UNDERSTANDING QUANTUM MECHANICS

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Abstract. Quantum mechanics presently has many unanswered questions, paradoxes, and even outright logical contradictions. To make progress in understanding quantum mechanics, we begin by proposing that relativity be set aside in favor of an absolute aetherial theory. Once that step is taken, we can understand quantum collapse as a description of real wave-packets collapsing in a faster-than-light way. By assuming that a partially observable reality exists, we can then extend our analysis of wave-packets into the subquantum, and the Heisenberg uncertainty principle then follows from the Fourier uncertainty principle coupled with the de Broglie relation. Further progress in understanding quantum mechanics is possible by modifying the de Broglie and Planck relations. Those modifications lead to matter-waves moving at the speed of light rather than superluminally as presently theorized, and they allow the results of matter-wave two-slit experiments to be understood from any reference frame. A modified time-dependent Schrödinger Equation results from our modifications, but the spatial time-independent Schrödinger Equation is retained.

1. Introduction. Since its inception, quantum mechanics has been difficult to understand. Interference experiments show that entities sometimes behave like distributed waves, while scattering experiments show that entities sometimes behave like particles. This behavior led to the idea of a wave/particle duality. The concept of a wavefunction was introduced wherein the square of the wavefunction is the probability density of where an underlying particle will be found. The wavefunction is a distributed entity, and it can therefore interfere, and certain events can cause it to collapse to a much smaller state. However, this concept of quantum mechanics is inherently in conflict with Einstein's relativity[1], an issue most famously raised by Einstein, Podolsky and Rosen[2] (EPR). Bell[3] extended the work of EPR, and Aspect, Dalibard and Roger[4] provided experimental validation of Bell's inequalities, showing that quantum mechanics does indeed give correct predictions in spite of its confrontation with relativity.

Part of our inability to understand quantum mechanics comes from two fundamental contradictions often found in quantum mechanics interpretations: 1) a quantum collapse exists that must be (via Bell[3]), and yet cannot be (via Einstein[1]), a faster-than-light phenomenon; and 2) the ultimate nature of physical entities is that they are both a particle and a wave. Since these are statements of contradiction, they of course cannot be understood. Here we will eliminate these contradictions by asserting single choices for each: 1) quantum collapse is a faster-than-light phenomenon; and 2) the ultimate nature of physical entities is that they are never point-like particles. Since relativity is a point-like theory in a curved four-dimensional space-time continuum, and relativity also precludes faster-than-light phenomena, both of our assertions confront relativity. Hence, we shall set relativity aside. Instead we will adopt the absolute theory of the Quantum Luminiferous Aether[5], which returns us to a flat three dimensional Euclidean space and an absolute time which includes absolute simultaneity: the Quantum Luminiferous Aether theory is a continuum theory that allows faster-than-light collapse.

2. The Impulse-Initiated-Collapse Interpretation. To better understand quantum mechanics, we will begin with a simple physical interpretation for observed quantum behavior:

The impulse-initiated-collapse interpretation: A wavefunction experiencing an impulse undergoes a faster-than-light collapse determined by:

$$dx \geq \hbar/2dp \qquad (1)$$

In Eq. (1) dx is the post-impulse spatial spread of the wavefunction, dp is the relevant impulse, and ħ is Planck's constant h divided by 2π. If a high energy probe collides with a free particle wavefunction, the probe will either pass through the wavefunction or it will collapse the wavefunction to a size given by Eq. (1). In this case, the relevant impulse is the full momentum that the probe imparts to the wavefunction.

In our interpretation there are no issues involving what is or is not the 'environment', what is or is not being 'measured', nor who or what an 'observer' is: collapse occurs whenever an impulse affects a wavefunction. In situations where a tightly localized collapse of a free entity is required in some regions but not in others (such as the two-slit experiment) the collapse either occurs to a single small region dx where such a collapse is required, or to the entire region where no tightly localized collapse is required.

