, t)\, dt \tag{13}$$

is a line integral taken over the trajectory passing through the points of x_n (Figure 7).

We need a constant that will normalize these equations. Following the lead of Feynman and Hibbs,

$$\mathcal{A} = \left(\frac{2\pi i\hbar\epsilon}{m}\right)^{1/2} \tag{14}$$

we define:

$$\mathcal{A}_R = \left(\frac{2\pi i\hbar\epsilon}{m}\right)^{1/2} \tag{15}$$

We may write (equivalent to F&H Eq. 2.22):

$$K_R(a,b) = \lim(\epsilon \to 0)\ \frac{1}{\mathcal{A}_R} \int \ldots \iint e^{(i/\hbar)S_R(a,b)} \frac{dx_1}{\mathcal{A}_R}\frac{dx_2}{\mathcal{A}_R}\ldots\frac{dx_{N-1}}{\mathcal{A}_R} \tag{16}$$

We define the reverse path integral to be

$$\mathrm{K}_R(a,b) = \int_b^a e^{(i/\hbar)S_R(a,b)} \mathcal{D}[x(t)] \tag{17}$$

This is F&H's equation 2.25 after we swap the bounds of integration. (33)

For details see Supplementary Materials which are available in the second part of this article in the *Journal of Advances in Physics* (2022).(3) https://rajpub.com/index.php/jap/article/view/9268

2.3. Davisson-Germer Experiment

We will now show that the Davisson-Germer experiment of 1927, which experts say "proved wave-particle duality" can equally well be explained by TEW. In other words, the data from this experiment are consistent with either $+\boldsymbol{\psi}$ or $-\boldsymbol{\psi}$. Clinton Davisson and Lester Germer shot electrons at a crystal of nickel and measured the electrons rebounding.

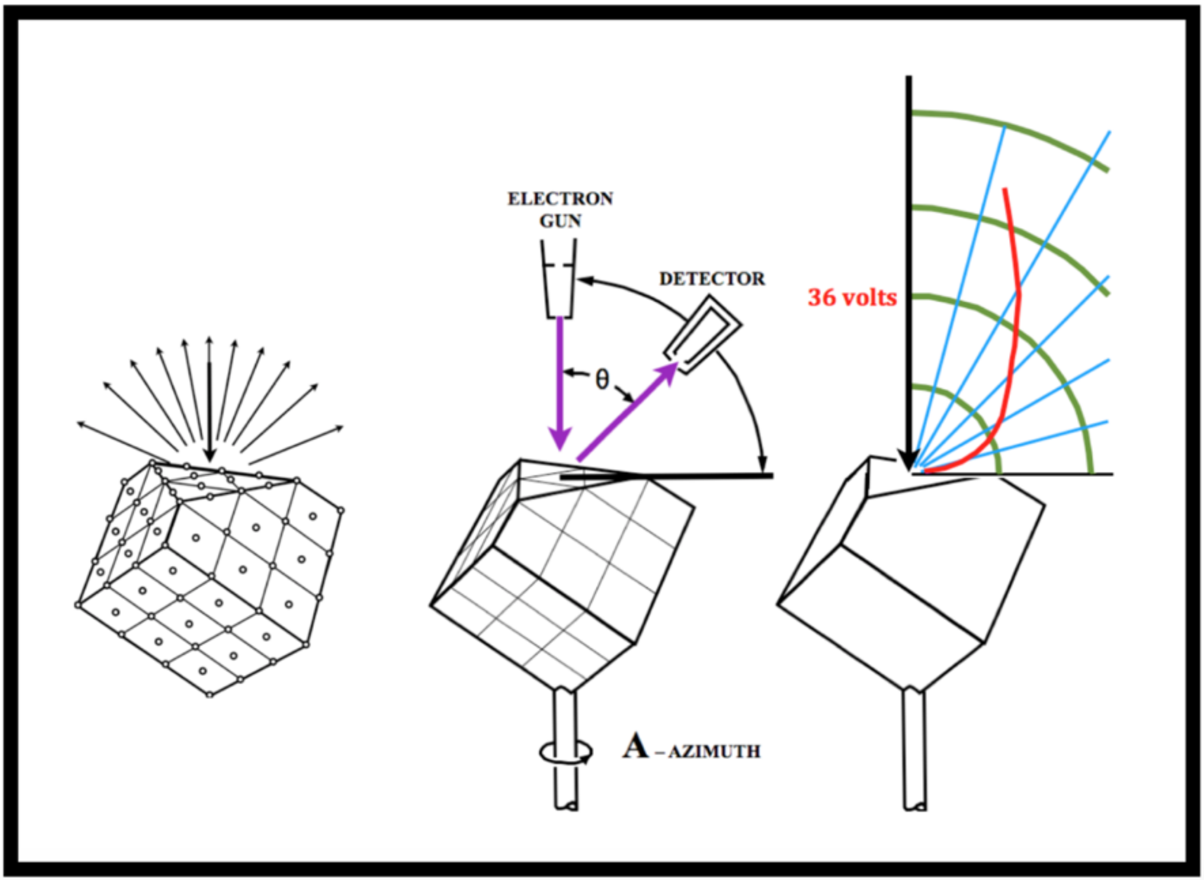

Fig. 8. The Davisson-Germer experiment. Left: a crystal of nickel, off which electrons ricochet. Middle: Electron gun shoots electrons at crystal and they are detected at angle *θ*. Right: polar coordinates graph the detected electrons (in red).

Davisson and Germer find a remarkable "spur" or "hump" (Figure 8) that can only be explained if electrons are interacting with waves of 1.67 Å.(30)

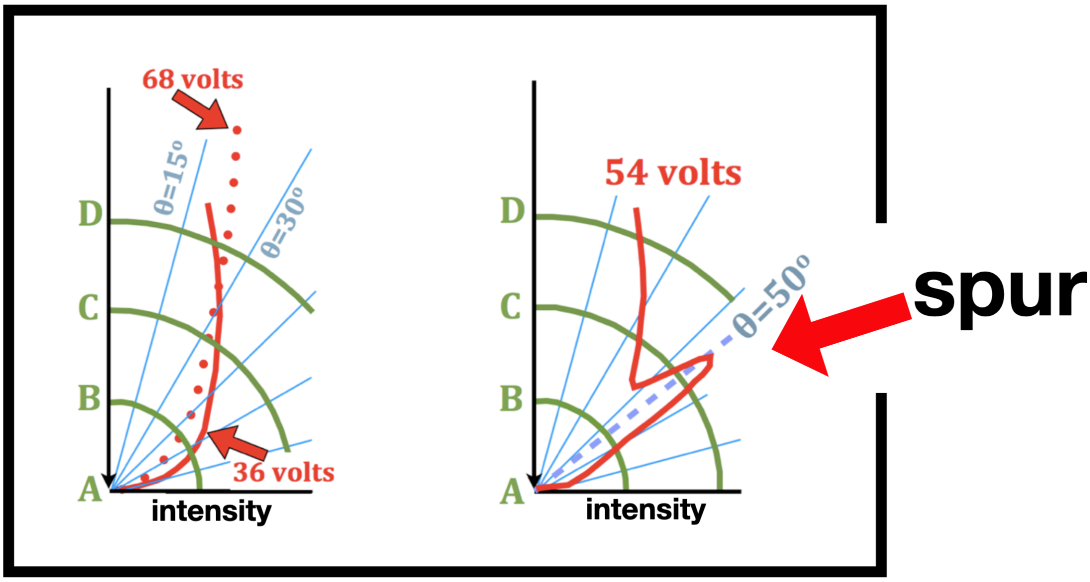

Fig. 9. Polar coordinate graphs of electrons coming off a nickel crystal at various voltages show an unusual spur at 50° and 54 volts. It indicates electrons are interacting with waves of 1.67 Å.

TEW can explain the data (Figure 10 right). Elementary Waves of 1.67 Å start at the detector, refract backwards through the crystal, then electron particles follow the waves backwards from the gun to the detector, producing that spur in the data. The experiment can be explained by either theory. The experiment does not provide information that would allow us to determine which of the two is the correct interpretation.

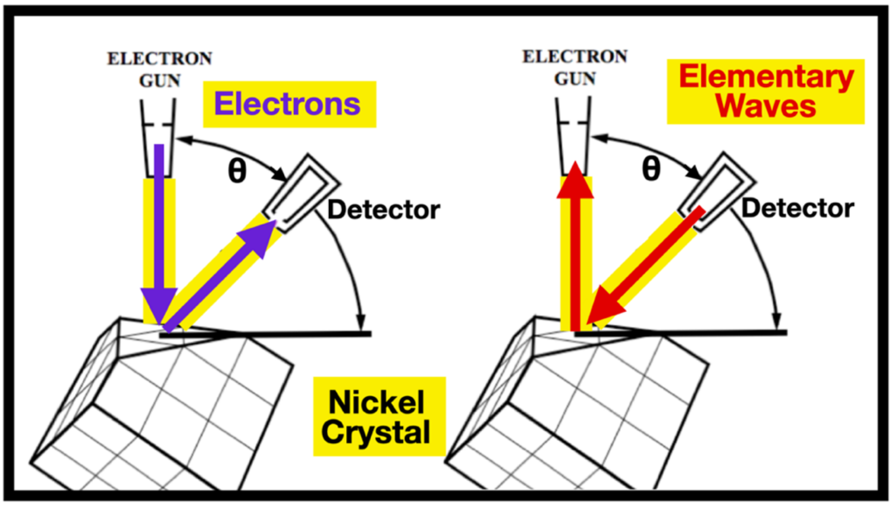

Fig. 10. Left: electrons target a nickel crystal. Right: Elementary Waves travel in the opposite direction first, and then electrons follow the Elementary Waves backwards to the detector from which that Elementary Wave is continuing to flow. This explains the data equally well, without wave-particle duality.

Details about the Davisson-Germer experiment can be found in the second part of this article in the *Journal of Advances in Physics* (2022)).(3) https://rajpub.com/index.php/jap/article/view/9268

3. Untangling the Mysteries of QM

If our thesis is correct (nature's quantum equations are the negative of QM's because particles follow zero-energy waves backwards) then we should be able to untangle some eccentricities of QM.

3.1. Quantum Eraser

There is a quantum eraser experiment that appears to show data can be "erased" backwards-in-time if we subsequently discover which slit the particle went through in a double-slit experiment. The experimenters ignore the laser and assume all decisions are made at the beam splitters or detectors. The TEW perspective is so radically different from the QM perspective, that it is as if we are discussing a different experiment. We claim Elementary Waves start at all the detectors and travel backwards through the equipment, converging on the laser. All decisions in this experiment are made at the laser, dozens of nanoseconds before the experimenters think decisions are made. Then photons follow the waves backwards with a probability of one. TEW can explain this experiment without a quantum eraser, without Complementarity, without time-reversal, or effect preceding cause. All the details of this experiment can be found in the second part of this article in the *Journal of Advances in Physics*.(3,40). https://rajpub.com/index.php/jap/article/view/9268

3.2. Wheeler's *Gedanken* Experiment

John Wheeler proposed a thought experiment in which a photon enters an interferometer as a wave or particle, depending on whether it will subsequently be measured as a wave or particle. "Gedanken" is a German word meaning "thought" experiment. Vincent Jacques, et.al. conduct this experiment and confirm Wheeler's ideas. This experiment also claims to prove backwards-in-time cause-and-effect. As was the case in the quantum eraser experiment, the TEW perspective is so radically different from the QM perspective, that it is as if we are discussing a different experiment. From the TEW perspective, the only thing they prove is that when they look for a wave they see a wave, and when they look for a particle, they see a particle. That proves that both waves and particles are **always** present at the same time, which is what TEW predicts. When TEW examines this experiment, effect does not precede cause, and once again, we demonstrate that wave-particle duality is false. Details of this experiment are also available in the second part of this article in the *Journal of Advances in Physics*.(3,38) https://rajpub.com/index.php/jap/article/view/9268

3.3. Wave-Function-Collapse

QM and TEW are discordant ways-of-thinking, corresponding to mutually contradictory paradigms. It is therefore difficult to have a constructive dialog. We will use the phrase "wave-function-collapse" to facilitate communication between QM and TEW. It is a term drawn from the QM vocabulary.

In QM wave-function-collapse is defined mathematically: multiple eigenvalues of an operator collapse to one eigenvalue when the corresponding observable is measured (Figure 11). If measured again, it still has that same value. Because of measurement, nature changes: an observable changed from having many values to just one.

