Wave-Particle Duality: A New Look from First Principles

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Abstract

Part I looks at duality for the photon; Part II does the same for the electron. The traditional division of kinetic energy between radiation (E = *hf*) and matter-in-motion (E = $^1/_2$ mv^2) is reexamined permitting new insights into duality.

An in-flight photon displays wave characteristics. Such a photon can interfere with itself and take all available space paths as a wave. In addition, photons pass through one another like waves whereas particles impact each other. It is only when the photon terminates on a material object and gives up its energy – and ceases to be a photon – that particle characteristics appear, namely: 1) the photon is finally space located; and 2) oscillation ceases. This suggests that the photon's wave and particle nature do not overlap. Understanding photon termination as a release of mass stored, rather than particle impact, permits a better understanding of presumed wave-particle duality for the photon.

Keywords: wave-particle duality, double slit, delayed choice, photon, radiation, de Broglie, Mach–Zehnder interferometer

Part I – Wave-Particle Duality for Photons

1.0 Introduction –

Tackling the mystery of wave-particle duality head-on is inadvisable. Most thinkers choose this route and wind up applying various models and explanations drawn from classical physics and common experience; none are very convincing. It should be more advantageous to first list all the characteristics and attributes of the photon before deciding how it behaves in a double slit. The problem with that approach is that we know so very little about the photon. Fortunately, photons are entities, or at least

we think they are. If we can enumerate the main attributes of entities in general, this might tell us something about the photon's behavior in the double slit. So we begin with a generalized look at those entities which constitute the subject matter of physics.

Ontology is the traditional study of things that exist as entities. Ontology in these pages will be narrowed to focus only on entities of interest to a physicist; and it will be broadened to include entities that occur, based on energy, as well as entities that exist, based on matter. Within physics we can hardly exclude energy as an equal partner with matter.

While some entities exist (particle) and some occur (photon), they have a number of features in common if we compare them at a more abstract (ontological) level. For example, both particle and photon are quantized and both obey a conservation law. This method of comparing very different quanta for generalized attributes is not new; Einstein used it to great effect between 1905 and 1925.[1]

We shall see that entities within physics may be "pure" or they may be blended (mixed) and all of them store their opposite. Storage is what gives entities their unusual properties; properties that may be familiar to us for existing entities but are much less familiar to us for occurring entities.

1.1 Pure Entities –

Matter in motion combines rest mass with the kinetic energy associated with movement. It is a "mixed" or hybrid entity because it features both rest mass and energy. But mass can exist without (kinetic) energy and energy (as radiation) can occur without (rest) mass.

Matter in motion is bracketed by two extremes. At the low end you have stationary, inertial matter with zero velocity; at the high end you have electromagnetic (EM) radiation proceeding at the speed of light, a speed matter can never reach. The low end has rest mass with no kinetic energy; the high end has kinetic energy (radiation) with no rest mass. Since they do not combine mass with energy, the two extremes – a stationary particle and a photon – may be described as "pure" entities. Once a particle acquires energy (of motion) it becomes a mixed entity; if a photon could acquire (rest) mass it too would become a mixed entity.

Since both particle and photon are entities, we must define entity so that it is neutral between matter and radiation, between mass and energy, between existence and occurrence (and between space and time). We may start with a list of attributes common to entities within physics.

[1] In 1925 Einstein wrote: "…for if one is justified in considering radiation as a gas of quanta, then the analogy between the gas of quanta and the gas of molecules must be complete." Quoted in Martin J. Klein, "Einstein and the Wave-Particle Duality," *Natural Philosopher*, Vol. 3 (1964) p. 33.

Entities in physics are discrete; both the mass particle and the energy photon are quantized. Entities have a dimensional presence in the sense of occupying (residing in) a dimension; the particle requires a space interval (volume), photon oscillation requires a time interval. And entities can store their opposite; the particle/object stores energy (e.g. thermal energy), the photon – as we shall see – stores (relativistic) mass.

Stored (potential) energy may stay in one place, but kinetic energy cannot. Kinetic energy is kinetic in the sense of movement, but sometimes movement depends upon one's perspective. The kinetic theory of gasses is an example of this. If you focus on individual gas molecules then they exhibit kinetic energy of movement. But if your focus is on the gas as a whole, then molecular motion becomes heat which is potential energy, not kinetic energy.

Since an entity occupies (resides in) a dimension (space or time), it must have a characteristic "form" in that dimension. That is, entities in the same dimension, space or time, must share something that makes them similar in the way they occupy an interval/volume. It is the occurring waveform that constitutes the "form" for all radiation. We can't have radiation without the waveform.

For the particle we need a term that characterizes matter as filling out (requiring, extending in) a space volume. "Field form" comes to mind but "field" is such a protean term in modern physics it might be best to avoid it. Let's settle for "spaceform" as the cognate of waveform. Material objects occupy space and by doing so they have a "spaceform." A spaceform may have a regular shape (e.g., a bocce ball) or an irregular shape (e.g., a chain of carbon atoms). The reader might object that photon waves require oscillation plus space progression. This is true, but spaceform objects require matter plus time progression; matter that has zero time duration (time progression) is not matter. Spaceform matter progresses (persists) over time just as waveform radiation progresses over space. 'Form' therefore involves extension in one dimension and progression in the other. In what follows the duality of wave versus particle will be properly framed as waveform versus spaceform.[2]

One consequence of storage is that pure entities have both an unstored (kinetic) identity and a stored (potential) identity. Thus a material object has its matter as its unstored identity and the thermal (or radioactive) energy it hosts as its stored identity. The two are different and each is measurable

[2] The phrase "wave-particle" is empirically derived and is a clumsy locution. A wave is a form; a particle is an entity. Has nobody noticed this? The proper dichotomy is between forms: occurring waveform versus existing spaceform. Note: "progression" is not an ideal word for advancing in a dimension, but it will have to do.

(quantifiable), yet they are united into a single entity. Two identities within a single entity is an easy concept to understand in the case of the existing material object or particle; less so in the case of the occurring photon.

Nevertheless, the photon too has its unstored (kinetic) identity, namely the frequency-dependent energy of its oscillatory electric and magnetic fields. Complementing this, the photon has its stored (potential) identity in its releasable relativistic mass. The fact that one is mathematically related to the other does not mean they are the same thing since each requires a different measurement. Frequency tells us photon energy while momentum tells us photon effective mass (photon velocity being constant). In addition, we shall see that one identity (relativistic mass) attenuates over space and the other (oscillation frequency) does not.

Entities of mass store releasable energy and entities of energy store releasable (relativistic) mass. For radiation, the process of release merits a closer look in the next section.