For bound quantum states it is possible for the impulse to either cause a transition to another bound state, or to eject the quantum out of its bound state and into a free state. If the quantum is transitioned to another bound state, the size of the quantum becomes that of the new bound state. If the quantum becomes freed, the relevant impulse dp used in Eq. (1) is the momentum excess above and beyond what it takes to free the entity from its binding. If we barely have enough energy in our probe to free the entity, the entity will have relatively low spreads of energy and momentum after the impulse. This will lead to a larger entity size than if the entire impulse had been transferred to an equivalent free entity.

For the case of mirrors, an individual photon can interact with many electrons and be reflected. The relevant impulse at each photon/electron interaction involves only a very small fraction of the photon's total momentum, and Eq. (1) is applied using that small momentum fraction at each participating electron/photon interaction. Since Eq. (1) describes a collapse size that is inversely proportional to the relevant impulse, this results in a very large size (dx) for the collapse in this case. Indeed, the collapse can occur over the entire mirror surface. Similarly, photons interacting with lenses involve many electrons rather than one. In that case, the impulse involved in the lensing action is again spread over so many electrons that the collapse can occur over the entire lens.

In every situation Eq. (1) applies. Here we are interpreting Heisenberg's[6] uncertainty principle not only as a limitation on our ability to observe, but also as a fundamental attribute of quantum entities. Each entity has a spatial spread and a momentum spread, and those spreads change whenever the entity's wavefunction collapses due to an impulse event.

Our impulse-initiated-collapse interpretation enables an understanding of the physics of quantum collapse experiments, and it is consistent with our assertion setting aside the dogma of wave-particle-duality. Instead, we propose that there are no point-like particles in nature at all. There are only finite-sized bodies undergoing wave-like motions. Sometimes these entities are quite spatially extensive, and other times they are well localized, but they are never points. This approach avoids the infinity problems associated with point-like particles.

3. A Physical Model of Light. Importantly, our proposal involves an assertion that we set relativity aside and return to the concept of an aether. And with an underlying model of light as of a wave upon the aether, we can now understand what is happening in the quantum collapse of a photon. Prior to collapsing at a wall, a photon consists of undulating aether over a large volume. The volume can for now be envisioned as being bounded by a rectangular box. One face of the bounding box is a large area parallel to the wall. Once the wavefunction collapses, the bounding box has a much smaller area parallel to the wall. Our model of the collapse process is hence one where a small undulation within a large box goes to zero in most of the large box, except for the region of a small box wherein the undulation becomes larger.

Notice that our description of a photon is now contemplating what is going on inside of the quantum: we are doing a subquantum analysis. This is possible because of our fundamental axiom in Ref. 5 which states that *a partially observable reality exists*. While we can't make observations within the subquantum, we nonetheless can postulate that it is real, and we are free to analyze it. This is different from the presently prevailing view that we can't do such an analysis, and it is one of the aspects needed to improve our understanding of quantum mechanics.

Next, we will advance beyond our simplistic model of a photon as undulations within a box and consider a model of a photon as a gaussian wave-packet. That gaussian will have a standard deviation of σ_X in configuration space. Taking the Fourier transform results in a view of the photon as being a wave-packet in the conjugate wave-number space, showing that the photon is made up of classical sinusoidal aetherial oscillations over a range of wave-numbers. As is well-known, the Fourier transform of a gaussian is itself a gaussian, and with an appropriate choice of convention it has a standard deviation σ_K such that $\sigma_X\sigma_K = 1/2$. It is also well-known that the gaussian case presents a lower limit for $\sigma_X\sigma_K$ and hence more generally:

$$\sigma_X\sigma_K \geq 1/2 \text{ (the Fourier Uncertainty Principle)} \quad (2)$$

We will now bring in two empirical equations governing light:

$$E = \hbar\omega \text{ (the Planck relation[7])} \quad (3)$$

$$\mathbf{p} = \hbar\mathbf{k} \text{ (the de Broglie relation[8])} \quad (4)$$

In Eqs. (3) and (4) ω is $2\pi f$, f is the frequency, **k** is the angular wave vector (**k** has magnitude $2\pi/\lambda$), λ is the wavelength, **p** is the momentum, and E is the energy. Taking the magnitudes of **p** and **k**, the de Brogle relation is $p = \hbar k$ and hence $\sigma_P = \hbar\sigma_K$. Substituting $\sigma_K = \sigma_P/\hbar$ leaves Eq. (2) as $\sigma_X\sigma_P \geq \hbar/2$, which is Heisenberg's uncertainty principle[6], equivalent to Eq. (1). Hence, a model of the underlying subquantum reality of the photon as a wave-packet leads directly to Heisenberg's uncertainty principle.