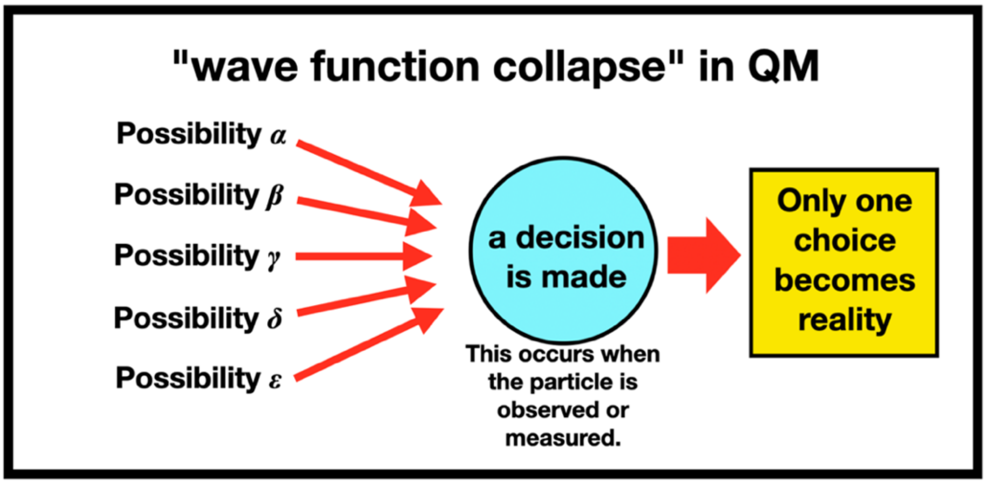

Fig. 11. In QM wave-function-collapse occurs when a quantum system is measured. The different possibilities on the left are eigenvalues of the operator in Hilbert space.

Thus wave-function-collapse means eigenvalue collapse. With TEW this occurs earlier and in a different location. In a double-slit experiment, it occurs as the particle leaves the gun. At that instant a quantum system is created. By "a quantum system" we mean that a particle attaches securely to its Elementary Wave, which it follows backwards to that point "**Z**" on the target screen from which that specific Elementary Wave emanates.

We propose that the single eigenvalue of the operator that is measured by QM at the detector, was already determined at the gun. This resolves the Schrödinger's cat paradox. Schrödinger's cat is a riddle for QM but not for TEW. Our approach yields a dead or alive cat, but not both, before the box is opened, and the cat observed.

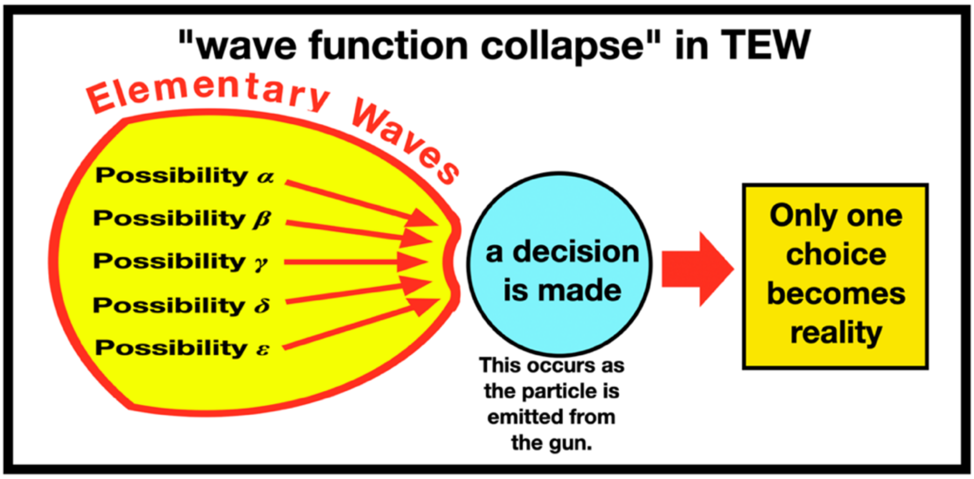

Fig. 12. In TEW wave-function-collapse occurs when a quantum system is created. The possibilities on the left are zero-energy Elementary Waves that start at different points $\mathbf{Z}_\alpha$, $\mathbf{Z}_\beta$, $\mathbf{Z}_\gamma$, $\mathbf{Z}_\delta$, and $\mathbf{Z}_\varepsilon$ of the target screen and move through Cartesian space to the gun before any particle is fired. The particle chooses one-and-only-one wave to follow backwards to precisely that point $\mathbf{Z}_x$ on the target screen from which its wave is continuing to flow.

3.3.1 Robert Jaffe's Six Postulates of QM

We can use Robert Jaffe's six postulates of QM to probe TEW, thereby building a communication bridge between two very-different ways-of-thinking. Jaffe says that every observable aspect of a quantum system corresponds to an operator in Hilbert space. The operator has an infinite number of eigenvalues. When the system is measured only one eigenvalue is found, which means the superposition of eigenvalues has collapsed to one value. After measurement, if we measure that observable again, we find the same value. Thus, measurement changes reality; measurement modifies nature. In a double-slit experiment "measurement" occurs when a dot appears on the screen.

TEW doesn't care about measurement. When a particle leaves the gun a quantum-system is formed, which consists of one Elementary Wave linked to one particle following that wave backwards. The two are permanently linked until that quantum system hits the target-screen. When that quantum-system is created at the particle gun wave-function-collapse occurs, and it is then that all the eigenvalues of an operator collapse to just one eigenvalue, which is carried to the target-screen where it is measured by QM.

Thus, QM and TEW disagree about the status of quantum systems before they are measured. QM says such systems have no specific characteristics prior to measurement. Everything is in a super-position. Measurement creates the specific features. We call this an observer-dependent theory. Below we will present empirical evidence that such observer-dependence is not found in nature. TEW says that definite characteristics exist before a quantum system is measured. That resolves the Schrödinger's cat dilemma. Details are given in Part 2 of this article: https://rajpub.com/index.php/jap/article/view/9268

3.3.2 A High-Energy Scattering Experiment

When and where does wave-function-collapse occur in Figure 13?

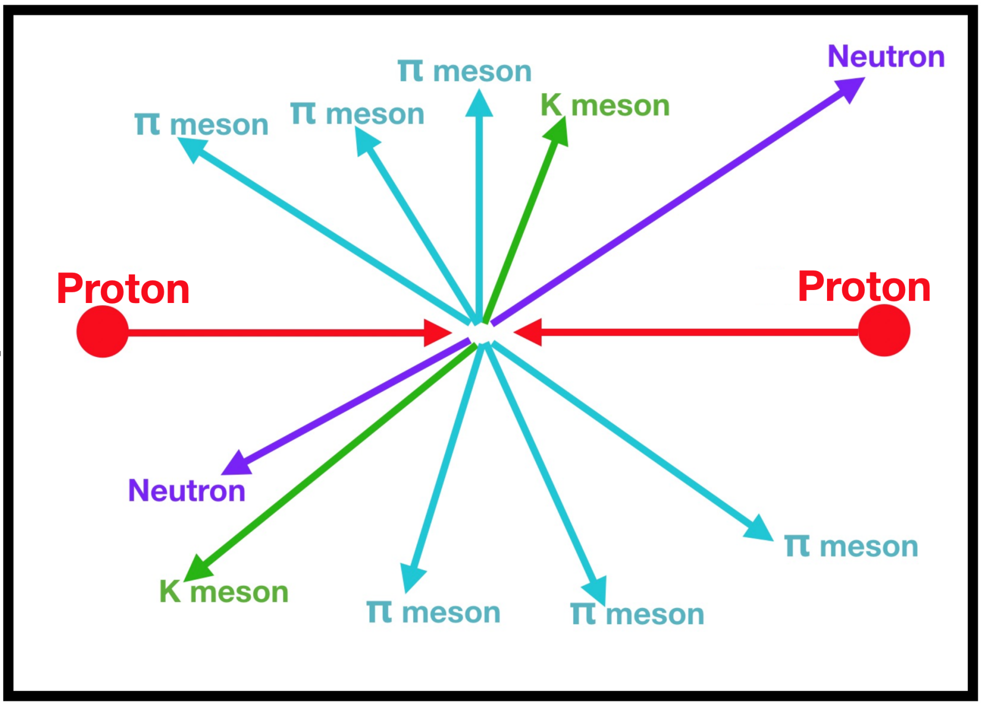

Fig. 13. If two protons collide at almost lightspeed, they annihilate. New particles spray out from inside the collider and are measured by detectors outside. When and where does wave-function-collapse occur?

TEW says the decisive event is when new particles, as they come into existence attach to Elementary Waves at the center of Figure 13. Thus wave-function-collapse occurs at the center of this diagram. QM says wave-function-collapse is located at the detectors, which are outside the collider, and at a later time.

3.4. Double-Slit Experiments

Feynman says double-slit experiments contain the "central mystery of QM." Complementarity allegedly shows that quantum particles behave differently if we are watching. Complementarity says, "If we observe which slit a particle went through then the wave pattern on the screen vanishes." This is what we call an "observer dependent" theory. We will now show that TEW can explain both the double-slit experiments and Complementarity in a logical way that is different than anything you have been previously taught by QM experts.

According to TEW, zero-energy waves travel from each point **Z** of the target screen (detector), backwards through the two slits, to the particle gun, whereupon a particle selects one-and-only-one to follow backwards with a probability of one, going through one-and-only-one slit (it doesn't matter which slit) and inevitably striking that point **Z** from which its wave is continuing to flow.

Each point on the target screen emanates zero-energy Elementary Waves of all frequencies in all directions. We ignore 99.999% of them because they don't interact with physical reality. Our reasoning for saying they exist will be explained below.

We focus our attention on waves with a frequency corresponding to the de Broglie frequency of the particle that will soon be emitted (Figure 14). After passing backwards through the two slits, the waves coming from **Z** through **A** interfere with those coming from **Z** through **B**.

The particle **α** in the gun sees a zillion in-coming Elementary Waves, one from each point on the target screen. At random **α** chooses one-and-only-one wave to follow backwards. That choice constitutes wave-function-collapse. The experiment changes from probabilistic to deterministic as the particle leaves the gun.

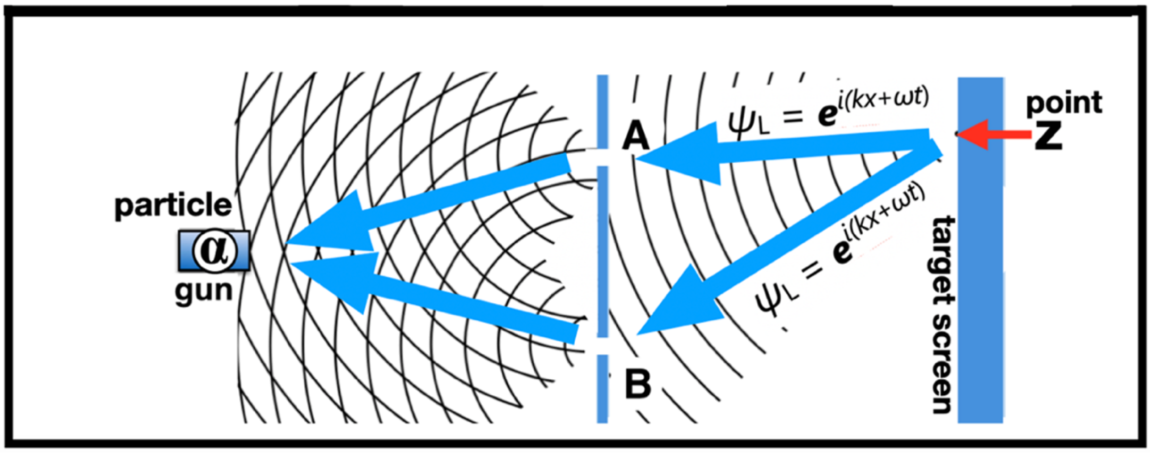

Fig. 14. Each point **Z** on the target screen (right) in a double-slit experiment, emanates Elementary Waves that pass backwards through the two slits (**A** and **B**) interfering as they approach the particle gun on the left.

3.4.1 Complementarity Explained

Complementarity is caused by mathematical rules we are about to state, not by human observation. The linear partial differential equations (**PDE**s) in this experiment can be added together if and only if they originate from the same point **Z** on the target screen. **PDE**s from two different points (like Z_1 and Z_2) cannot add together.

To discover which slit a particle uses, researchers insert a detector. The energy from the lamp is infinitely more than the zero-energy of the Elementary Waves passing through the lamplight. It changes the waves, so they no longer act as if they originated at point **Z**. The wave passing backwards through **A** no longer adds together with the wave passing backwards through **B**, because of the PDE rules. There is no wave interference near the gun.

What does the wave interference pattern on the target screen signify? Indirectly it arises from the interference of Elementary Waves near the particle gun. If-and-only-if there is interference in proximity to the gun, will the target screen display a wave interference fringe pattern (Figures 15 and 16).