Takeaways*: At the level of ontology, quantized matter and quantized radiation are simply entities and space and time are simply dimensions; at this (abstracted) level we see their similarities. The two quantized entities, one existing in space (a particle), and one occurring in time (a photon): 1) must be present in a dimension with a form (waveform or spaceform); and 2) will store their opposite. Storage means an entity will have a kinetic identity and a potential identity. As we shall see, kinetic identities and potential identities operate differently for our two dimensions (space versus time). Hint: there is a difference between occupying (residing in) a dimension versus progressing-advancing in that dimension (e.g., a particle resides in space but progresses [persists] in time).*[3]

1.2 Release and Entity Form –

Whether pure entities exist (e.g., inertial atoms, objects) or occur (photons) they have a presence in a dimension which means they have a form. The form of a pure entity characterizes both its kinetic and it potential identities. That is, an entity and its releasable stored content share the same form.

[3] Extending, or residing, or occupying-a-place in a dimension are used interchangeably in these pages to describe how entities of mass or energy require (take up) either space (for matter) or time (for oscillation) and thereby have a form.

This is easy to see in the case of the material object or particle. An object's kinetic identity – its matter – has a shape; we cannot imagine an existing mass (object) that does not have a spaceform. This mass will have a potential identity (thermal energy, binding energy, charge energy, etc.) that assumes the same form/shape. As an example, a chair's kinetic (massy) identity has a certain irregular form in space and the thermal energy it stores has exactly the same form.

Mass then has the spaceform for its kinetic identity and for it potential identity. If what is true of one pure entity is also true of the other, then EM radiation has the waveform for both its kinetic oscillation energy and its potential (relativistic) mass.

Of course physicists regard relativistic (stored) mass as a formless quantity, but that is partly because their measuring techniques all depend upon quantitative measures involving either momentum or inertia.[4] For example, photon relativistic mass may be measured by momentum transfer to a material target. Inertial measurements are also employed for relativistic mass. A rapidly moving charged particle has relativistic mass and the particle's deflection in an electric field will reflect the contribution of that additional mass.

Physicists have no instruments capable of detecting the form of potential (relativistic) mass; our knowledge in that regard must be indirect. We should not and cannot reasonably expect that we humans possess instruments that can detect every aspect of physical reality, especially the form of something immaterial (radiation).[5] The prevailing assumption – patterned after stored energy in thermodynamics – has always been that stored (relativistic) mass is simply a quantity. But if quantized matter has the same form for its kinetic and potential identities, then the same should be true for quantized radiation. We can embrace this idea heuristically and see where it leads us. For our two pure entities:

- **Potential energy stored by kinetic/unstored mass (stationary matter) has the spaceform; it exists and it progresses as a spaceform in time.[6]**

[4] Einstein didn't care for the concept of relativistic mass. Other physicists have followed his lead, most of them for pedagogical reasons ("don't confuse students"); they use energy for "acquired mass." But physicists who object to the term relativistic mass are invariably not consistent: "There is no argument in the literature about the uses of rest length versus moving length, so why should there be any argument about the uses of rest mass versus moving mass?"Quote is from: http://math.ucr.edu/home/baez/physics/Relativity/SR/mass.html

[5] The reader should not take the "form" (or shape) of relativistic mass too literally. This "form" occurs rather than exists; it can be thought of as space-progressing, alternating intensities which yield a kind of undulation.

[6] One meaning of `kinetic' is `unstored' so the term can apply to mass just as it does to energy. To clarify its use with mass the locution `kinetic/unstored' is employed. Using "kinetic" for both mass and energy emphasizes their unstored status at the ontological level; "potential" serves the same purpose for stored status.

- **Potential (relativistic) mass stored by kinetic energy (EM radiation) has the waveform; it occurs and it progresses as a wave in space.**

- **Anything with a form – spaceform, waveform – has a dimensional presence (Section 1.1). Hence relativistic mass has a dimensional presence (in space where it progresses).**

This last point is significant. EM radiation relativistic mass is now seen as having a real presence (and form) in space in addition to having a quantitative measure. It has become a "player" in physical processes, not a simple by-stander. The justification for this is: 1) its symmetry with the potential identity of matter; 2) its yet-to-be-seen explanatory utility.

Material objects and radiation (photons) are constantly exchanging what they store. The thermal energy a mass stores is released to radiation via photon emission. And the mass the photon stores is released to matter as a particle-like momentum impulse impinging at a space point during photon absorption.

During emission photon energy stored by the material realm crosses over to the realm of radiation. Thus the thermal energy of a body produces infrared radiation. Photon absorption is the opposite; mass stored by the radiation realm crosses over to the material realm. It is convenient to have a single term that covers both cases.

- ***Crossover*** **occurs when that which is stored in one realm (matter or radiation) is released to the opposite realm.**

Takeaways: The kinetic and potential identities of entities are different but they share the same form. For material entities, matter in space and the energy it stores have the spaceform; for radition, oscillation in time and the (relativistic) mass it stores have the waveform. Anything with a form is present in a dimension, space or time. Matter and its stored energy both progress (persist) in the time dimension; radiation oscillation and it stored mass both progress in the space dimension.

1.3 A Duality that Isn't a Duality –

Matter and radiation release what they store and in the process that which is released changes from spaceform to waveform (or vice versa). That which is released also converts from existence to occurrence (or vice versa). This is built-in to the very nature of mass and energy storage.

This is easiest seen in the case where matter stores energy (e.g., thermal, radioactive, etc.). Such stored energy is space confined/located and has the spaceform of its host. Once released this energy has the waveform of radiation (e.g., infrared rays, x-rays). Hence energy stored by matter exists and has the spaceform but when released it occurs and has the waveform. We would expect the inverse to apply for mass that is stored by waveform radiation and then released.[7]

The waveform photon is oscillatory kinetic energy and is space-dispersed since it travels all available paths toward some distant material target. The potential (relativistic) mass the photon stores also occurs, is space-dispersed and has the waveform. When the photon impinges upon a target its relativistic mass – and the associated momentum – is released at a space point. This tells us that upon crossover the space-dispersed, waveform, stored mass has become space-discrete which means it now has the spaceform: a spaceform is space-discrete, space-located; a waveform is not.

- **Crossover for pure entities – from stored to released – involves a change of form, spaceform to waveform (photon emission) or waveform to spaceform (photon absorption).**

A change of form involves a change of existence/occurrence. The photon's relativistic mass occurs (it oscillates) and progresses in space along all available paths. Once it crosses over (is released), that mass now exists and extends in (occupies) a defined space.

This change of mass from stored and path-continuous to released and discrete in space means that a transitory particle has been created. The mass of this particle is so tiny that it disappears as energy; like a virtual particle it cannot be detected by instruments and it is not part of the "particle zoo." The photon's particle nature is therefore a consequence of stored mass release/conversion upon photon reception (termination).