It is already widely known that the Fourier uncertainty principle leads to Heisenberg's. Not presently appreciated are the realizations that: 1) we can indeed do a subquantum analysis; 2) the photon component waves continue to obey Maxwell's equations within the subquantum realm; 3) faster-than-light collapse is possible; and 4) there is no wave/particle duality, only collapsing wave-packets. These realizations allow for an improved understanding of the quantum mechanics of light, as the photon subquantum can be understood as being governed by Maxwell's Equations for each component frequency making up a wave-packet, while the collapse of the wave-packet envelope is governed by Eq. (1) in every situation.

4. Planck/de Broglie Matter-Waves. With a physical model now allowing an understanding of the quantum mechanics of light, we turn next to consideration of matter-waves. Matter is different than light. Here we'll use the term matter to mean anything that: 1) is extrinsic to the aether; and 2) has a rest mass. We will temporarily assume that Eqs. (3) and (4), the Planck and de Broglie relations, will also apply to matter-waves and we'll assume that an underlying matter-wave exists:

$$\xi = \exp[i(\mathbf{k}\cdot\mathbf{x} - \omega t)] \quad (5)$$

In Eq. (5) ξ is a displacement of the matter, i is the square root of minus one, $\mathbf{x}$ is the three-dimensional spatial coordinate vector and t is the time. It is our assumption of an underlying wave, expressed in Eq. (5), that introduces our underlying physical model. Taking derivatives of Eq. (5):

$$\partial\xi/\partial x = ik_x\xi \quad , \quad \partial\xi/\partial y = ik_y\xi \quad , \quad \partial\xi/\partial z = ik_z\xi \quad (6)$$

and

$$\partial\xi/\partial t = -i\omega\xi \quad (7)$$

Differentiating Eqs. (6): $\partial^2\xi/\partial x^2 = -k_x^2\xi$, $\partial^2\xi/\partial y^2 = -k_y^2\xi$, and $\partial^2\xi/\partial z^2 = -k_z^2\xi$; which can be combined to form

$$\nabla^2\xi = -k^2\xi \quad (8)$$

Eq. (8) uses the usual nomenclature for the Laplacian, $\nabla^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2$. We now take the dot product of Eq. (4) with itself, and rearranging leaves $k^2 = p^2/\hbar^2$ while rearranging Eq. (3) leaves $\omega = E/\hbar$, and substituting these values into equations (7) and (8) leaves $\partial\xi/\partial t = -iE\xi/\hbar$ and $\nabla^2\xi = -p^2\xi/\hbar^2$, respectively, which can be rearranged as:

$$E = i\hbar(\partial\xi/\partial t)/\xi \quad (9)$$

$$p^2 = -\hbar^2\nabla^2\xi/\xi \quad (10)$$

Now recall the low energy expression for energy:

$$E = p^2/2m + V \quad (11)$$

In Eq. (11) m is the entity's mass and V is the potential energy. Next, we substitute expressions (9) and (10) into Eq. (11):

$$i\hbar(\partial\xi/\partial t)/\xi = -\hbar^2\nabla^2\xi/2m\xi + V \quad (12)$$

And now we multiply through by ξ:

$$i\hbar(\partial\xi/\partial t) = -\hbar^2\nabla^2\xi/2m + V\xi \quad (13)$$

Eq. (13) is recognized as Schrödinger's Equation[9].

5. Problems with Planck/de Broglie Matter-Waves. With Schrödinger's Equation now derived, we can again turn to the issue of an underlying subquantum reality, this time for matter-waves. We'll see that an underlying model based on Eqs. (3), (4), (5) and (13) has a couple of significant problems.