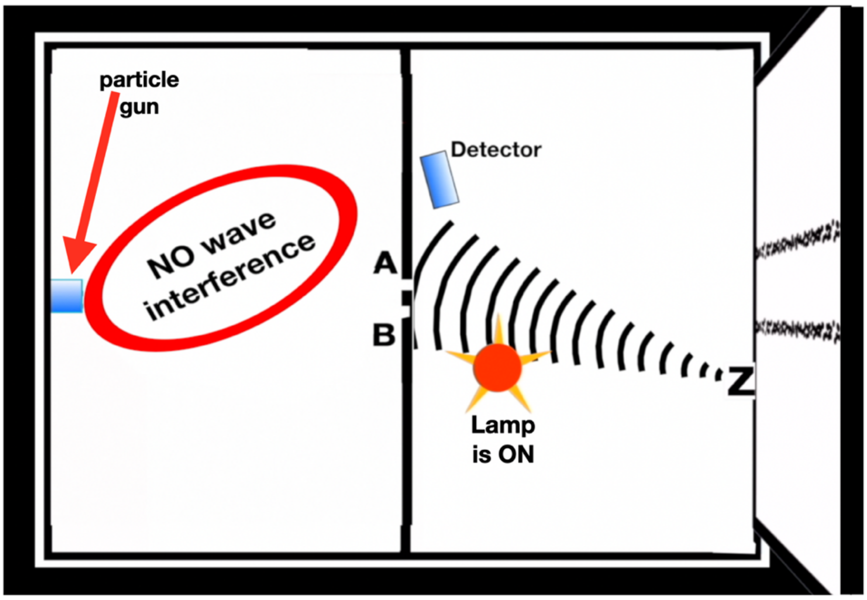

Fig. 15. Elementary Waves from point **Z** do not interfere after passing backwards through the two slits because the energy from the lamp modified them. The wave through **A** acts as if it originated at **A**. The other as if it originated at **B**. Because of the **PDE** rules they do not interfere. The absence of wave

interference in proximity to the gun indirectly causes an absence of a wave pattern on the target screen on the right.

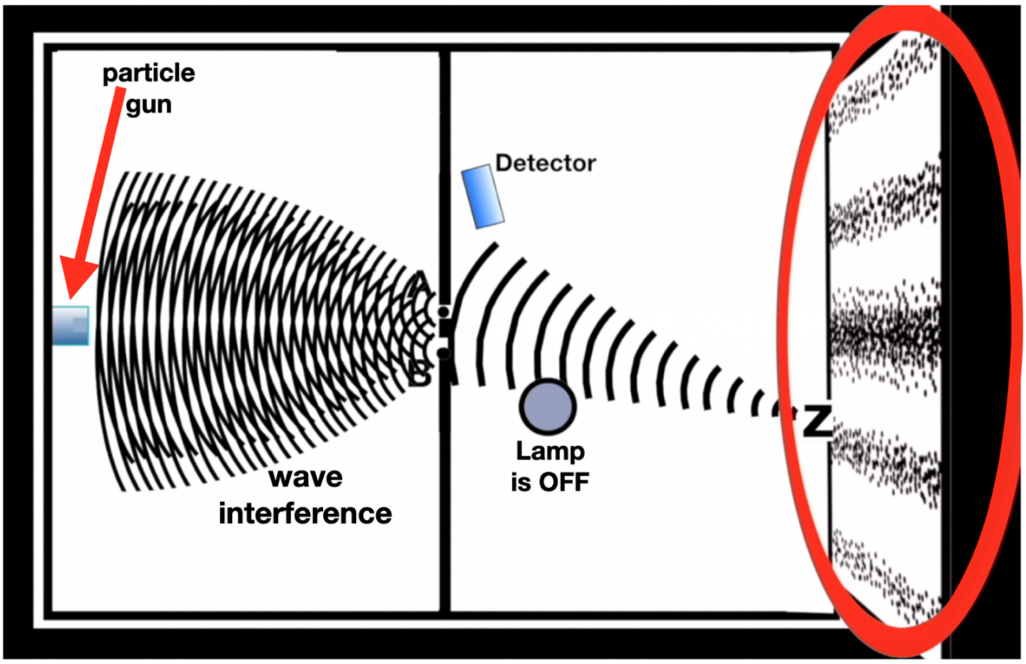

Fig. 16. With the Lamp OFF the waves from point **Z** through slit **A** add into a superposition with those from **Z** through **B**, because of the **PDE** rules. Wave interference on the left indirectly causes the wave pattern on the target screen (right). Figures 15 and 16 explain "Complementarity" without human observers.

In the Supplementary Materials we show that Robert Pfleegor and Leonard Mandel, using a variant of a double-slit experiment, disprove wave-particle duality.(43) We also demonstrate that our explanation of the double-slit experiment will reproduce the expected wave-interference-fringe pattern on the target-screen. See: https://rajpub.com/index.php/jap/article/view/9268

3.4.2 An Infinite Number of Elementary Waves

We say that everywhere in space there are an infinite number of Elementary Waves travelling in all directions and at all frequencies. How do we know that?

If a particle impacts point **Z** on the target screen of a double-slit experiment, that means the particle has followed backwards an Elementary Wave that originated from point **Z**. What does that imply?

First, it implies that for every point **Z** from which an Elementary Wave emanates, there are a "zillion" (i.e., large finite number) other points from which other Elementary Waves emanated, but the particle selected only the wave from **Z**. The other waves vanish, never having interacted with physical reality. This is similar to how Feynman diagrams involve "virtual particles" that are never directly observed. So also our theory involves "virtual waves" that are never directly observed.

Second, it implies that for every wave passing backwards through the two slits (**A** and **B**) there is an entire sphere of waves aimed in other directions, that weren't travelling toward slits **A** or **B**. Those other waves, pointed in the wrong direction, vanish forever.

Third, the double-slit experiment performs the same way for a wide range of particles varying from photons of all frequencies to electrons, to atoms, to molecules as large as Buckminsterfullerene (C-80) and phenylalanine molecules. Each of these has a different de Broglie frequency, which implies that there are a wide range of frequencies of Elementary Waves for which the double-slit experiment works. The only assumption that makes sense is that it would work for all frequencies.

When you add up the number and variety of Elementary Waves cited in the last three paragraphs, it implies that when a dot appears at point **Z** on the target screen, everywhere in space there are an infinite number of Elementary Waves travelling in all directions and at all frequencies, all carrying zero-energy. Perhaps we should call them "virtual waves."

Georg Cantor taught us there are an infinite number of infinities. The number of Elementary Waves that do not interact with the physical universe is a high order of infinity. Similarly, the number of "virtual particles" in Feynman diagrams is a high order of infinity.

It implies the universe is packed with such waves. Relativity and cosmology lie outside our boundary of focus.

3.5. Bell-Test Experiments

Bell-test experiments without loopholes disprove Einstein's local-realism but worsen quantum bewilderment. Some scientists now claim everything here on earth is immediately affected nonlocally from the other side of the Milky-Way. Other quantum experts say, "Nonsense!" TEW clarifies and simplifies the picture. (36)

TEW says nothing travels faster than lightspeed. The other side of the Milky-Way is irrelevant locally. Our experiments start earlier than QM's. So, our light-cones are larger (twice-as-long temporally, twice-as-wide spatially). These larger light-cones include more phenomena as "local." Therefore, TEW defines fewer things as "nonlocal."

3.5.1 Definition of Bi-Rays

There is a more advanced version of TEW, called Bi-Ray Theory, which we will now teach you. If everywhere in space there are Elementary Waves of all wavelengths, travelling in all directions, this implies every Elementary Ray has a mate, namely an identical Ray travelling coaxially in the opposite direction at lightspeed (Figures 17 and 18).

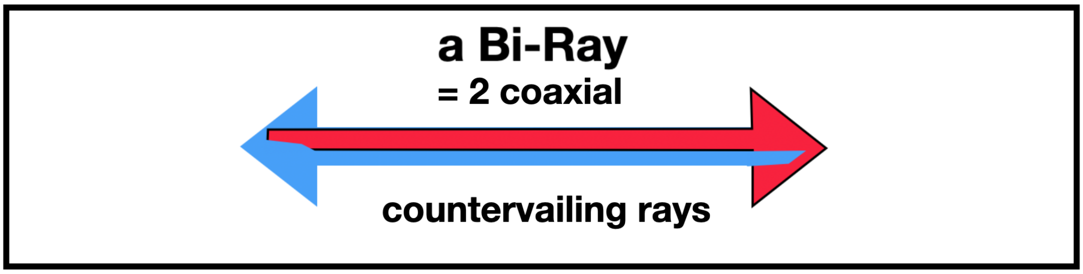

Fig. 17. A Bi-Ray is two coaxial, countervailing Elementary Rays, of the same frequency.

A Bi-Ray spans from Alice to Bob. A pair of entangled photons is emitted into the center by a 2-photon source (Figure 18).

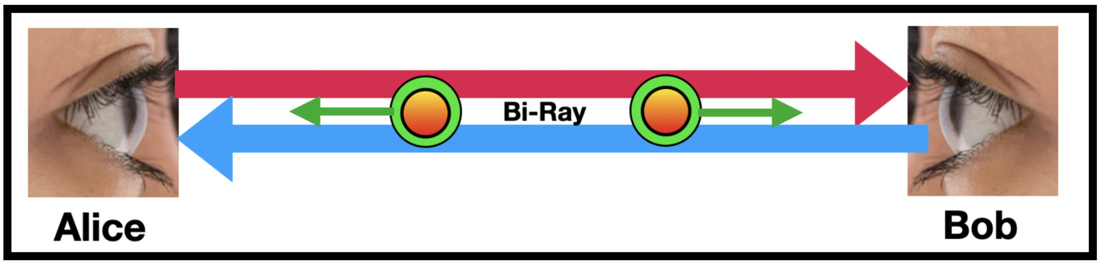

Fig. 18. A 2-photon source (not shown) emits a pair of entangled photons into a Bi-Ray.

3.5.2 Mathematics of the Bell-Test Experiments

TEW can explain the Bell test experimental results. Only two assumptions are needed. First, what makes the countervailing Elementary Rays coherent is a photon following both rays. Second, the probability of each photon following a Bi-Ray is the amplitude of it following one ray times the amplitude of it following the other.

Based on the equations we are about to derive, we will show that the probability for Alice and Bob both seeing a photon simultaneously is $P = cos^2(\varphi_2 - \varphi_1)$ or $P = sin^2(\varphi_2 - \varphi_1)$, where "*P*" means "probability." In the Bell test experiment literature, they use the metric "coincidence rate" instead of *P*.

The difference between cosine and sine in the final data depends on what technology is used to generate two entangled photons. For example, in Alain Aspect's experiment they used a calcium cascade source to generate 2-photons with the same polarization, and therefore the coincidence rate they discovered was $P = cos^2(\varphi_2 - \varphi_1)$. If Aspect had used a different source that generated photons orthogonal to one another, then his coincidence rate would have been $P = sin^2(\varphi_2 - \varphi_1)$.

One experiment found a coincidence rate of $sin^2(\theta + x)$, where the variable "x" varied depending on the time of the day, as the temperature of their equipment changed. The variable $\theta = \varphi_2 - \varphi_1$. That entire family of sinusoidal squared curves violates Bell's inequality.

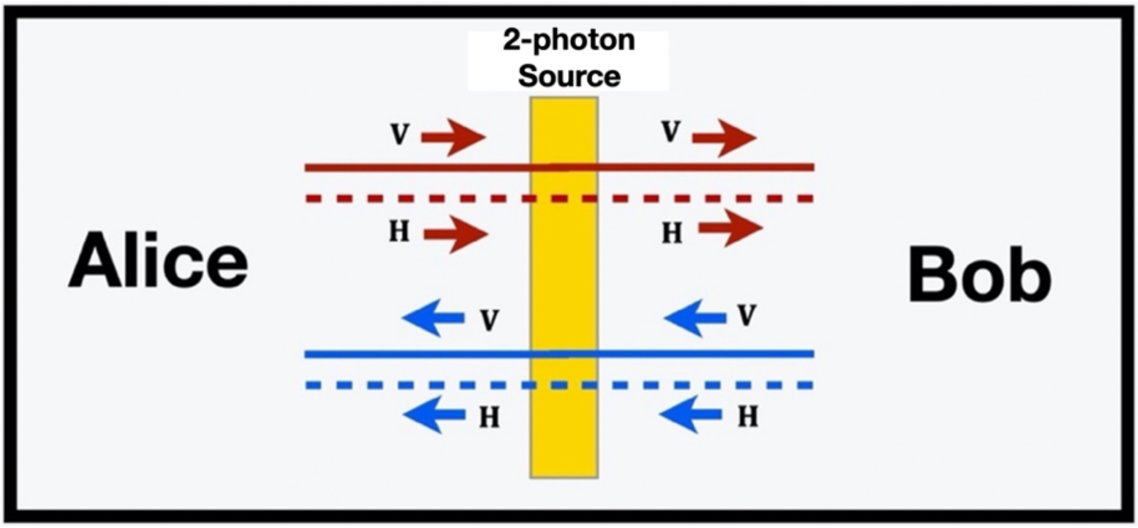

Fig. 19. Using vertical (solid lines) and horizontal (dashed lines) eigenstates of elementary waves, we re-draw Figures 17 and 18. We will use red to denote an elementary ray travelling to the right, and blue for one travelling to the left. These are eigenstates of the individual Elementary Rays, not Bi-Rays.