We conclude that the <u>in-flight</u> photon is not a particle at all. Its reception upon matter (our instruments, our eyes) does create a transitory particle; but to imagine that the yet-to-be-received photon as a particle is incorrect. The notion of EM radiation as both a particle and a wave ***before*** termination is an unwarranted extrapolation backward from photon termination at a space point. All

[7] For a table of particle-photon parallels see appendix A.

experiments on in-flight photons reveal wave behavior: diffraction, interference and superposition. Only photon termination reveals a particle character because at that point the photon's stored (relativistic) mass has changed its form and changed its ontological category from occurrence to existence.

Physicists get away with regarding the photon as a particle because it acts like a particle when interacting with their instruments. Abraham Pais writes that although the photon has zero mass, physicists "… nevertheless call a photon a particle because, just like massive particles, it obeys the laws of conservation of energy and momentum in collisions, with an electron say (Compton Effect)."[8] Using the word `particle' for the photon may be useful for physicists, but the usage is at odds with the photon's wave character. Regarding the in-flight photon as an actual particle stands in the way of making any progress on wave-particle duality for electromagnetic radiation.

Takeaways: At the abstract (ontological) level inertial mass and the photon are merely entities with common features. Both are discrete, possess a form and store (and release) their opposite (mass or energy). They both have a potential identity which requires us to take seriously (not dismiss!) the photon's relativistic mass. Photon stored, relativistic mass is not space discrete; it has the waveform. The in-flight photon is purely a wave. Only with the termination (reception) of a photon does photon stored (relativistic) mass become space-discrete and space-located as a transitory particle.

Recognizing the in-flight photon as strictly a wave, not a particle, explains how a photon can take all available space paths toward termination at a space point. It also explains how a single photon, as a wave, can split and follow both arms of an interferometer. But it does not explain why the photon's energy remains undiminished while as a wave it is dispersing over space or following both arms of an interferometer.

1.4 The Photon's Two Identities –

Richard Feynman claimed that the double slit experiment was the central mystery of quantum mechanics.[9] An even simpler phenomenon is equally mysterious.

[8] *Niels Bohr's Times,* Oxford Univ. Press, 1991, pp. 350-1.

[9] *Feynman, Richard P.; Robert B. Leighton; Matthew Sands (1965). The Feynman Lectures on Physics,* Vol. **3**, Addison-Wesley. pp. 1.1–1.8.

Imagine a planet or an asteroid in a distant galaxy emitting a single photon with a spherical wave front. That photon wave front then travels all available paths over much of the universe such that its probability of reception upon some distant planet is infinitesimally small. Despite this rarefaction, when the photon does terminate upon matter it does so with its source energy undiminished. Probability rarefies, quantized energy does not.

Explaining this is difficult because our knowledge of the photon is basically limited to its interaction with our material instruments. But once again, comparing the photon as a pure entity with its ontological twin can provide us with some hints.

We have seen that entities store their opposite and this gives them two identities. And what is stored is different from that (host) which does the storing. Thus an inertial rest mass object (the kinetic identity) is different from the thermal or radioactive energy it stores (the potential identity). It is the same for radiation. The photon's oscillation (its kinetic identity) is different from its stored (relativistic) mass (its potential identity).[10] The latter determines probable reception, the former does not.

Pure entities occupy a time interval or a space volume and this constitutes their extension in a dimension. Matter cannot exist without extending in space; and photon energy cannot occur without extending in time (oscillating).

A space-stationary (inertial) material object occupying space will progress in time toward possible release of what it stores (energy). A time-stationary photon residing in (occupying) time will progress in space toward possible release of what it stores (mass). In general, a pure entity resides in (occupies) its extension dimension and also progresses in its alternate (progression) dimension.

If the reader has not yet internalized the concept of a pure entity's two identities (kinetic and potential) making use of space and time differently, it is not too late. An inertial, space-stationary object/particle has a defined location in space (where it extends and is stationary) relative to some arbitrary spatial reference point. It has no defined location in time where it progresses (persists). We can pulse that object with a signal at time t_1, but t_1 is the time location of the interaction and not of the object itself. Similarly, a photon may have a defined

[10] Those who deprecate relativistic mass will object to this and argue that relativistic mass is really an expression of (no different than) kinetic energy. There is no definitive (experimental) resolution of these two views. As with a concept like inertia, ultimate judgment depends upon which view explains more phenomena. Relativistic mass is measurable. Eliminating it leaves one with fewer "constituents" to explain the subtleties of photon behavior; eliminating it also violates symmetry with the material side of reality. See appendix A.

location in time (where it extends and where it is stationary) relative to some reference photon, but the photon has no defined location in space; it progresses there (on all available paths). The idea that items that are pure existence (inertial matter) or pure occurrence (photon) have defined locations in both space and time is simply wrong.
The dimension where an entity exists/occurs (where it resides: space for matter, time for the photon) is its extension dimension. Where that entity progresses (time for matter, space for the photon) is its progression dimension. Because a pure entity extends in one dimension and progresses in another, so do its two identities.

An entity has two identities but remains singular and has but one form. Both identities – kinetic and potential – reside in the extension dimension and both identities progress in the alternate dimension. This is easiest seen in the case of the material pure entity. Thus stored thermal energy extends (resides) in space just as its kinetic material host does; both the thermal energy and its material host also progress in time.

But whatever an entity stores is subject to release which means that potential identities typically will change in the course of progression. Stored thermal energy of an atom or molecule may diminish via the release of infrared photons. But such photon emission does not change the makeup of the atom or molecule; all of the sub-atomic constituents are still in place after the photon is gone; only some stored energy has departed. So time progression for an object may see its potential identity change but its kinetic identity will remain constant. Barring such events as radioactive decay, objects don't change over time; they are common for all temporal observers (for all observers at all time locations while the object exists).

To summarize for material pure entities: their kinetic identity exists as matter, occupies space and all observers in time see the same mass object. What these entities store also exists, occupies space but is subject to release and diminution while progressing in time.

Identity	Category	Extends in	Progresses in:
Kinetic Mass[11] (Spaceform)	Exists (matter)	Space	Time (Matter is common for all observers in time)
Potential Energy (Spaceform)	Exists (e.g., thermal energy)	Space	Time (Potential energy subject to release/diminution)

[11] 'Kinetic' as in unstored.

Having a material object being common to all observers in time is something we depend upon in our everyday lives; the things we see are the same things others see. Conservation of mass insures that the same is true at the atomic level. A corollary of this is that the kinetic identity of mass (i.e., matter) cannot be partitioned or rarefied in time. All of this, naturally, has its parallel for radiation and energy.