Recall Eq. (5) which defines the matter-wave, $\xi = \exp[i(\mathbf{k}\cdot\mathbf{x} - \omega t)]$. For one dimension, we can manipulate this to $\xi = \exp[i(kx - \omega t)] = \exp[ik(x - \omega t/k)] = \exp[ik(x - wt)]$. In the last expression we see that $w = \omega/k$, where w is the matter-wave phase velocity. Above we found $\omega = E/\hbar$ and $k^2 = p^2/\hbar^2$ and taking the square root of the latter we get $w = \omega/k = E/p$. With c the speed of light, v the matter velocity, $\gamma = [1 - v^2/c^2]^{-1/2}$, $E = \gamma mc^2$ and $p = \gamma mv$, we see that $w = E/p = \gamma mc^2/\gamma mv = c^2/v$. Now, v can certainly be zero, and this leads to an infinite phase velocity in that case. Within the status quo, singularities are accepted, but under our realist approach the phase velocity is a physical attribute and singularities are unacceptable.

A second problem becomes apparent if we arrange an electron beam to have a low momentum spread and pass it through two slits. Doing so will lead to a two-slit interference pattern similar to that obtained in Young's two slit experiment for light. Presently, the wavelength of the electrons is theorized to be that given by the de Broglie condition, $\lambda = h/p$, where p is the momentum of the electrons as determined from any reference frame. (The de Broglie condition follows from Eq. (4).) Under the standard simple analysis, we expect the interference fringes to be spaced by $z\lambda/d$ where d is the separation distance between the two slits and z is the distance between the slitted wall and the downstream wall. This expectation agrees with observations when we are at rest with respect to the walls. But if we observe that very same experiment from a spaceship moving along with the electrons, the electron velocity will be zero. From that frame the momentum p is zero and by the de Broglie relation λ is infinite, the fringe spacing is calculated to be infinite, and we expect no interference pattern. Yet it is the same experiment, just viewed by different observers, so this is a second problem with real matter-waves based on Eqs. (3), (4), (5) and (13).

Notice that we retain the term "frame of reference" even though we are using an absolute theory. We are keeping the Lorentzian physical length contraction and time dilation and we interpret the Lorentz transformation equations just as Lorentz did: observers moving through the aether arrive at a "fictitious" coordinate system due to their faulty instruments. Each "fictitious" coordinate system is a frame of reference, and the Lorentz transformation between such coordinate systems is the same as what relativity gives us.

Note that the paradox for matter-waves in a two slit experiment does not exist for light. In the case for light, consider first the lab frame with a distance between the walls of z_0, a separation of the slits of d, and an original light wavelength of λ_0. In the lab we calculate and observe interference fringes to be spaced by $z_0\lambda_0/d$. Next, consider a second observer moving toward the light. In that frame, the two walls will be moving in the direction the light, the distance between the walls will be length contracted, and the light will be blue-shifted. From the moving frame, the time T_2 it takes for light to get from the slitted-wall to the second wall is

$$T_2 = (z_0/\gamma + vT_2)/c \qquad (14)$$

In Eq. (14) the second wall moves a distance vT_2 during the transit time T_2, and so the total transit distance is vT_2 plus the distance between the walls, which is z_0/γ because of the length contraction of the moving apparatus. The total distance the light travels between the walls is $z_2 = cT_2$. From Eq. (14) we find $T_2(c - v) = z_0/\gamma$ so $T_2 = z_0/[\gamma(c - v)]$. Hence we get $z_2 = cT_2 = cz_0/[\gamma(c - v)] = z_0/[\gamma(1 - v/c)]$. The blue shifted light is Doppler shifted to a wavelength of $\lambda_2 = \gamma(1 - v/c)\lambda_0$. The fringe separation is $z_2\lambda_2/d = \{z_0/[\gamma(1 - v/c)]\}\gamma(1 - v/c)\lambda_0/d = z_0\lambda_0/d$. We see that the second problem that we found for matter-waves does not occur for light.