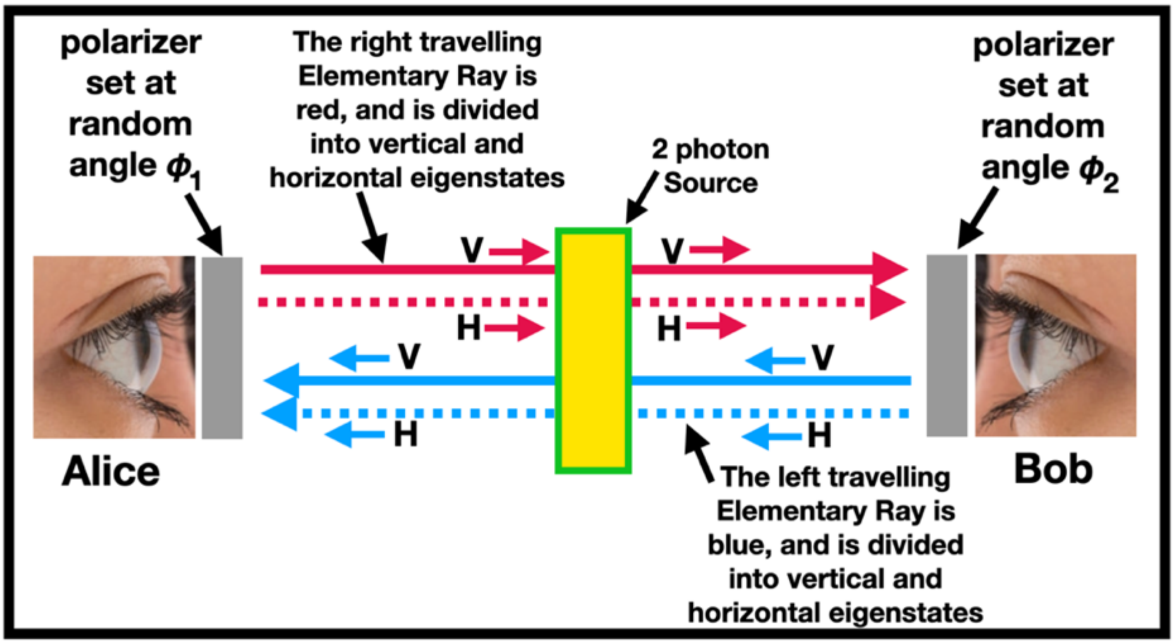

Fig. 20. This elaborates the previous Figure. Each photon follows both Elementary Rays, i.e., each photon follows all the red and all the blue arrows. Notice that the vertical and horizontal eigenstates (V,

H, V and H) of the four Elementary Rays, are different than the eigenstates of the Bi-Rays, which we will name (***α***, ***β***, ***γ*** and ***δ***) in the next Figure.

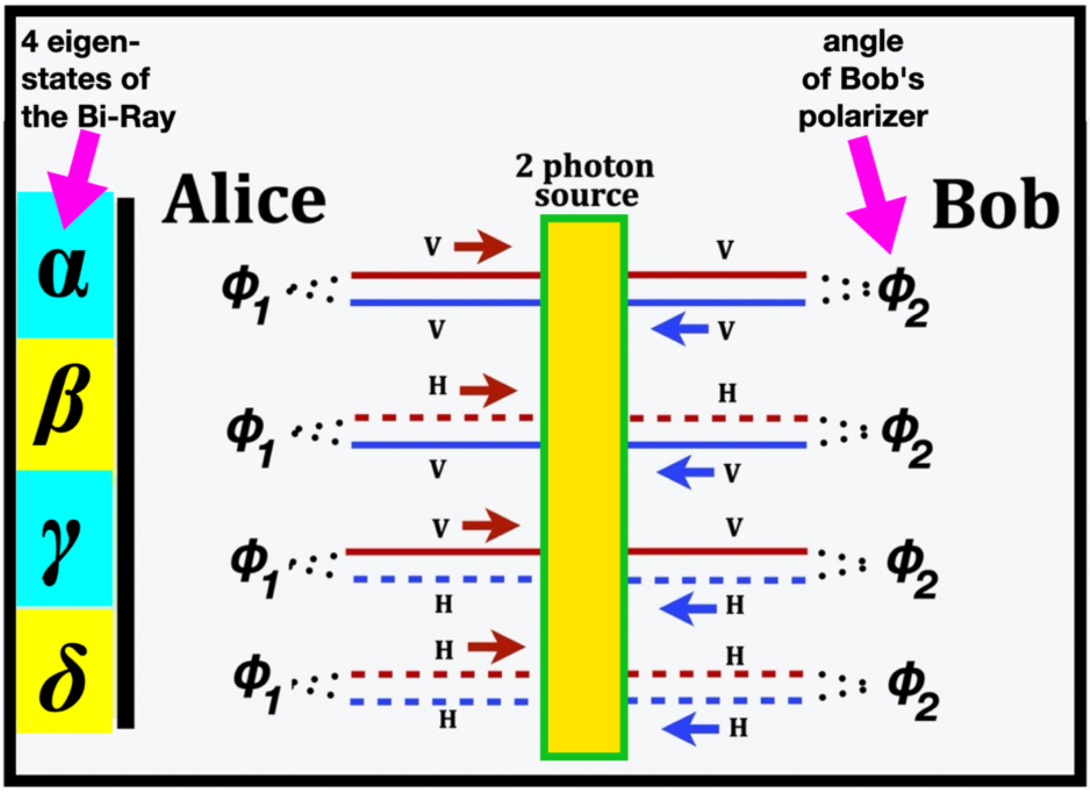

Fig. 21. We define four new eigenstates (***α***, ***β***, ***γ*** and ***δ***) of the Bi-Ray between Alice (whose polarizer is set at random angle $\boldsymbol{\Phi}_1$) and Bob (polarizer set at $\boldsymbol{\Phi}_2$).

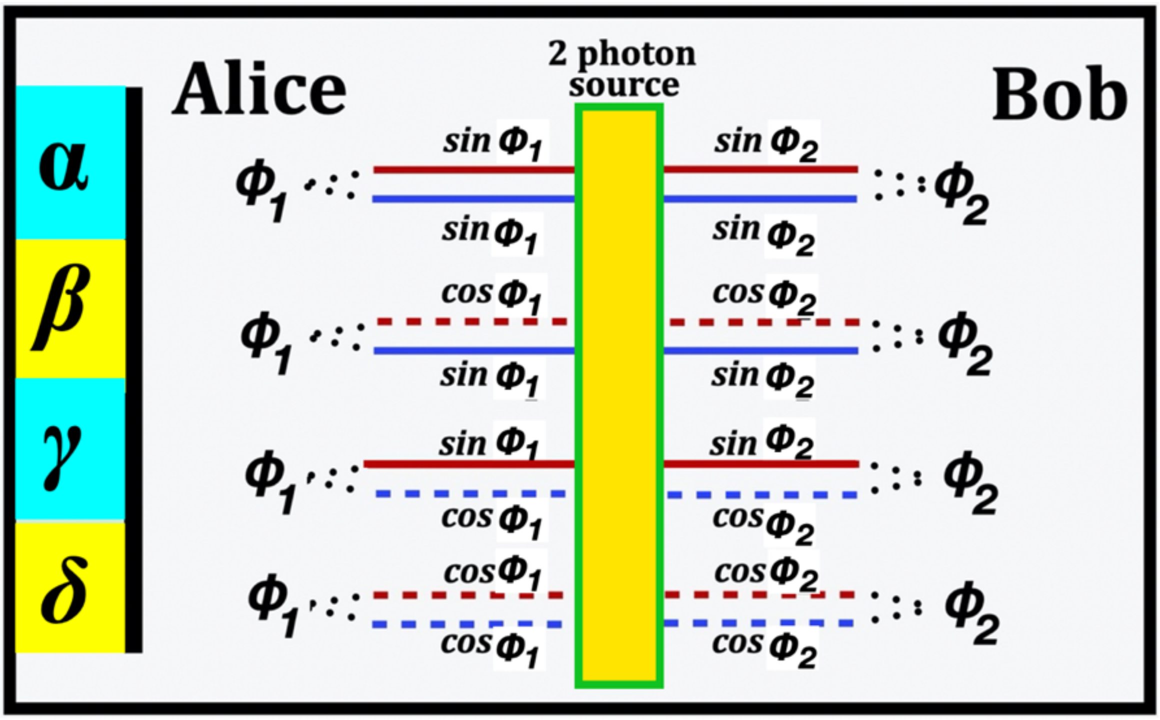

Fig. 22. These sines and cosines show the amplitude for a photon from the source being detected by Alice or Bob in a specific eigenstate. The diagram implicitly shows that Alice and her equipment never know anything about Bob's photon, nor about Bob's equipment, and vice-versa.

The probability of both Alice and Bob simultaneously seeing a photon (the so-called "coincidence rate") in the **α** eigenstate is the probability of Alice seeing a photon ($sin(\Phi_1)$ $sin(\Phi_1)$) ***times*** the probability of Bob seeing a photon ($sin(\Phi_2)$ $sin(\Phi_2)$). This provides the first line of the next equation:

location of the
2-photon Source

$$P = sin(\phi_1)\ sin(\phi_1) \times sin(\phi_2)\ sin(\phi_2) \ldots$$

To find the probability of Alice and Bob simultaneously seeing a photon we add together the probability in each of the four of the eigenstates (***α, β, γ*** and ***δ***) in Figure 22:

$$P = sin(\Phi_1)\ sin(\Phi_1) \times sin(\Phi_2)\ sin(\Phi_2) \leftarrow (\text{within eigenstate } \alpha)$$
$$+\ cos(\Phi_1)\ sin(\Phi_1) \times cos(\Phi_2)\ sin(\Phi_2) \leftarrow (\text{within eigenstate } \beta)$$
$$+\ sin(\Phi_1)\ cos(\Phi_1) \times sin(\Phi_2)\ cos(\Phi_2) \leftarrow (\text{within eigenstate } \gamma)$$
$$+\ cos(\Phi_1)\ cos(\Phi_1) \times cos(\Phi_2)\ cos(\Phi_2) \leftarrow (\text{within eigenstate } \delta) \quad (18)$$

When we add those four lines together, the result can be factored:

$$= [sin(\Phi_1)\ sin(\Phi_2) + cos(\Phi_1)\ cos(\Phi_2)]$$
$$\times\ [sin(\Phi_1)\ sin(\Phi_2) + cos(\Phi_1)\ cos(\Phi_2)] \quad (19)$$

There is a trigonometry relationship that allows us to compress that into:

$$= cos(\Phi_2 - \Phi_1) \times cos(\Phi_1 - \Phi_1) \quad (20)$$
$$= cos^2(\Phi_2 - \Phi_1) \quad (21)$$

This is how TEW accounts for the Bell test data. Our prediction is that the coincidence rate will be $P = cos^2 (\Phi_2 - \Phi_1)$. If the 2-photon-Source were changed so it emitted photons orthogonal to one another, then the final coincidence rate would be

$$P = sin^2 (\Phi_2 - \Phi_1). \quad (22)$$

Wave-function collapse (which is located at the 2-photon source and consists of entangled photons attaching themselves to the same Bi-Ray) occurs as the photons are emitted, not when the photons are measured by Alice and Bob. However, the stopwatch for our experiment starts earlier. Our stopwatch starts when the Elementary Waves start at the polarizers and travel to the 2-photon source. When you start your stopwatch determines the size of your light-cone.

3.5.3 Local Realism

The Bell test experiments are said to test "local realism," and it is alleged that those experiments disproved "local realism." But this is wrong. That term has two different meanings, depending on whether you include or exclude Elementary Waves as part of "reality." Einstein did not know about and did not include Elementary Waves. Therefore, anything that was **local** to a quantum particle over the course of one second would include a nanometer distant. We **include** Elementary Waves as part of reality, so that which is **local** to a quantum particle over the course of one second would be anything that is within 300,000 kilometers, which is how far an Elementary Wave travels in one second.

Einstein's view of the world was that cause-and-effect are local, and that local reality has definite characteristics even before we measure them. He disliked what he called, "Spooky action at a distance," because it violated his sense of reality. Seventy years of Bell test experiments have discredited Einstein's idea of how reality works. However, it turns out that both sides made a mistake. On Einstein's side, he didn't consider Elementary Waves, which are the source of the apparent "Spooky action at a distance." So, Einstein worldview was too small.