Radiation pure entities (photons) occur; their oscillation means they occupy and extend in time. Both their kinetic identity (oscillation) and their potential identity (relativistic mass) will progress in space. But a photon's space progression has no effect upon its kinetic identity; all space observers will experience the same oscillation frequency. The kinetic identity of radiation energy (i.e., oscillation) extends in time and cannot be partitioned or rarefied in space; just as the kinetic identity of mass extends in space and cannot be partitioned or rarefied in time. The photon's kinetic identity, oscillation, is common for all observers in space. As a photon moves along all available space paths, all observers on those paths are witness to (capable of measuring) the one-and-only entity oscillation with its defined frequency. [12]

But such invariance during space progression does not hold true for what the photon stores, namely relativistic mass. Photon stored mass is tied to oscillation frequency ($m = hf/c^2$) which is constant for inertial observers. But photon progression on all available (diverging) space paths means a set amount of space-continuous relativistic mass must rarefy to fill the expanding space volume. The table for the radiation pure entity is then:

Identity	Category	Extends in	Progresses in:
Kinetic Energy (radiation waveform)	Occurs (oscillation)	Time	Space (Oscillation is common for all observers in space)
Potential Mass (radiation waveform)	Occurs (relativistic mass)	Time	Space (Potential mass subject to release/diminution)

For pure entities, inertial mass or photon, we can say:

- **Entity identities (kinetic and potential) extend in one dimension and progress in the opposite (orthogonal) dimension.**

- **An entity's kinetic (unstored) identity (mass or frequency) is unaffected by progression.**

[12] Inertial observers in relative motion will measure different frequencies (Doppler Effect). But all observers in the same inertial system witness the same frequency.

So the kinetic identities of pure entities are present in the progression dimension, but they remain unaltered there. This is true even if the entity progresses on multiple paths as is the case with radiation. While photon frequency is undiminished by space progression because it is common to all space paths, it is the local probability of photon reception that will diminish over space. And this diminution of probability involves something more real and more physical than a mathematical construct like the wave function Ψ, which doesn't apply to the massless photon anyway.

Waveforms by their inherent nature occur and spread over all available space paths making them space-continuous. This spatial continuity on available paths is true of water waves, sound waves or radiation waves. For radiation, something physically real that also occurs, progresses and enables probabilistic release must fill these individual space paths. That something is the photon's potential identity, its stored (relativistic) mass which, like any wave, is capable of self-interaction. Probability of release and being stored (potential) go hand-in-hand. To deprecate relativistic mass is to eliminate the source of radiation's probability.

Since radiation must progress in the three dimensions of space, a set amount of what each photon stores (relativistic mass) must attenuate to fill an ever-expanding space volume. Quantitatively the relativistic mass is unchanged by space progression; what attenuates is its local intensity. As the photon's wave front expands in space the diminishing intensity of potential mass on space paths reduces the local probability of release (crossover). But when release does come it is for the entire stored-and-dispersed mass which, as an immaterial occurrence, can collapse instantly (non-locally[13]).

Takeaways: Photon potential (relativistic) mass is an insubstantial occurrence (no rest mass involved) whose local intensity in space determines probable release. A photon traverses space as: 1) a path-common oscillation; and 2) a path-continuous, rarefying wave front of stored mass. Release is quantized and individually random in space because it crosses the occurrence/existence divide. Release involves the transition from continuous, stored/potential mass to discrete, unstored/kinetic mass (i.e., matter). Because a waveform determines probability, release in space will be predictable as an ensemble despite individual randomness.

It is the dual nature of the photon (two identities) that accounts for its unusual capabilities, namely

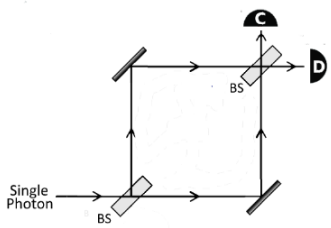
[13] For more on non-local path collapse, see Section 1.5 on the Mach–Zehnder interferometer.

conservation of (path-common) oscillation energy versus rarefaction of path-dispersing stored mass and probable reception.

1.5 Interferometer and Delayed Choice –

A single photon traversing an interferometer is good illustration of how photon potential (relativistic) mass can space progress and space-rarefy while its kinetic identity (its oscillation) is unaffected.

A Mach–Zehnder interferometer has two mirrors and two beam splitters (BS) diagonally opposite. A single photon entering the lower beam splitter will take both the upper and lower paths and meet at the second beam splitter. There the photon interferes with itself[14] and registers (undiminished) at detector C (constructive interference). Detector D can never receive a photon providing interference of upper and lower beams has taken place.



The photon's potential identity, waveform relativistic mass, oscillates in time but progresses along paths toward release and is therefore divisible by the first beam splitter. But the photon's kinetic identity, oscillation, extends (resides) in time and, while present in space, it is common there to all space paths; it is not spatially divisible.[15] So both paths – upper and lower – have a single, shared kinetic energy due to the photon's oscillation residing (occurring) in the time dimension and being common in the space dimension.

Confusion arises for commentators because they fail to recognize that, like any entity, the photon has both a kinetic and a potential identity. The kinetic identity (oscillation) is spatially indivisible; there is only one kinetic identity (one photon) for the two paths. But the potential identity (and hence probable termination) will subdivide on the two paths. Partition takes place at the first beam splitter of the potential (relativistic) mass wave. This means that the photon is travelling both paths but with only half the probability of photon termination (crossover) on each path. Partition in space has no effect on the quantity of stored mass released at a possible termination since that is set and determined by the oscillation energy of the photon's kinetic identity. Receiving (terminating) a photon on a detector on one

[14] Recall Dirac's pronouncement: "Each photon …interferes only with itself. Interference between two different photons never occurs." P.A.M. Dirac, *The Principles of Quantum Mechanics*, p. 9 (Oxford, 4th ed.)

[15] As noted when an entity's kinetic/unstored identity resides (extends) in one dimension you cannot divide it in the other (progressing) dimension. Inertial rest mass resides/extends in space; you cannot divide it in time.

path does not mean that is the one path the photon chose at the beam splitter; the photon "chose" both paths. The kinetic (oscillation) photon identity was common to both paths; the potential identity split equally on the two paths.

Photons in general (in free space) follow multiple paths toward a material target. This means that their probability wave (their potential identity) progresses on all those paths (with unequal intensities). When the photon terminates, the broad wavefront of probable reception collapses instantly because the space-dispersed waves involved are pure occurrence and carry neither rest mass nor energy. They carry no rest mass since the photon has none. They carry no energy because: 1) the oscillation energy of radiation is an entity residing in time; 2) this energy is common to all space-paths but does not reside in those paths since it is orthogonal to them; and 3) this energy "delegates" its stored, retractable, probabilistic mass to do the actual filling-out of space paths.

A photon entering an interferometer is constrained to but two space paths. If path A of an interferometer contains a photon detector (obstacle), the photon's (reduced) potential mass wave front will reach it but with only a 50% chance of terminating on it. If photon reception (termination) does not take place on this detector, then path B instantaneously (non-locally) converts from 50% to 100% probability of photon reception. Stored (relativistic) mass progressing on space paths and constituting a non-material, waveform, probability occurrence can be retracted instantly if it cannot progress on that path. Stored (relativistic) mass is a collapsible "ghost wave"[16] of probable release.