6. A Realist Modeling of Matter-Waves. Note that Eqs. (3) and (4) are empirical equations. Since we are running into difficulty in understanding we will now propose alternatives. Instead of de Broglie's Eq. (4) we will now propose the following fundamental relationship for matter-waves:

$$\mathbf{p_S} = \hbar\mathbf{k_S} \qquad (15)$$

Eq. (15) proposes that the wavenumber of the matter-wave is determined by its source: $\mathbf{k_S}$ is the wavenumber and $\mathbf{p_S}$ is the matter momentum where each is evaluated from a frame of reference moving along with the matter-wave source. We will define the matter-wave source velocity as the velocity of the center of mass of the entities involved in the wavefunction collapse. Ignoring the small recoil: for electrons leaving a neutron in beta decay, the source is the neutron; for electrons leaving a metal cathode, the source is the cathode; for the two-slit experiment, the source for the matter-waves is the apparatus. Upon each wavefunction collapse a new source velocity is established based on the center of momentum of the interacting entities involved.

Since $\lambda_S = 2\pi/k_S$, where k_S is the magnitude of $\mathbf{k_S}$, Eq. (15) results in λ_S becoming infinite when $\mathbf{p_S}$ goes to zero, but an infinite λ_S is not a physical problem. We assert that any physical entity can be described as a wave-packet which can be decomposed into a Fourier integral of fixed-wavelength waves, and this does involve a case where λ_S is infinite, but this case is merely a constant displacement within the integrand. Since both a wave-packet and its Fourier transform rapidly approach zero far from the wave-packet center we have no problem with a physical infinity here.

Next, instead of Planck's Eq. (3) we will now propose the following fundamental relationship for matter-waves:

$$E_S = \hbar\omega_S c/v_S \qquad (16)$$

In Eq. (16) ω_S is the angular frequency of the matter-wave, v_S is the matter velocity as observed in the source frame, $\gamma_S = [1 - v_S^2/c^2]^{-1/2}$, $p_S = \gamma_S m v_S$, and E_S is the matter energy evaluated in the source frame, $E_S = \gamma_S mc^2$. Taking the magnitude and rearranging Eq. (15), $k_S = p_S/\hbar = \gamma_S m v_S/\hbar$. And rearranging Eq. (16), $\omega_S = v_S E_S/\hbar c = v_S\gamma_S mc/\hbar$. Hence the phase velocity of matter-waves in the source frame is

$$w_S = \omega_S/k_S = [v_S\gamma_S mc/\hbar]/[\gamma_S m v_S/\hbar] = c. \qquad (17)$$

Note that even though the phase velocity of matter-waves is now found to be the speed of light, there is no issue with matter moving at the speed of light. During a half period, the matter will move a distance 2A from crest to trough, where A is the amplitude of the wave. Meanwhile, the wave will move a distance $\lambda/2$ during the half period. Hence the velocity of the matter will be $[2A/(\lambda/2)]c = 4Ac/\lambda$. Provided $4A \ll \lambda$, the matter velocity in the direction perpendicular to the matter motion will be much less than the speed of light.

Also note that Eq. (15), $\mathbf{p_S} = \hbar\mathbf{k_S}$, leads to v_S going to zero when k_S goes to zero, and with Eq. (17), $\omega_S/k_S = c$, we have $\omega_S = ck_S$ and hence ω_S also goes to zero when k_S goes to zero and there is no problem with an infinity in Eq. (16) when v_S goes to zero.

Our proposed modifications of the de Broglie and Planck equations address both matter-wave problems discussed in section 5 above. We no longer have infinite phase velocities; matter-waves always travel at the finite speed of light. And we can now understand the two-slit matter-wave experiment in any reference frame. In the source frame we do so by the usual analysis. And now, since the phase velocity of the matter-wave moves at the speed of light, we have the same Doppler shift for matter-waves that we have for light. The calculation of the fringe separation from a moving frame is the same as that discussed at the end of section 5 for light. Also, notice that our proposed modifications of the de Broglie and Planck equations can be applied to light as well as to matter-waves. For light, $v_S = c$, and in that case Eq. (16) becomes $E_S = \hbar\omega_S c/v_S = \hbar\omega_S$, and we can identify a source frame for light just as we do for matter-waves.