On the QM side of the argument, the Bell test experiments reported their light-cones incorrectly. It is the size of light-cones that determines what is defined as "local" versus "nonlocal." For reasons having to do with when you start your stopwatch, the Bell test experiments have classified too many things as "nonlocal." Our light-cones are twice as large.

These two mistakes dovetail. The Bell test experiments can be explained by TEW, and Elementary Waves are part of reality. The enlarged light-cones of TEW mean that we must redefine what we classify as "local realism" versus "nonlocal realism."

A critic told us that TEW is a "nonlocal realism." He said that it has been known for decades that nonlocal realism can explain the Bell test experiments. We disagree with his use of the word "nonlocal." Because of our larger light-cones we say that our explanation of the Bell test experiments is a new variety of "local realism." By this, we mean there is no spooky action at a distance because what appears to be "spooky action" is Elementary Waves that Einstein didn't know about.

Our view of reality differs from Einstein's because we know that Elementary Waves are part of reality, and Einstein didn't. The Bell test experiments endorse TEW's "local realism" but reject Einstein's "local realism."

3.6. Dirac's Superposition of States

In his book, *Principles of Quantum Mathematics* (pages 4–7), Paul Dirac speaks of the principle of superposition of a photon. We modify his idea, because Dirac was speaking of wave-particles, and we split them asunder. TEW says only waves have a superposition. Particles don't. (31)

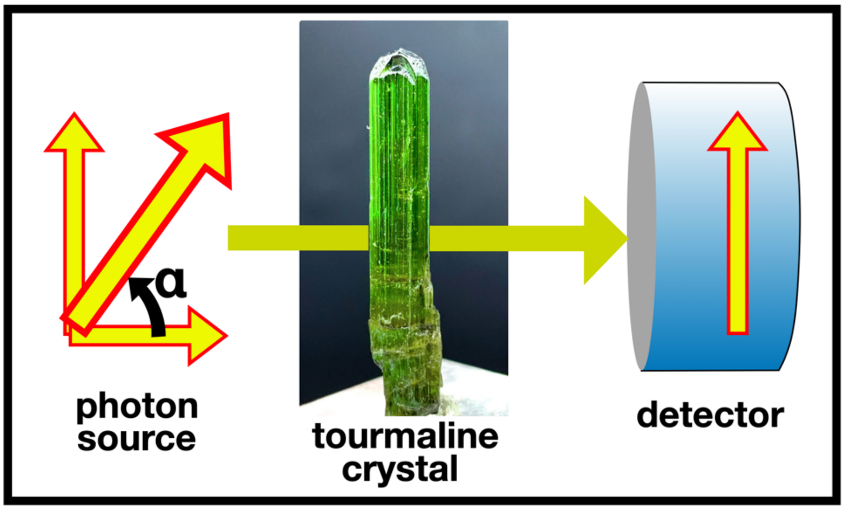

Fig. 23. Dirac's model. A photon polarized obliquely at angle **α** is in a superposition of vertical and horizontal polarization. As it meets a tourmaline crystal the crystal, a measurement occurs. The crystal only allows through light polarized perpendicular to its optic axis. The photon's superposition collapses so that what comes out of the crystal are whole photons polarized vertically, or no photons. The percentage of photons observed by the detector is $\sin^2\boldsymbol{\alpha}$.

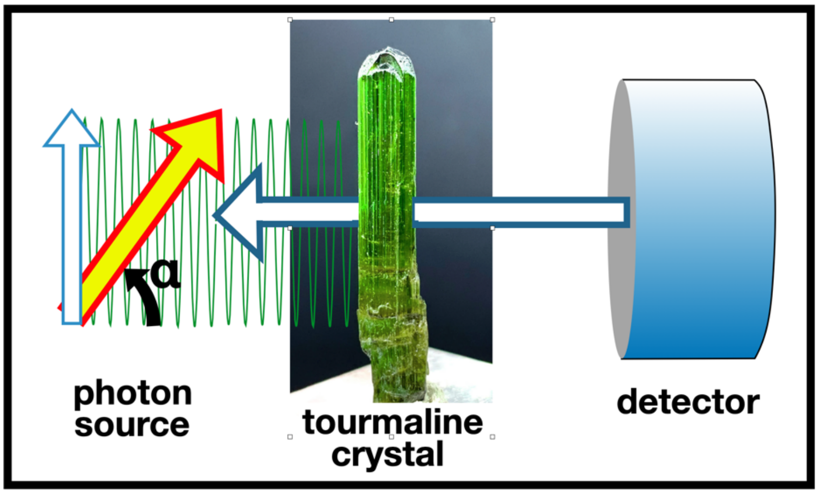

Fig. 24. Our model. An elementary wave (white) goes from the detector to the photon source. As it passes through the tourmaline crystal it acquires a vertical polarization. If a photon responds to this polarized wave, only whole photons, polarized vertically follow the wave backwards. This superposition collapse occurs at the photon source, distant from the tourmaline crystal. That determines what reaches the detector. The percentage of such photons is $\sin^2\boldsymbol{\alpha}$. In this model wave-function collapse occurs earlier and at a different location than in Dirac's model.

TEW starts earlier, at the detector. We say that zero-energy Elementary Waves start at the detector, travel backwards through the tourmaline to the source, acquiring vertical polarization inside the crystal. A photon chooses which wave to follow backwards. Only photons following backwards a vertically polarized wave reach the detector from which that wave originated. Horizontally polarized waves never reached the photon source, having been obliterated inside the crystal.

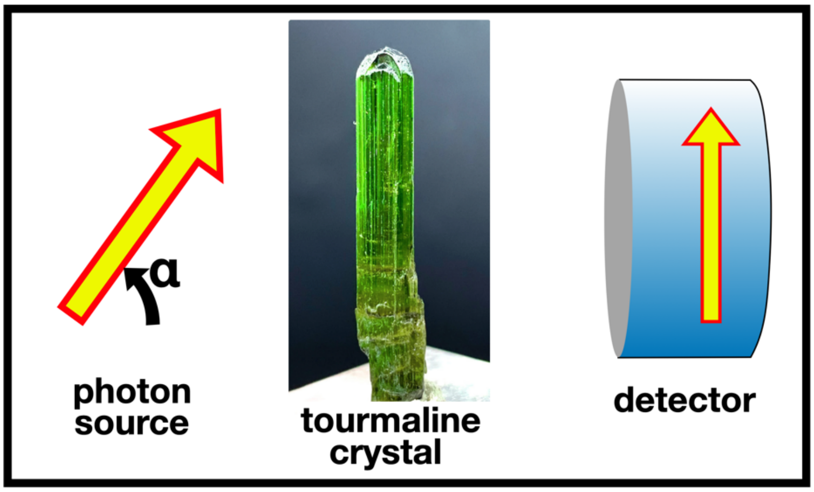

Fig. 25. This is the outcome of both experiments: ours and Dirac's. An obliquely polarized photon at angle $\boldsymbol{\alpha}$ becomes a vertical image of that photon inside the detector, with a probability of $\sin^2\boldsymbol{\alpha}$.

3.7. No Observers Needed

TEW eliminates the need for human observers. QM is wrong when it says human observers are required for nature to function. Nature has existed for 14 billion years and spans billions of galaxies. To say, as QM does, that nature acts differently if observed, contradicts the postulate that the laws of nature are uniform. The same laws of nature prevail here as in the Andromeda Galaxy. Observer-dependence needs to be eliminated from the physical sciences.

We show repeatedly in this article that observer-dependent experiments can be understood based on Elementary Waves with no observers needed. In Part 2 of this article, we will show that observer-dependent interpretations of Stern-Gerlach experiments, and Feynman high-energy scattering experiments can be explained by Elementary Waves. See Part 2 of this article: https://rajpub.com/index.php/jap/article/view/9268

4. Untangling the Mysteries of TEW

This fourth section of our article explores the depths of TEW. We start with experiments in which zero-energy Elementary Waves are visible in plain sight.

4.1. Purcell Effect

Edward Purcell observed the enhancement of spontaneous emission of a Rydberg atom depending on the diameter of the micro-cavity surrounding it.

If a Rydberg atom (such as sodium, cesium, beryllium, magnesium, or calcium) is heated in an oven, then a laser excites the outer electron to a higher energy state, and the atom is injected into a microcavity or nanocavity, the outer electron will drop to a lower energy level and emit a photon hundreds of times faster if the cavity has a diameter that is a multiple of $\lambda/2$, where λ is the wavelength of the photon that would be emitted.

How does an atom know the diameter of the cavity? That information about the diameter of the cavity is transmitted into the atom by what is called "resonance, available states, or modes" of the cavity. We rename those phenomena and call them "zero-energy Elementary Waves."

Research about the Purcell Effect and Elementary Waves could be fruitful. So far Purcell research is about other applications, such as nano-photonics and plasmonics, Smith-Purcell free-electron lasers, photonic bandgaps, NV-center photoluminescence, Mie scattering, quantum dots, Planckian thermal emissions, etc. There is an opportunity here for someone steeped in Purcell research to teach us what those technologies reveal about Elementary Waves. In other words, we are asking Purcell experts for help.

4.2. Proposed Experiments

In Part 2 of this article (https://rajpub.com/index.php/jap/article/view/9268) we design four experiments, never done, that will produce different outcomes if nature uses $-\boldsymbol{\psi}$ versus $+\boldsymbol{\psi}$. This could be what a graduate student needs as an innovative research project.

4.3. Wave-Equations

We will now derive one-dimensional wave equations that would allow a particle to follow a zero-energy Elementary Wave backwards. What we derive is not necessarily the way nature does it. We seek only to demonstrate that such an equation is possible. The trick will be that an Elementary plane wave make a U-turn, so it becomes a plane wave travelling toward the detector, and then blossoms into a Schrödinger wave. The U-turn is how we arrange to have a Schrödinger wave-packet moving in the opposite direction as the Elementary Wave. (44)

The following Figure is a roadmap so the reader can keep track of our equations.

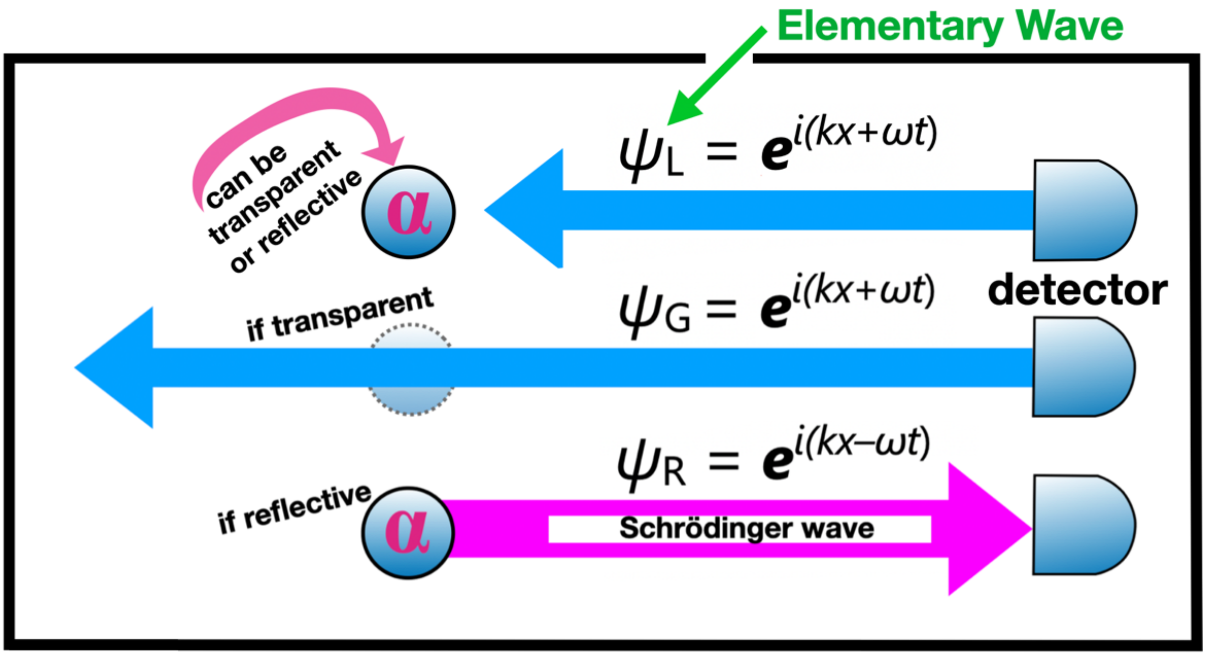

Fig. 26. Top: zero-energy plane wave ψ_L emanates from a detector toward particle **α**. Middle: the wave almost always passes through the particle without interacting. We call such waves $\boldsymbol{\psi}_G$ where "**G**" is for "ghost." The overwhelming majority of waves are "ghosts", meaning they don't interact with physical nature. Bottom: Sometimes the particle will reflect the wave ($\boldsymbol{\psi}_L \rightarrow \boldsymbol{\psi}_R$), so it becomes a zero-energy plane wave $\boldsymbol{\psi}_R$ moving to the right. As the wave reflects it blossoms from a plane into a Schrödinger wave capable of carrying a photon or the particle from point **α** to the detector.