A single photon traversing both arms of a Mach–Zehnder interferometer yields wave information (interference) when it exits. This is because the single photon's potential (relativistic) mass – divided by the first beam splitter – undergoes interference when reunited by the second beam splitter. If you place a detector on one arm of the interferometer to obtain "which-way" (which path) information, you block the passage of the photon's relativistic mass on that arm. If the photon does not register (terminate) on that detector it is a mistake to conclude that nothing was on that path and that the photon chose the other path. If the photon does register on that detector it is equally a mistake to conclude that nothing traversed the other path.

Blocking the passage of the potential (relativistic) mass wave on one arm prevents any wave interference at the second beam splitter. Similarly, for a photon traversing a double slit, positioning a detector behind one slit has the same effect as a detector on one arm of an interferometer; the wave

[16] The term "ghost wave" is from Einstein; see https://arxiv.org/ftp/arxiv/papers/0709/0709.3226.pdf, pp 2-3. His instincts, as usual, were correct about a retractable wave of probability. But the irony is that Einstein tried to eliminate relativistic mass. Perhaps his biggest mistake was not the cosmological constant.

pattern disappears. Space location ("which-way") and wave interference phenomena (multiple paths) are mutually exclusive. The blocking of probability wave paths constitutes a physical change for radiation even if photon reception does not occur.[17]

Wheeler's delayed choice thought experiment[18] has generated a huge literature and several attempts to carry it out in practice. Wheeler sought answers to a couple of questions. When a photon encounters a physical object (a beam splitter) that generates two paths for the photon, is the photon thereby constrained to choose one path (as particle) or both paths (as wave)? Does the measurement design affect the choice made?

Imagine a single photon entering an interferometer. Immediately *after* the photon has passed the beam splitter an experimenter may insert (activate) detectors on both interferometer paths and determine which path the photon-as-particle chose to take. Or, one may remove (deactivate) such detectors (again, after the photon has passed the beam splitter) and allow the photon-as-wave to follow both paths unimpeded and then recombine to create interference. The object here is to change the mode of detection after the photon has made its "choice" at the beam splitter: follow one path as particle, or follow both paths as wave.

According to Wheeler, at the point of division (beam splitter) the photon chooses either the particle identity (follow but one path) or the wave identity (follow both paths). And yet Wheeler argues it is the observer who has the ability to measure (receive) an identity (single path = particle or both paths = wave) after the photon has made its "choice." This implies retrocausality: the beam splitter's choice gets determined by the subsequent observation choice. This led Wheeler to claim that "we…have an inescapable, an irretrievable, an unavoidable influence on what we have the right to say about what we call the past."[19]

When particle detectors are placed on both paths only one detector will receive the one photon. This leads to the too-easy assumption that nothing traversed the other path. In fact, the photon's

[17] Such a physical change is the basis of interaction-free measurement. And one does not need 'many-worlds' or quantum superposition (photon replication) theories to explain such "counterfactual" measurement. See: https://en.wikipedia.org/wiki/Elitzur%E2%80%93Vaidman_bomb_tester

[18] J.A. Wheeler, "The 'past' and the 'delayed-choice' double-slit experiment," in *Mathematical Foundations of Quantum Theory*, ed. A.R. Marlow (Academic Press, New York,1978) , 9–48. For a summary see https://en.wikipedia.org/wiki/Wheeler%27s_delayed_choice_experiment#Cosmic_interferometer

[19] Wheeler, "Hermann Weyl and the Unity of Knowledge": **http://www.weylmann.com/wheeler.pdf** p. 6. Wheeler softened his position elsewhere. See https://arxiv.org/pdf/0706.2596.pdf

potential identity travelled both paths. Once again the mistake here is to limit the photon to but a single identity (that of kinetic energy) and ignore its probability identity (relativistic mass). The photon's kinetic identity is pure oscillatory occurrence that is common to all space paths; you cannot divide a kinetic identity in its progression dimension. As we have seen, it is the photon's potential identity that progresses on both space paths; that is what gets divided. The in-flight photon is not a particle required to choose one path; it is a pure, waveform occurrence whose energy never divides but whose probability does. There is no such thing as retrocausality.

1.6 Conclusion –

Sections 1.2, 1.3 showed that the photon's wave and particle nature do not overlap:

- **The photon only becomes a particle when it terminates upon a material target; the in-flight photon is purely an energy wave storing releasable mass.**

More subtle and more profound is why the photon can subdivide on multiple paths and yet terminate with undiminished energy.

- **The photon's unstored (kinetic) oscillatory EM identity is common to all space path observers. It is the photon's stored (potential) identity that attenuates on the multiple paths and determines probable reception of the undiminished kinetic energy.**

Recognizing radiation's potential mass as a waveform completes its equality and symmetry with matter's potential energy as a spaceform. Mass-stored potential energy (thermal, binding, radioactive) is probabilistic for release in time. Similarly, radiation-stored potential (relativistic) mass is probabilistic for release in space.

But potential mass as a waveform is not confined to the photon. It also plays an important role for moving bodies. It makes sense that what we have learned about pure entities and their potential identities will help us understand hybrid, or mixed, entities: matter-in-motion and matter waves.

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Part II – Wave-Particle Duality for Electrons

Abstract

De Broglie waves appear as a type of radiation and yet there is minimal connection made with EM radiation. We also have two different varieties of energy, one dependent on oscillation ($E = hf$) and one dependent on velocity ($E = {}^1/_2\, mv^2$). Why would nature give us two varieties of radiation and two varieties of energy? This duplication suggests that a reexamination is overdue regarding the traditional view of energy as a simple quantity possessed by a moving object. An alternate view is that a body in motion (with its de Broglie radiation) is a union of two entities, namely mass that exists in space and (radiation) energy that occurs (oscillates) in time. This interpretation sheds light on a number of problems, including wave-particle duality for particles. In what follows, an understanding of the concepts from Part I is assumed.

2.0 Roadmap –

When viewed critically, current assumptions regarding de Broglie radiation and even kinetic energy are not satisfactory. The first section below will look at de Broglie's assumptions regarding the origin of matter waves and find them suspect. The next section will explore the reasons why we have two separate sources of kinetic energy. Following that, subsequent sections will outline and develop an alternate, single view of kinetic energy that unites EM radiation with de Broglie radiation.

2.1 De Broglie and Matter Wave Oscillation –

Part I showed that wave-particle duality is a misnomer for electromagnetic radiation. The dual forms – waveform and spaceform (particle) – do not overlap. The in-flight photon is a wave but only the terminated photon can qualify as a (transitory) particle. But this is not the case for speeding electrons and similar rest mass particles where particle and wave identities are always present. Despite this difference, there are significant commonalities between speeding photons and speeding electrons. Both involve radiation and probability and can image objects; and both possess an oscillation. Photon oscillation is based on changing electric and magnetic fields, but the nature of electron wave oscillation is not really understood. De Broglie originally attributed matter wave oscillation to the latent energy of

particle rest mass. Many years later he and David Bohm traced it to the wave function Ψ. This section finds both of these explanations unconvincing.