Next, we wish to obtain an understandable physical model for the underlying matter-waves. Let us now again assume an underlying wave and use a modified version of Eq. (5):

$$\xi_S = \exp[i(\mathbf{k_S}\cdot\mathbf{x_S} - \omega_S t_S)] \qquad (18)$$

In Eq. (18) the S subscript designates quantities evaluated in the source frame. We differentiate Eq. (18) to achieve: $\partial\xi_S/\partial t = -i\omega_S\xi_S$, or $\omega_S = i(\partial\xi_S/\partial t)/\xi_S$, and $\nabla^2\xi_S = -k_S{}^2\xi_S$. We can use $k_S{}^2 = p_S{}^2/\hbar^2$, this time achieved from Eq. (15). From Eq. (16) we also have $E_S = \hbar c\omega_S/v_S$, which leads to

$$p_S{}^2 = -\hbar^2\nabla^2\xi_S/\xi_S \qquad (19)$$

$$E_S = i\hbar c(\partial\xi_S/\partial t)/\xi_S v_S \qquad (20)$$

We'll now use the low energy form of the energy, $E_S = p_S{}^2/2m + V_S$ and then substitute in Eqs. (19) and (20):

$$i\hbar c(\partial\xi_S/\partial t)/\xi_S v_S = -\hbar^2\nabla^2\xi_S/2m\xi_S + V_S \qquad (21)$$

And we now multiply through by ξ_S:

$$i\hbar c(\partial\xi_S/\partial t)/v_S = -\hbar^2\nabla^2\xi_S/2m + V\xi_S \qquad (22)$$

Eq. (22) is no longer Schrödinger's Equation, as we have an extra factor of c/v_S multiplying the term on the left-hand side and we use variables with respect to the source frame. We can next derive the more exact version of Eq. (22) by using the general energy expression:

$$E_S = [p_S{}^2c^2 + m^2c^4]^{1/2} + V_S \qquad (23)$$

Next, we substitute expressions (19) and (20) into Eq. (23):

$$i\hbar c(\partial\xi_S/\partial t)/\xi_S v_S = [-\hbar^2c^2\nabla^2\xi_S/\xi_S + m^2c^4]^{1/2} + V_S \qquad (24)$$

Eqs. (22) and (24) are the new quantum mechanical formulas for our realist quantum mechanics.

While the factor v_S appears in the denominator in Eqs. (20), (21), (22), and (24) this does not lead to an infinity when v_S becomes zero. In each case, $\partial\xi_S/\partial t$ appears in the numerator and when v_S vanishes ξ_S becomes a constant so $\partial\xi_S/\partial t$ also vanishes. (Both $\mathbf{k}_S$ and ω_S go to zero as v_S goes to zero, so $\xi_S = \exp[i(\mathbf{k}_S\cdot\mathbf{x}_S - \omega_S t_S)]$ becomes a constant when v_S goes to zero.)

For the case of time-independent potentials, ξ can be decomposed into temporal and spatial functions:

$$\xi_S(\mathbf{r},t) = \Psi(\mathbf{r})\Phi(t) \qquad (25)$$

Substituting Eq. (25) into Eq. (21) yields:

$$i\hbar c(\partial\Phi/\partial t)/\Phi v_S = -\hbar^2\nabla^2\Psi/2m\Psi + V_S \qquad (26)$$

We now set each side of Eq. (26) to a separation constant E_N leaving:

$$E_N = i\hbar c(\partial\Phi/\partial t)/\Phi v_S \qquad (27)$$

$$E_N = -\hbar^2\nabla^2\Psi/2m\Psi + V_S \qquad (28)$$

Using Eq. (16), $E_S = \hbar\omega_S c/v_S$, and assigning $E_N = E_S$, Eq. (27) becomes $i\hbar c(\partial\Phi/\partial t)/\Phi v_S = \hbar c\omega_S/v_S$ or $i(\partial\Phi/\partial t)/\Phi = \omega_S$, and this can be solved by inspection:

$$\Phi(t) = \Phi_0 \exp[-i\omega_S t] \qquad (29)$$

Eqs. (28) and (29) are the usual equations derived from the Schrödinger Equation that we use to solve problems for infinite square wells, simple harmonic oscillators, and the hydrogen atom.