4.3.1 Derivation of Wave-Equations

We will start with a wave equation

$$\Psi = e^{ik \pm \omega t} \tag{23}$$

We define the wave moving to the left with the subscript "L"

$$\Psi_L = e^{ik + \omega t} \tag{24}$$

and the wave moving to the right

$$\Psi_R = e^{ik - \omega t} \tag{25}$$

Usually, two solutions to a linear PDE can be added together to produce a third solution. But in this case the wave travelling to the left $\boldsymbol{\psi}_L$ is a plane wave, while the one travelling to the right $\boldsymbol{\psi}_R$ instantly transforms from a plane into a Schrödinger wave by methods we are about to describe. So, $\boldsymbol{\psi}_L$ and $\boldsymbol{\psi}_R$ are not of the same species, and should not be added lest our thinking becomes muddled.

The subscript "$_R$" in these equations no longer means "Reverse" as it did in the Feynman path integral equations. Now "$_R$" means "right", and "$_L$" is "left."

Someone might wonder why the point particle **α** isn't washed away by the wave, rather than causing the wave to reflect. Well, it is a zero-energy wave, incapable of washing anything away. Our purpose is not to build the equation most people would expect, but to build an equation that mimics nature.

When Murray Gell-Mann and George Zweig proposed three quarks in each proton and neutron, contrary to what anyone expected, it was not comfortable to think that way. What they proposed was more ludicrous than our idea of plane waves reflecting off a point particle **α** and flowering into a

Schrödinger wave. Our point is that we are not seeking to derive wave equations that look respectable. We are seeking equations that imitate nature.

What we see in nature is that Elementary Waves usually pass through a particle without interacting (middle of Figure 26). It was Einstein who coined the term "ghost waves" for waves that don't interact with physical reality. Einstein thought that a zero-energy wave would not have enough energy to make a detector "click," and therefore we would never know it was there. TEW deals with this problem by saying that it is particles that make detectors "click." The reason zero-energy waves interact with the physical world is that quantum particles have an intrinsic vulnerability to be triggered by a zero-energy wave, and then follow that wave backwards. Thus, it is the particles that do the heavy lifting. One of the most outrageous ideas of TEW is that particles have this capacity to be influenced by ghost waves, thereby turning ghost waves into real waves.

Particle **α** is almost always "transparent" and almost never "reflective." If it is reflective, we move from the middle to the bottom of Figure 26 where the wave makes a "U" turn as it interacts with the particle.

As the plane wave $\boldsymbol{\psi}_L$ reflects off the particle **α** it immediately blossoms from a plane into a Schrödinger wave. Here are the equations to show how that might happen.

We define

$$\lambda = \frac{2\pi\hbar}{mv} \tag{26}$$

where m and v are the mass and velocity of the particle. We define

$$k = p/\hbar \quad \text{and} \quad p = mv \tag{27}$$

where p is the momentum of the particle. We define

E = kinetic energy + potential energy

$$E = \frac{1}{2}mv^2 + u = \frac{p^2}{2m} + u \tag{28}$$

Taking the second derivative $\partial^2/\partial x^2$ of the wave function $\psi_R = e^{i(kx-\omega t)}$ we get:

$$\frac{\partial^2 \psi_R}{\partial x^2} = \frac{\partial^2}{\partial x^2}(e^{i(kx-\omega t)}) = (ik)^2\psi_R = -k^2\psi_R = \frac{p^2}{\hbar^2}\psi_R \tag{29}$$

$$\hbar^2 \frac{\partial^2 \psi_R}{\partial x^2} = p^2\psi_R \tag{30}$$

Multiplying both sides of $E = (p^2/2m) + u$, by ψ_R, we get:

$$E\psi_R = \frac{p^2\psi_R}{2m} + u\psi_R \tag{31}$$

Inserting Equation 30, we get the **Time Independent Schrödinger Equation (TISE):**

$$E\psi_R = -\frac{\hbar^2}{2m}\frac{\partial^2 \psi_R}{\partial x^2} + u\psi_R \ \textbf{= TISE} \tag{32}$$

The time dependent equation can easily be derived by differentiating our wave equation

$$\psi_R = e^{i(kx-\omega t)} \qquad \text{by } \partial/\partial t:$$

$$\frac{\partial \psi_R}{\partial t} = -i\omega\psi_R \tag{33}$$

We define $E = \hbar\omega$. Multiplying that by ψ_R we get:

$$E\psi_R = \hbar\omega\psi_R \tag{34}$$

$$-\frac{i}{\hbar}E\psi_R = -i\omega\psi_R = \frac{\partial \psi_R}{\partial t} \tag{35}$$

$$E\psi_R = -\frac{\hbar}{i}\frac{\partial \psi_R}{\partial t} = i\hbar\frac{\partial \psi_R}{\partial t} \tag{36}$$

We can substitute that into the TISE (Equation 32), and it gives us

$$i\hbar\frac{\partial \psi_R}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2 \psi_R}{\partial x^2} + u\psi_R \quad = \quad \textbf{TDSE} \tag{37}$$

which is the **Time Dependent Schrödinger Equation (TDSE).**

As expected, the Schrödinger equation has a "+" sign, not a "–" sign. Why is that what we want? Remember that our wave makes a "U" turn. There is no word available to describe a "U" shaped arrow.

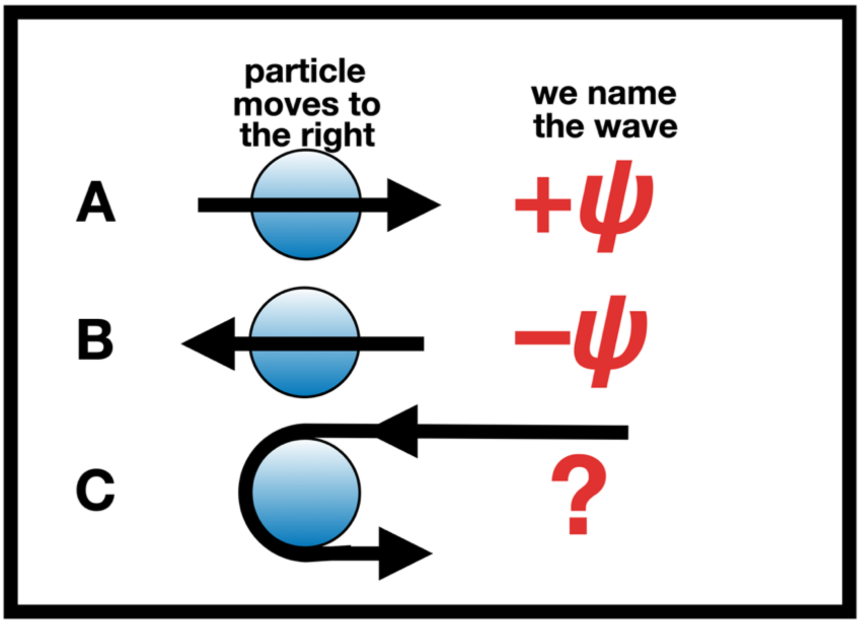

Fig. 27. In these diagrams a particle (blue) is moving to the right. By convention, the name of the wave is in reference to the particle. In the top row we name a wave moving to the right "**+ψ = e**$^{(kx-\omega t)}$ ". Middle row, we name a wave moving left "**–ψ= e**$^{(kx+\omega t)}$ ". Bottom row: what do we name a wave that makes a "U" turn? We have no term "–{then}**+ψ**".

The next Figure describes that third arrow in more detail:

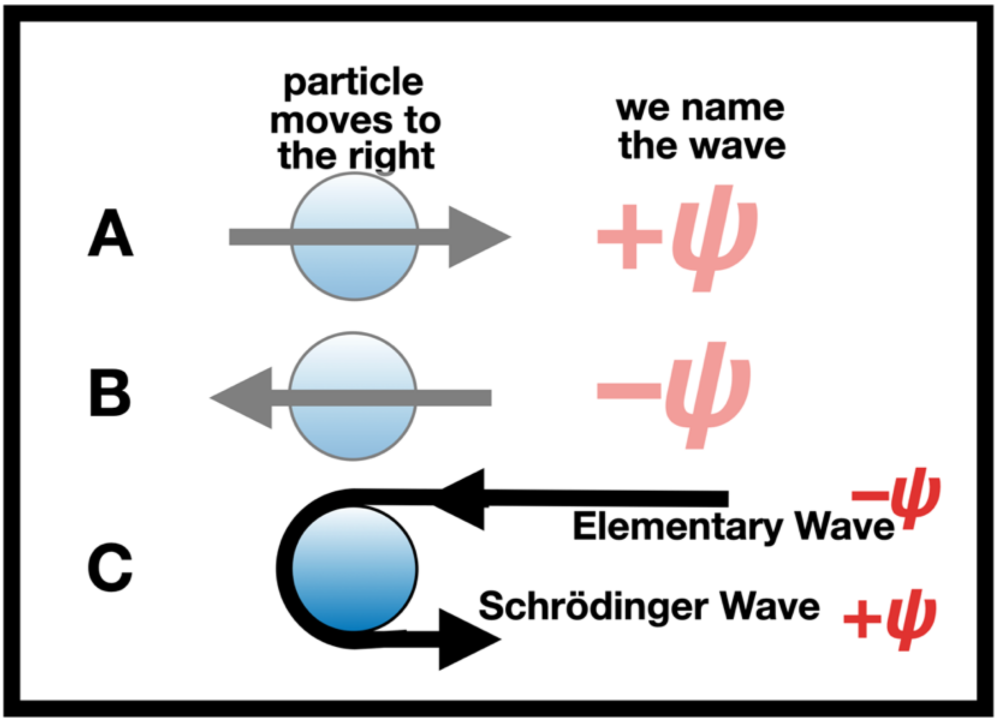

Fig. 28. This reproduces the preceding Figure but clarifies which is the "Elementary Wave" and which is the "Schrödinger wave."

Figure 28 makes it clear why our Schrödinger wave should have a "**+**" sign.

We are choosing the **−*ψ*** Elementary Wave as more important than the **+*ψ*** Schrödinger wave in Figure 27.

If the reader disagrees and insists that the Schrödinger wave is the more important of the two, and therefore the "U" shaped wave in Figure 27-C should be named "**+*ψ***", that means that the "U" shaped wave name is indistinguishable from the straight "**+*ψ***" wave in the top of Figures 27-28. That makes no sense.

4.3.2 Visualizing Elementary Waves in Relationship to Schrödinger Wave-Packets

Now that we have derived a TDSE, we will give you an intuitive sense of how it works. These pictures depict how Elementary Waves create Schrödinger waves that interact with the physical obstacles.

Below are three snapshots of a zero-energy Elementary Wave ("$-\psi = e^{(kx+\omega t)}$") followed backwards by a Schrödinger wave-packet ("**+*ψ***") moving across a one-dimensional line. Halfway across each line is an obstacle.

We start with the TEW picture of quantum tunnelling.