It was Louis de Broglie who proposed that matter, specifically the electron, had a wave character. This somewhat bizarre idea soon proved pivotal for the development of quantum mechanics. It led Einstein to his theory of condensed gases where particles (bosons) in a dilute gas would oscillate in concert because of their wave character. And this idea led Schrödinger to develop his famous wave equation for the hydrogen atom. But the irony is that the initial assumptions de Broglie made were sometimes incorrect or lacked a factual basis.[20]

Although his older brother Maurice was an experimental physicist, Louis de Broglie was more of a speculative philosopher very much interested in physics. His grand idea (which he never gave up) was the fundamental unity of radiation and matter, of optics and dynamics. This naturally gave him an early interest in extending the wave-particle duality of Einstein from radiation to matter (electrons). Aside from Einstein, most of the thinkers that influenced him were French. He was certainly aware of the electromagnetic theory of matter that tried to connect mass and energy to radiation. Both Henri Poincaré and Paul Langevin (de Broglie's thesis examiner) were supporters of this theory.[21]

The early 1920s were years of considerable confusion and uncertainty in physics and we may forgive de Broglie some of his speculations that now appear fanciful. He believed that light quanta had (very tiny) rest mass, that this mass was not constant and that particles could be regarded as thermodynamic machines.[22] This latter idea involved an attempt to bring together the ideas of his favorite (French) scientists: Fermat (optics), Maupertuis (dynamics) and Carnot (thermodynamics). De Broglie's 1924 thesis constitutes a "…barrage of novel ideas and confusing developments …."[23] Textbooks and historians of physics rightly laud de Broglie for opening the way to a true quantum theory. But those few[24] who examine his thesis closely agree that his (shifting) arguments do not support his conclusion; he achieved spectacular success based on wrong supporting ideas.

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[20] In what follows, de Broglie's ideas are criticized. Inevitably some of this criticism depends upon knowledge coming after his original thesis. No Whiggish judgment of de Broglie the scientist/thinker based on subsequent knowledge is intended. He did very well for his time; nevertheless, ideas are required to stand the test of time.

[21] MacKinnon, E. (1976). "De Broglie's thesis: a critical retrospective," *Am. J. Phys.* **44**: 1047-48.

[22] https://en.wikipedia.org/wiki/Louis_de_Broglie#Non-nullity_and_variability_of_mass.

[23] MacKinnon, 1054.

[24] MacKinnon; also Roberto de Andrade Martins, "*Louis de Broglie's Struggle with the Wave-Particle Dualism, 1923-1925,*" http://quantum-history.mpiwg-berlin.mpg.de/eLibrary/hq1_talks/waveMech/23_martins

The one argument of interest here is de Broglie's famous assertion that particles had an internal oscillation such that their rest mass constitutes a frequency giving rise to a radiation wave: $m_0c^2 = hf$. The initial quantity in this formula is latent (potential) energy locked inside matter and possessing the spaceform, while the subsequent quantity is the waveform kinetic energy of accumulated action quanta in a time interval. Time is irrelevant to m_0c^2 whereas time is all-important to hf. Calculating the relativistic time dilation of this frequency, as de Broglie did, makes little sense since matter waves appear at non-relativistic velocities (e.g., the electrons Davisson and Germer used in their experiment were relatively slow). Nor has de Broglie's idea of particle "internal oscillation" proved at all useful for later theories.

Knowledge of radiation was quite limited when de Broglie started on his theories which he did even before Compton announced photon-electron scattering. Two ideas appear to have been central to his thought processes. First, he judged that Einstein was correct that light quanta had a particle nature. And second, he was anxious to show that the electron had a wave character since this could then explain the stationary orbits of the Bohr atom. On this basis de Broglie set out to establish that the electron possessed an oscillation that, when combined with movement, creates a wave.

It is true you can write a wave equation for a particle that oscillates and moves along a space path. But matter (electron) waves are more complex, more subtle than that; they have a probabilistic character as well. We know now that the photon can interfere with itself and can superpose as a wave with other photons. We also know that radiation is radiation; whether quanta are photons or electrons both produce images in a microscope. An electron entering a crystal lattice must be able to interfere with itself (probabilistically) just as a photon does in a pinhole. And both quanta when launched *individually* into lattice or pinhole create a probabilistic scattering pattern. It is impossible to conceive of an oscillating (vibrating), moving material particle having these capabilities.[25] This is why the physically real, matter-based waves of de Broglie's speculation soon became the probabilistic, phase-space waves of Schrödinger.

[25] The ontological explanation for this is as follows. The electron's rest mass can oscillate but it will never have a probabilistic character because rest mass is the kinetic/unstored identity of the electron entity. Only the stored/potential identity of an entity (the electron's relativistic mass) can possess probability (of possible release).

Faced with the difficulties (and critiques) of his own theory and the success of Schrödinger's equation, de Broglie give up (at least publically) on his ideas only to revive them (with David Bohm) in the 1950s. The de Broglie–Bohm (pilot wave) theory remedies one major flaw in de Broglie's earlier proposal. Oscillation is now assigned to the wave function Ψ and not to the particle (electron) itself and this provides for probability. However, the particle/electron is granted unusual qualities, namely "a 'complex and subtle inner structure' that provides the capacity to react to the information provided by the wavefunction by the quantum potential."[26]

The pilot wave theory has its adherents and its merits are outside of discussion here save for a couple of observations. First, physics is about mass and energy and for those of us who wish to exclude everything else it is unsettling, even repugnant, to grant a mathematical expression (the complex-valued wave function Ψ), entity status such that it can operate on and guide physical objects (particles).[27] Second, a comprehensive theory of quantized radiation should include wave properties and interference characteristics of both radiations: photons traversing a double slit and electrons traversing a crystal lattice. The pilot wave theory, despite its advantages, depends upon the Schrödinger equation which cannot apply to the (massless) photon.

Takeaways: We have no acceptable explanation for matter wave oscillation. The oscillation of rest mass – by whatever mechanism – cannot account for the probabilistic nature of de Broglie wave radiation. And the wave function Ψ is a mathematical expression; it is not an entity of mass or energy that has a physical presence (and form) in space or time. In addition, our knowledge of matter in motion and of de Broglie waves is incomplete in other ways.

2.2 Our View of Kinetic Energy –

While mass and the square of velocity were first seen as related to energy in the eighteenth century, the correct concept of kinetic energy came much later. Our current view of kinetic energy of moving matter goes back only to the middle decades of the nineteenth century and the work of Coriolis,

[26] https://en.wikipedia.org/wiki/De_Broglie%E2%80%93Bohm_theory#The_ontology. Such an "inner structure" certainly sounds like something from the de Broglie of the early 1920s.