For the general case, we can substitute Eq. (25) into Eq. (24) to obtain:

$$i\hbar c(\partial\Phi/\partial t)/\Phi v_S = [-\hbar^2c^2\nabla^2\Psi/\Psi + m^2c^4]^{1/2} + V_S \qquad (30)$$

We can set each side of Eq. (30) to a separation constant E_N. Since the left-hand side of Eq. (30) is the same as the left-hand side of Eq. (26) we again arrive at Eqs. (27) and (29) for the time dependent equation. For the spatially dependent equation we obtain:

$$E_N = [-\hbar^2c^2\nabla^2\Psi/\Psi + m^2c^4]^{1/2} + V_S \quad (31)$$

We now bring V_S over to the left side and square both sides, leaving $-\hbar^2c^2\nabla^2\Psi/\Psi + m^2c^4 = [E_n - V_S]^2$, which, after we expand the square, move the mass term to the other side, and multiply through by Ψ leaves:

$$-\hbar^2c^2\nabla^2\Psi = [E_n^2 - 2E_nV_S + V_S^2 - m^2c^4]\Psi \quad (32)$$

In a 2017 paper[10] we derived Eqs. (29) and (32) starting from the traditional Planck and de Broglie relations. Note that our proposed changes to the Planck and de Broglie relations only affect the wave phase velocity, the equations involving time-dependent potentials, and the temporal equations resulting from time-independent potentials. The spatial equations resulting from time-independent potentials are left unchanged.

And now let us now examine the underlying subquantum reality for matter-waves. We propose that free matter entities will exist as a wave-packet, and each Fourier component of the wave-packet will obey Eq. (18), $\xi_S = \exp[i(\mathbf{k_S}\cdot\mathbf{x_S}-\omega_S t_S)]$. Eq. (17) relates that the matter-waves move at the speed of light $c = \omega_S/k_S$. Yet the velocity of matter propagation is $v_S < c$. Therefore the matter-waves move upon the matter and not at the same speed as the matter. The displacement ξ_S is perpendicular to the direction of the matter propagation.

A matter wave-packet consists of waves, where each wave is expressed by Eq. (18). The Fourier transform of a wave-packet in configuration space again results in the Fourier uncertainty principle of Eq, (2), $\sigma_X\sigma_K \geq 1/2$, just as we had for light. And with Eq. (15), $\mathbf{p_S} = \hbar\mathbf{k_S}$, we again arrive at the Heisenberg uncertainty principle, $\sigma_X\sigma_P \geq \hbar/2$, just as we did for light. However, unlike light which always moves at speed c, each solution to Eq. (18) will be associated with matter propagating at different velocities as we have $\gamma_S m\mathbf{v_S} = \mathbf{p_S} = \hbar\mathbf{k_S}$. Each matter entity will have a momentum spread σ_P and a matter-wave-packet will be dispersive.

Matter-waves and aetherial oscillations both travel at the speed of light $c = [T_A/m_A]^{1/2}$ where T_A is the aetherial tension per unit area and m_A is the aetherial mass density. (See Ref. 5.) Since T_A and m_A are aetherial quantities unrelated to the matter quantities, we conclude that each matter-wave is coupled to an aetherial oscillation, and it is the properties of the aether that determine the speed of the matter-waves.

When an impulse occurs, we propose that a wave motion is initiated on the matter, with the wave moving in the direction of the impulse, and then that wave reflects from the end of the matter and the matter acquires a standing wave. The wavelength of the matter wave in the source frame is specified through Eq. (15), $\mathbf{p_S} = \hbar\mathbf{k_S}$. The matter will always have the wave motion determined from the last time it experienced an impulse. When it gets a new impulse, it acquires new values for $\mathbf{v_S}$, $\mathbf{p_S}$, $\mathbf{k_S}$ and ω_S. So not only does the impulse reset the spatial and momentum spreads of the matter entity through Eq. (1), but it also gives the matter entity new momentum and wave characteristics.