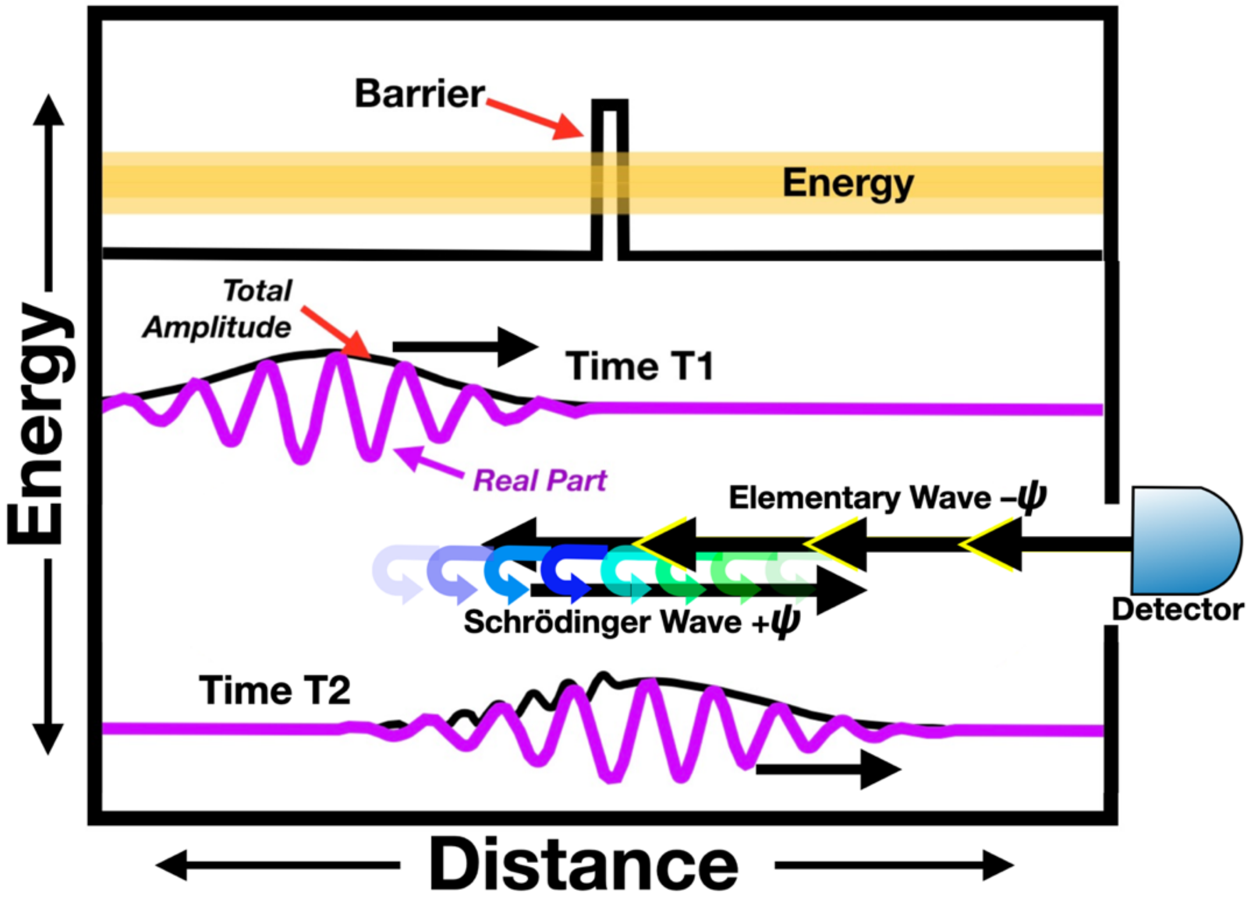

Fig. 29. Tunnelling: A thin barrier is at the top center. A Schrödinger wave-packet (+ψ) follows backwards an Elementary Wave (–ψ = $e^{(kx+\omega t)}$) coming from a detector on the right. At time T1 the Schrödinger wave-packet approaches the barrier. At time T2 (bottom) most, but not all, of the Schrödinger wave tunnels through the barrier and keeps moving to the right.

What is "tunnelling"? Consider your smartphone. Tunnelling is used by the memory cells inside your smartphone. In a charge-trap-flash memory unit, electrons tunnel through a wall of dielectric material to enter an energy well, where they remain trapped, for hours, days, or years. This is how your smartphone stores information. For example, if you snap a picture to post online, the picture is stored inside your smartphone in thousands of such charge-trap-flashes, each based on tunnelling. Engineers who design charge-traps follow the tunnelling equations developed by Ralph Fowler and Lothar Nordheim in the 1920's. There are millions of these charge-trap-flash units inside your smartphone.

We said earlier that the classical and quantum world are governed by the same rulebook except for size. Some critics object, saying that tunnelling is found in the quantum but not in the classical world. We disagree. We claim that a human, if downsized to quantum size, would be able to walk through a wall. Unfortunately, the person would suffer catastrophic damage from the downsizing process.

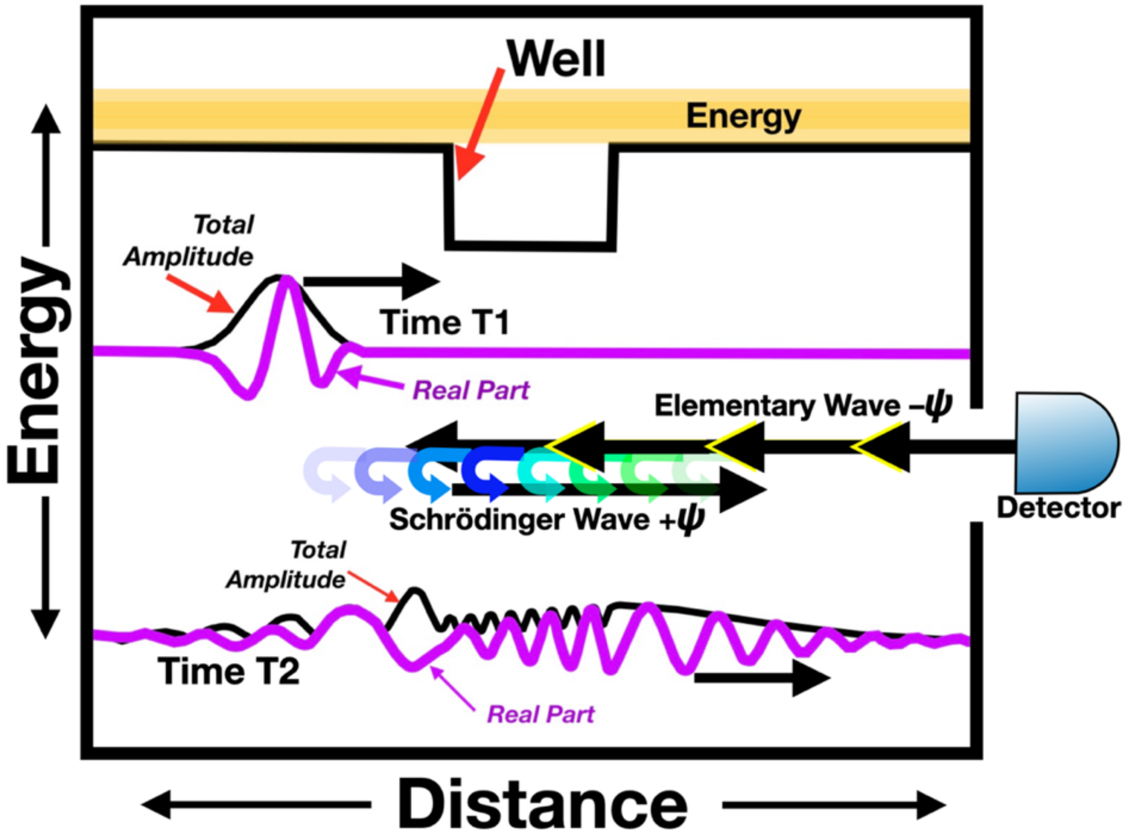

Fig. 30. Here is a one-dimensional potential energy well in the center at the top. A Schrödinger wave-packet (+ψ) follows backwards an Elementary Wave (–ψ = $e^{(kx+\omega t)}$) coming from a detector on the right. At time T1 (middle) the Schrödinger wave approaches the energy well. At time T2 (bottom) much of the wave-packet crosses the well, some of it is reflected by one or the other side of the well, and waves are found inside the well. Some of the wave reflects off the right side of the well and then reflects off the left side also, like an echo chamber.

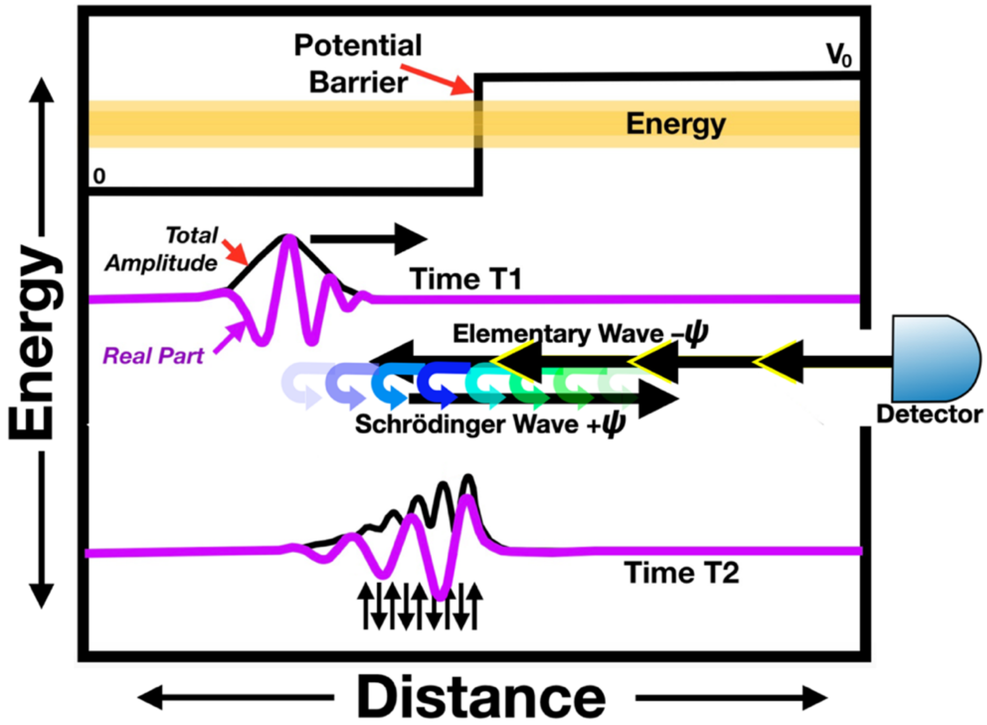

Fig. 31. Here is a one-dimensional potential energy barrier in the center at the top. A Schrödinger wave-packet (**+ψ**) follows backwards an Elementary Wave (**–ψ = e^(kx+ωt)**) coming from a detector on the right. This diagram shows snapshots at two different times: T1 in the middle, as the Schrödinger wave approaches the barrier it loses altitude and spreads wider. At time T2 at the bottom, the Schrödinger wave crashes into the barrier and becomes standing waves.

4.4. How Do We See Stars?

If photons follow backwards Elementary Waves coming from our retinas, how do we see starlight from 106,000 years ago? Answer: see Supplementary Materials, available in the second part of this article in the *Journal of Advances in Physics* (2022).(3)

5. Conclusions

Niels Bohr said quantum experimental data are determined by the final arrangement of detectors. It never occurred to Bohr that zero-energy waves must therefore be coming out of detectors and guiding home the incoming particles.

5.1 How to Motivate Students to Want to Study Quantum Technologies

There is an obvious next step in the development of TEW. It is to redesign TEW in such a way that it can teach students quantum mathematics in a down-to-earth and intuitive way that would excite them.

This author will sketch out the direction, but he is not the person who can carry the ball.

The inability of quantum technologies to attract enough students to meet the demand, is the most prominent unsolved problem in QM today. A recent article in the *APS News* contrasted the success of quantum technologies with the shortage of students interested in those careers. It said, "Quantum computers can have hundreds of quantum bits (up from a few dozen just a few years ago), quantum information can be transmitted hundreds of miles and even to and from orbital satellites, and quantum sensors are becoming some of the most precise instruments in the world. But as this wave of innovation continues, a necessary element lags behind: a quantum-educated workforce. (35)

"'Investments in [quantum information science and technology] by new and existing companies have accelerated over the last decade, and the supply of talent is not keeping up with demand,' reads a strategic plan published by the U.S. National Science and Technology Council. The answer? Train and prepare more people for quantum careers." (35)

Our proposal is to listen to the complaints of students and redesign QM subject matter accordingly. Specifically, we propose the creation of a new quantum mathematics called "elementary QM" or (eQM) that would teach the mathematical skills and concepts in an unconventional way.

Here is our blueprint for how to develop eQM, a new theory that proposes the following interpretation of the Born Rule: $\sqrt{Probability}$ = **±ψ**, and nature uses **–ψ**, because quantum particles follow zero-energy Elementary Waves backwards.

This will be a radical and controversial approach to teaching quantum mathematics. It has all the characteristics needed to attract and motivate students to learn quantum mathematics, but it is not quite quantum math. It is the negative of quantum math and a very unconventional picture of nature.

A teacher could introduce eQM to students with the following challenge: "Here is a controversial new theory of quantum physics that is easy to understand and rejected by the experts. Your assignment is to prove this eQM theory is wrong!" Hint: If a student embraces eQM she or he will covertly learn quantum math.

eQM is not another "interpretation" of quantum mathematics. It is a brazen discarding of quantum math and its worldview, replacing it with the negative equations and a startlingly different worldview. It is just what students have been wanting. A place where they could be change agents making their mark, making a name for themselves. Arguing about something clever. Reshaping everyone's picture of the world we live in.

5.2. How to Market Quantum Studies to Prospective Students

The first step in marketing is not to advertise your product widely. The first step is to study the needs of your target audience, then figure out how to offer a product that addresses those needs. The target audience is young people and especially STEM students. The product is quantum training.