[27] Physical entity status requires occupation of a space interval/volume or a time interval. It is hard to see how a mathematical expression can fulfill this.

James Joule and William Thompson (Lord Kelvin). Kinetic energy is therefore a true latecomer to physics compared to mechanics which began with the ancient Greeks.

The idea of energy as a simple quantity became firmly entrenched in the last half of the nineteenth century. Assuming mass remains constant, the kinetic energy of matter-in-motion was correctly defined as ½ mv^2 (Coriolis). Then numerous experiments confirmed that energy is conserved as a quantity and can be transferred (work to heat and back). Conservation of energy took its place alongside of conservation of mass as laws of physics. But just as mechanical energy and thermodynamics were achieving their secure place in classical physics, a new form of energy was being explored.

Attempts to understand blackbody radiation led Planck to formulate his radiation law in 1900. In the process he was forced to regard the energy of black body oscillators as quantized. Einstein took this a step further and argued that radiation itself was quantized and its energy was E = *hf*. This was a radical idea for the time and most physicists had trouble accepting energy as quantized. Opinion only shifted when Compton published (1923) his experiments showing radiation lost energy when "colliding" with electrons, something the wave theory could not explain. If radiation had both a wave character and a particle character, then the duality Einstein had long advocated had to be taken seriously. The capstone to this was de Broglie's proposal that matter in motion had a wave character just as radiation had a particle character.

The new view of quantized radiation energy did not supplant the classical view of the kinetic energy of matter in motion. The classical idea of energy as formless quantity was too secure and too fundamental to be given up. Radiation energy and the energy of moving bodies were regarded as separate and still are today.

We thus have two models for the transmission of kinetic energy through space. There is EM radiation, the photon, and there is a material body in motion. Both transport energy from one space locale to another, but they are not seen as related; they appear to describe quite different energetic phenomena and their evolution in physics was separate and unrelated. One energy has a (wave) form, the other is a simple quantity. We also have two different types of radiation, EM and de Broglie both featuring oscillation, but we have no convincing explanation for the basis of de Broglie oscillation.

While our concepts of energy and radiation are both in duplicate, most everybody agrees on something that is common to both radiation and matter-in-motion, namely wave-particle duality. And yet, as Part I argued, we have absolutely no evidence that the in-flight photon is a particle or can even

assume particle characteristics before termination. Attributing wave-particle duality to the in-flight photon is quite wrong.[28]

All of this is highly unsatisfactory. Ideally, we should have a single concept of energy and the two forms of radiation should be closely related by their oscillatory nature; specifically:

- **Kinetic energy requires oscillation so anything – photons, particles – with kinetic energy moves and will exhibit the (oscillatory) waveform.**
- **Space-stationary rest mass has the spaceform; time-stationary photon has the waveform. Both are pure entities with their own (pure) forms. Neither one exhibits duality of form.**
- **Let moving matter be the union of two different entities with their opposing forms: kinetic/unstored (rest) mass with its form and kinetic energy with its form.**

Our textbook view of the kinetic energy of moving bodies as a formless quantity is now 150 years old and it went untouched by subsequent breakthroughs in physics, including the theory of radiation (Maxwell, Hertz, Planck, Einstein, de Broglie) and quantum mechanics. The quantum revolution was crisis-driven; it addressed the conflicts that had developed with classical physics. But kinetic energy and the conservation of energy didn't appear to need revision so it was not questioned. Meanwhile, our concepts of mass, space and time have all changed in the last century and one-half; only energy of moving bodies has remained the same. And so we are stuck with two versions of energy plus a simplistic view of the energy of moving bodies as a mere quantity.

A century after Einstein confronted the two definitions of mass – inertial and gravitational – and coalesced them, we face the problem of two definitions of energy. Can we emulate him? Physics rarely gets things right on the first try; seeing connections is not easy.

Takeaway: If oscillation is kinetic energy then de Broglie oscillation of matter-in-motion follows from that and we don't have to invoke wave-particle duality as "explanation."

2.3 EM Radiation Again –

[28] Or as Pauli would say, "Not even wrong." Or per Asimov: "wronger than wrong."

Electrons bound to a nucleus can change their energy (their orbital) and emit or absorb photons. Free electrons in a conductor (antenna) driven back and forth by an oscillating voltage undergo energy change and radiate photons (an EM carrier wave). These are two familiar examples of changing charged particle energy to create an EM energy packet (photon) that will travel forever until intercepted.

The photon is a self-sustaining entity; it has a point of creation and a point of termination. It features both electric and magnetic fields. The in-flight photon is independent of its source; whatever happens to the photon does not affect the source. The photon speeds along in space while its electric and magnetic fields exhibit a transverse oscillation. One field does not create or induce the other; they occur together (in phase) but at 90^{o} to each other. The electric field may oscillate positive and negative along the Z axis, the magnetic field positive and negative along the X axis with the ensemble moving along the Y axis. The two fields appear to unite space and time; interchangeably a time-change in one field is proportional to a space-change in the other field. The two fluctuating fields essentially unite occurrence in time with progression in space. If you compress one field (e.g., by moving toward the source) you compress the other as well so space propagation stays the same. Because both photon fields cycle together and require some time duration to do so, we can say that they reside (occur) in time while progressing in space. In this way they conform to the entity template of Section 1.1: extending (in this case occurring) in one dimension while progressing in the other.

A harmonic oscillator is sustained by the interchange of a set amount of energy from kinetic to potential and back again. However, this is not the case with the electric and magnetic fields of EM radiation; in phase with each other, their presence gives the received photon energy neither a charge nor a magnetic dipole moment. Accelerating a charged particle (e.g., electron) in time over space creates the two fields oscillating in unison. Photon energy then seems to be a consequence of oscillation itself with the electric and magnetic fields being a by-product of EM radiation's dependence upon charged particles. Thus when uncharged mass is accelerated, it too creates (de Broglie) pure energy oscillation, but minus any electric, magnetic fields. Kinetic energy requires oscillation; the presence of in-phase electric-magnetic fields is not fundamental to the oscillation; it is the work done (acceleration) of a particle/object, charged or not, that is fundamental.

Takeaway: Oscillation in time, movement in space and relativistic mass define kinetic energy. The photon's electric-magnetic fields merely reflect the charged particle origin of the photon.

2.4 Two Types of Energy –

In Part I, the photon as a pure energy entity was compared (ontologically) with an inertial mass, a pure matter entity. A distinction was then made between these two pure entities versus a hybrid entity; the latter being matter-in-motion which mixes both rest mass and kinetic energy. The question then arises as to the exact nature of the energy possessed by matter-in-motion. Is it comparable to the energy of radiation (the photon) or is it something entirely different?