In bound states, the solution for ξ_S is given by Eqs. (25), (28) and (29) for the low velocity cases and Eqs. (25), (32) and (29) generally. Eq. (29) reveals a standing wave within bound states, which breaks down into counter-propagating waves traveling at speed c just as we've seen for free states. (Eqs. (15), (16), (17) and (18) are the foundation for further equations, so the matter waves travel at speed c within bound states just as they do in free states.)

We now have a physical model for the underlying subquantum reality of matter. In the appropriate frame, matter-waves consist of standing waves for both bound and free entities. Matter-waves, moving at speed c, are waves upon the matter while the matter itself moves at speed v_S in the source frame. And free physical matter entities contain a wave-packet of matter-waves.

7. Summary and Conclusion. Here we have proposed three significant changes to quantum mechanical thinking. The first and most radical change is to set relativity aside. Once that is done, observations of faster-than-light quantum collapse can be understood, and wave/particle duality can be set aside in favor of waving entities that always have a finite size. Our second change is to modify the de Broglie relationship such that the momentum and wave number used in the expression $\mathbf{p} = \hbar\mathbf{k}$ are determined with respect to the source of the wave; we set $\mathbf{p_S} = \hbar\mathbf{k_S}$. And our third change is to modify the original Planck relationship $E = \hbar\omega$ to a new form: $E_S = \hbar c\omega_S/v_S$. Our changes result in matter-waves that move at the speed of light, allowing us to avoid infinite and superluminal matter-wave phase velocities, and we can understand the electron two slit experiment from any moving frame.

Once our changes were made, we developed new quantum mechanical expressions based on a proposed underlying subquantum reality that avoids infinities while also enabling an understanding of the foundations for the Heisenberg uncertainty principle. This returns physics to a physical modeling, enabling understanding. We found that only the time-dependent aspects of Schrodinger's equation change due to our approach; the spatial Schrodinger's equation for time-independent potentials remains unchanged. Since no experimental observations exist concerning the frequency of matter-waves our new approach is consistent with all present observations.

Yet despite the suggested improvements described herein, we must admit that we do not yet fully understand quantum mechanics. Several questions remain concerning the nature of the subquantum. How does quantum collapse occur? Are there new forces to discover concerning the collapse? Is quantum collapse instantaneous or merely superluminal? QED provides an excellent match to experimental data; can QED somehow be reinterpreted to be consistent with a realist non-point-like theory? Could doing so eliminate the infinity problems within QED? Or is there an alternative to QED that can be just as successful? These are significant questions that remain for future research.

Another question for future research involves quantum collapse to regions where no impulse is required, such as the slits of the two-slit experiment. Is the source velocity used in Eqs. (15), (16) and (18) now the velocity of the slitted-wall? Or is it the velocity of the prior source, since no impulse was applied to the portion of the wavefunction that passes through the slits? This question can in principle be answered experimentally, but at this point it remains open.

Of course, questions will always remain. Physics is an endeavor wherein we continually probe for an ever deeper understanding. Yet at each step of this journey, we should aim to resolve any outright contradictions and paradoxes. By setting relativity aside for an absolute aetherial theory, and by modifying the de Broglie and Planck equations, we can eliminate present contradictions and paradoxes. This gets us significantly closer to our goal of understanding quantum mechanics.

References

[1] A. Einstein, Ann. Phys. **17**, 891 (1905).
[2] A. Einstein, B. Podolsky, and N. Rosen, Phys. Rev. **47**, 777 (1935).
[3] J. S. Bell, Physics (NY) **1**, 195 (1964).
[4] A. Aspect, J. Dalibard, and G. Roger, Phys. Rev. Lett. **49**, 1804 (1982).
[5] D. Larson, Physics Essays, **37** (1): 10–33, (2024).
[6] W. Heisenberg, Zeitschrift für Physik, **43** (3–4): 172–198, (1927).
[7] M. Planck, Annalen der Physik, **309** (3): 553-563, (1901).
[8] L. de Broglie, Ann. Phys. (Paris) **3**, 22 (1925).
[9] E. Schrödinger, Physical Review, **28** (6): 1049–70 (1926).
[10] D. Larson, Physics Essays, **30** (3): 264–268, (2017).