Here is what we learn when we listen to the target audience: "The field [of QM] is notoriously unintuitive. Fundamental concepts such as superposition and entanglement have no direct analogy to a person's everyday experience, and so are often taught using their mathematical foundations. (35)

"'Teaching quantum mechanics using standard differential equations doesn't work very well with the students', says James Freericks, professor of physics as Georgetown University. 'We teach it three times, almost identically every time: sophomore, upper-level undergraduate, and graduate. And often even after seeing it three times, students struggle with it.' (35)

"Gina Passante at California State University Fullerton said 'Quantum mechanics was an obstacle for all students. One faculty member said that 'how much quantum mechanics the students had previously been exposed to was not a very good indicator of how well they did in the course.'" (35)

This assessment of the needs of the target audience (students) tells us that QM is a product that lacks the characteristics needed to market it. We must somehow re-design or overhaul QM if we want to solve the student-motivation problem.

We propose that eQM is the overhaul of QM that meets those requirements.

5.3 Sketch of How eQM Might Look

We return to Dirac's book, *The Principles of Quantum Mechanics*. The first chapter is focused on why classical physics is insufficient to describe nature at the atomic and subatomic scale, and why we therefore need a new science, which is the quantum mathematics that Dirac then provides.

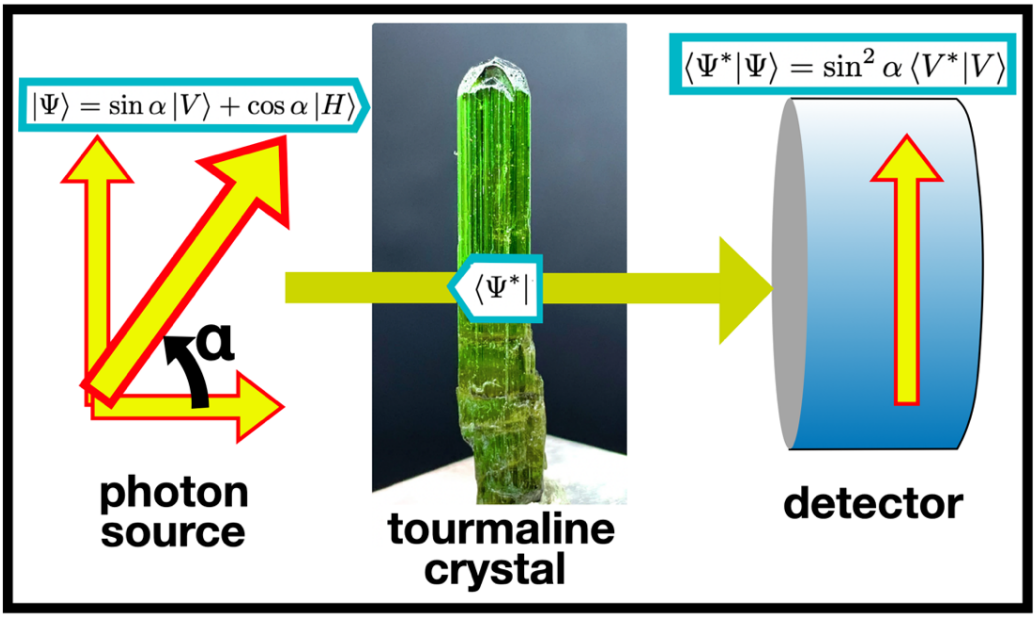

Fig. 32. Dirac's model of how a photon interacts with a tourmaline crystal, with Dirac notation. As the photon passes through the crystal, that is a measurement, the superposition collapses, and only vertically polarized whole photons emerge on the downstream side. The percentage of whole photons is $\sin^2\alpha$.

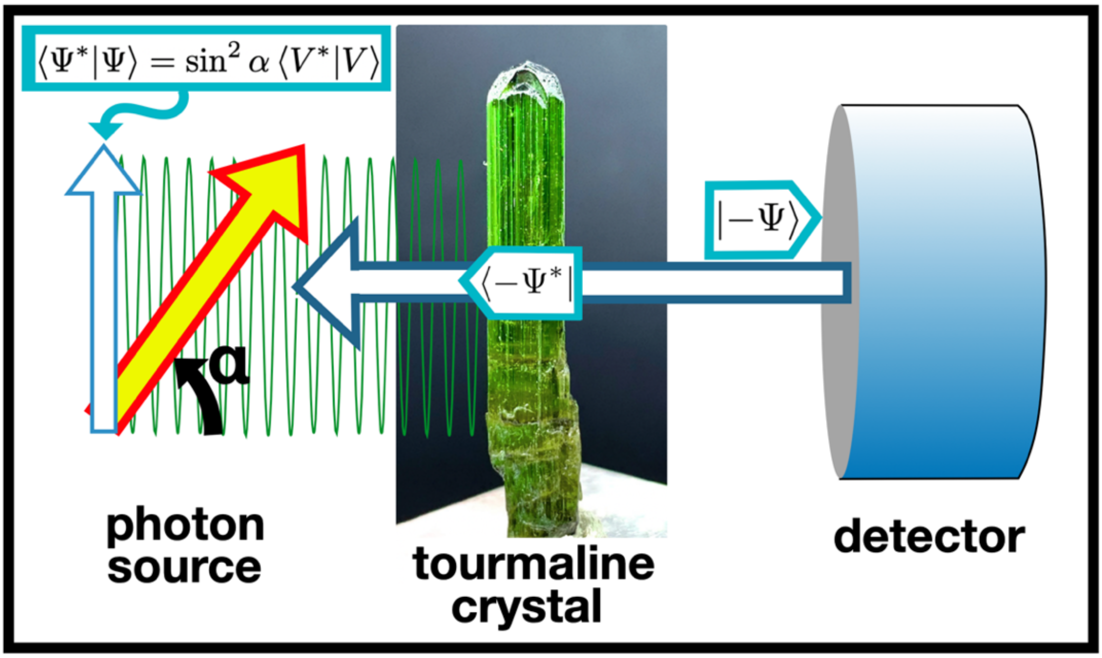

Fig. 33. The eQM model for how this experiment works. From the detector come a full spectrum of Elementary Waves, the vast majority of which are irrelevant. The only Elementary Ray we need to pay attention to is the one with the same frequency as the photon on the left. As that ray passes through the tourmaline crystal it acquires a vertical polarization. If the photon chooses to respond to that specific Elementary Wave, only the vertically polarized whole photon responds and follows that wave backwards. Superposition collapse occurs at the photon source (on the left). After that it is simply a matter of translating that information back to the detector. The vertically polarized photon follows its Elementary Wave backwards with a probability of one. Nothing interesting happens to the photon inside the crystal. The percentage of photons observed by the detector is $\sin^2\boldsymbol{\alpha}$.

The last two Figures (32 and 33) illustrate of the power of eQM to make quantum math intuitive. Guess how many illustrations Dirac uses to clarify his ideas? Zero! His argument is that quantum superposition cannot be understood using classical, Newtonian concepts, and therefore we need a new way of thinking, which consists of Dirac notation. He then introduces the reader to Dirac bra-kets. At the end of Chapter One, just when you think he is about to go back to the tourmaline crystal and show exactly how his notation would apply to superposition collapse inside the crystal, he fails to do so. It is an intellectual failure, failure as a teacher.

It appears that once Dirac has justified rocketing into the mathematical stratosphere, he considers those abstractions to be "reality," and loses interest in helping his students understand the down-to-earth example of a photon passing through a tourmaline crystal. When this author created Figure 32, he had to **guess** how Dirac would apply Dirac notation to the diagram, because Dirac never bothered to say.

Here is an analogy. Suppose the ISRO launches a satellite from the Satish Dhawan Space Centre, to make geographic and hydrological surveys of India. Once the satellite is in orbit, it devotes all its attention to other satellites and the Milky Way. It sends no information about India's surface water at ground-level. What kind of satellite would that be? It would be one designed by Dirac.

The goal of eQM is to restructure all of quantum mathematics so it is no longer located in the stratosphere, but is brought down to earth, to tangible and picture-able applications that can be understood by common people. We will know we are pursuing the goal if we speak infrequently of "Hilbert space," or a "space of states." Those ideas should be translated into what they mean in Cartesian space. Show us how to apply QM to objects like a tourmaline crystal that we can touch, see, smell, and taste!

Students today struggle to understand the idea of a "superposition of states" but have no difficulty grasping a "superposition of Elementary Waves."

Fig. 34. A superposition of Elementary Waves means adding waves together.

At a minimum this approach would excite students because it is down-to-earth.

But the real challenge is more fundamental. If we are correct that TEW describes the universe we live in, then our approach should simplify quantum mathematics. We hypothesize that the overabundance of mathematical equations in QM is a way of compensating for their incorrect picture of reality (based on $+\boldsymbol{\psi}$). If we correct the picture, the need for equations should diminish. Textbooks of three hundred pages of convoluted equations might be rewritten in two hundred pages, with fifty pages of colored illustrations to make it intuitive.

When Copernicus revised the geocentric model of Ptolemy, he prevailed because he simplified the mathematics. In the end, to the astonishment of astronomers, there was no need for epicycles, deferents, nor equants. Everything could be replaced with Galileo's elliptical orbits. That is what the next generation of leaders in TEW needs to create, the equivalent of Galileo's simplification for quantum math.

If this can be done, then TEW will be an immediate worldwide success because it will offer to solve the most glaring problem in quantum technology today: how to attract and motivate students. Such an eQM could excite quantum leaders for this reason, and the new approach might be promoted by them. It might take the tedium out of quantum studies and inspire enthusiasm.

The person who is called to the task of creating eQM will probably have these characteristics:

a) Younger than the author (who is age 78),
b) Mathematically talented, able to intuit the reality behind an equation,
c) Steeped in quantum mathematics,
d) An ability to unify divergent ideas by grasping the soul of each,
e) Have a rich fantasy life,
f) Able to make illustrations in three dimensions,
g) Be highly articulate,
h) Have no fear of success.

This author is not the man for that job. He is too old and not steeped in quantum mathematics. We need a scholar fluent in two languages. First, quantum languages, and second, the eQM language which will be created by you as the project proceeds.

This author can easily imagine an American Sikh quantum student responding to this call, pursuing it fruitfully for decades, achieving worldwide recognition, an Abel Prize, and a Nobel Prize. The leader we are describing might create a new field of academic studies, "Quantum Education." This would come under the umbrella of an Information Technologies Department, not a Physics Department. Probably the new leader would be able to find funding to financially support this effort, because the need for motivated students is well-known to governments, academia, industry, and foundations.

Competing Interests: none.

Funding: none.

Supplementary Material: Available in the second part of this article in the *Journal of Advances in Physics* (2022), https://rajpub.com/index.php/jap/article/view/9268

Author Biography:

The author is a retired medical researcher, an MD, and physician who has never taken a course in physics, and who therefore has no orthodoxy to defend. He is free to endorse scientific heresy without fear of losing his career or being unable to support his family. He learned a new theory of quantum physics from his cousin Lewis E. Little, who had earned a PhD in physics, then spent more than three decades alone seeking a way to eradicate what he called "quantum weirdness." His career, meanwhile, consisted of investigating in commodities on Wall Street. In 1993 it dawned on Little that quantum particles follow zero-energy waves backwards, and he called it the Theory of Elementary Waves (TEW). Twenty years later, in 2013 he invented the Theory of Bi-Rays. He taught these ideas to the author, who is three years younger. He assigned Boyd the task of formulating a new mathematics for TEW. At first Boyd thought he was incapable of doing so. In 2010 Boyd began explaining TEW to physicists at conventions of the American Physical Society (APS). Little never spoke to the APS.

Fig. 35. In February 2010 Lewis Little (left) accompanied Jeffrey Boyd (right) to Boyd's first presentations of TEW at a convention of the American Physical Society during a snowstorm in Washington, DC. Boyd addressed the APS eleven more times, half the time with posters, the other half with lectures to audiences with blank faces, who made no comments and asked no questions. They were polite au tdiences, who applauded at the end. It was as if the audiences were asking themselves, "What on earth is this?"

Boyd discovered that he had the unique assortment of talents need by this paradigm shift. He learned physics by reading countless published articles describing quantum experiments. Boyd published 27 scholarly articles in peer-reviewed academic journals of physics, mathematics, and chemistry. Boyd's obsession persists because he considers TEW decisively important. It is said that someone's "calling" is that which he cannot stop doing because it is all-consuming. Boyd's calling could not be accomplished without the Council for Innovative Research. After working on the mathematical problem for a dozen years, Boyd came up with what he calls the **Max Born asymmetry** $\boldsymbol{|-\psi|^2 = |+\psi|^2 =}$ **probability**, which is where this article comes from.

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