The conventional view opts for different. This view argues that when rest mass is subjected to force acting over distance, then the work done is a formless quantity of energy that becomes a property of the rest mass. Unlike other properties such as mass, density or shape, kinetic energy is not intrinsic to an object. It is observer-relative and it can be subtracted (transferred) from that object by applying a counter force over distance. Kinetic energy is strictly a quantity according to the conventional view; it has no apparent connection with de Broglie waves and their oscillation. This view has kinetic energy as oscillatory for EM radiation ($E = hf$), but as a simple quantity for the moving body ($E = \frac{1}{2}mv^2$). Radiation energy requires occurring cycles but they are denied to the kinetic energy of moving bodies. Having two models for the same process – the transmission of kinetic energy in space – is far from satisfactory.

An alternate (ontological) view argues that kinetic energy is always an entity, never a mere property. It is a radiation entity residing in time (as oscillation) and progressing in space just as inertial matter resides in space and progresses in time. Kinetic energy can be pure (the photon) or it can be joined with rest mass to create matter-in-motion plus (de Broglie) radiation. Kinetic energy therefore occurs/oscillates and has a dimensional presence (a form); it is not a passive quantity that lacks both a form and a dimensional presence.

Takeaway: Is the kinetic energy of matter-in-motion a simple, formless, passive quantity as our textbooks say? Or does work create an occurring, time-residing energy entity (with a form) that can join with rest mass to create a hybrid entity with two opposed forms?

2.5 Energy and Work Done –

A photon has releasable relativistic mass and oscillation; a moving rest mass has releasable relativistic mass and (de Broglie) oscillation. The current approach in physics is to view them as unrelated, deprecate relativistic mass in both cases and relegate de Broglie oscillation to its own category of wave-particle duality unconnected with energy. The approach here is to regard any relativistic mass plus oscillation (it turns out they are always together…) as constituting the measurable features of an entity of energy; not an entity that exists and occupies space, but one that occurs and occupies time (and progresses in space). To repeat, relativistic mass and waveform oscillation are the measurable features of kinetic energy as a radiation entity, either EM radiation or de Broglie radiation.

Radiation is the inverse of matter: radiation occurs whereas matter exists; radiation occupies time whereas matter occupies space; radiation progresses in space whereas matter progresses in time; radiation has the waveform whereas matter has the spaceform; and radiation stores mass whereas matter stores energy. In light of all this, why should not radiation have an entity that is the inverse of the matter entity?

So kinetic energy is not a formless property; rather it is the radiation energy entity whether that radiation is EM or de Broglie in character. Like any entity, the radiation energy entity must have two identities. The kinetic identity is pure oscillation that resides in the time dimension and is merely present in the space dimension, being common for (shared by) all space observers. The potential identity of this entity is stored (relativistic) mass that progresses in space while oscillating in time. These waves – EM and de Broglie – are probabilistic because they constitute stored mass embodying the potential for release. De Broglie radiation gets packetized; that is, multiple, out-of-phase waves superpose to create a field-like probability region accompanying the matter in motion.[29]

Whether kinetic energy is a pure entity (no rest mass) or whether kinetic energy is joined to rest mass, it is always a radiation entity that extends and occurs in time while featuring relativistic (stored) mass that progresses along all available space paths; hence probability for both photons and speeding electrons.

[29] The waves of a single moving object can be represented mathematically in 3-dimensional space. For a system of n particles the mathematics requires a 3n-dimensional configuration space to account for the degrees of freedom. But the waves of n particles still (must) have a physical presence (can interfere) in our 3-dimensional space whatever their degrees of freedom and their mathematical representation.

Doing work upon a material body creates kinetic energy as an oscillatory entity in the time dimension. This work done is the joining of two orthogonal entities: matter residing in space and kinetic energy residing in time. Matter in the union and has now acquired a time locus. That is, time is no longer unmarked; time points are now distinct based on the body's space position. Kinetic energy as (de Broglie) radiation-oscillation is also present in the union and it has now acquired a space locus, namely the radiation wave packet centered on the particle's position. The progression of two pure entities with defined location in but a single dimension has given way to a hybrid entity with defined location in both space and time (a trajectory).

Every inertial observer regards himself as motionless. From his or her viewpoint, objects that move have undergone work (force over distance) to achieve their motion. The kinetic energy of a moving object therefore involves the transmission of the past work done on the object. This work (energy) as transmitted is now entirely in the realm of force-free energy occurrence (as opposed to force acting on mass).[30] Kinetic energy of motion is hence a consequence of past work done. This energy accompanies the mass but regarding it as a property is not warranted. Rather, the act of doing work upon matter joins that work, that kinetic energy, to that matter. This joining together is most subtle because matter as entity is dimensionally (and ontologically) orthogonal to radiation kinetic energy as entity: the former extends in space and progresses in time; the latter extends in time and progresses in space. Another way to view it is the joining of existence (matter) to occurrence (kinetic energy).

> *Note: Something physically real (energy is real) that is created by work done, that resides only in time and is unsupported by – and independent of – mass is a difficult concept for us because we are so oriented toward matter, space and existence. So much easier to make energy a formless property and attach it to matter. But of course this doesn't work for the photon where there is no matter to attach to, hence the assumption of two varieties of energy….*

While a material entity exists, a kinetic energy entity occurs (oscillates) and is observer-relative. Different inertial observers, all in relative motion one to another, have their own particular history of accumulated past work. On that basis they assign different kinetic energy entities (and energy magnitudes) to the same material object in motion. The kinetic energy entity joined to an object may be negated or transferred via dissipation or negative work done: the kinetic energy of the speeding car is removed/transferred by the work done by its brakes. The relativity of kinetic energy per observer and

[30] Radiation is the space transmission of waveform kinetic energy. Force acting over distance is: 1) the transfer of energy from stored (potential) to unstored (kinetic); and 2) the creation of the kinetic energy entity.

the ease with which it may be transferred is possible because kinetic energy is something that occurs and is created when stored energy is released or when work is done.

Tying kinetic energy to work done removes kinetic energy's supposed dependence on matter-simply-being-in-motion. Kinetic energy (as radiation energy entity) then has its own source/origin, its own ontological standing. And tying kinetic energy to oscillation gives kinetic energy a defined functionality and a presence in a dimension (time). Kinetic energy thereby becomes an occurring entity whose (wave) form gets added to the form matter possesses.

Takeaway: Kinetic energy is the transmission of past work done. Nature is subtle and symmetrical; she allowed for two pure entities, spaceform matter and waveform radiation, and then allowed them to join together to yield matter-in-motion combining both forms.

2.6 Kinetic Energy as an Entity: Metaphysical Speculation? –

Making the kinetic energy of a moving body into an entity may strike the reader as ungrounded speculation. There are two responses to that.

First, recall that our method of inquiry requires that mass and energy have parallel features; they must be ontologically symmetrical.[31] So if the matter side of reality has a space-residing entity which progresses in time, then the radiation side of reality should have a time-residing entity which progresses in space.

- **Just as existing mass entities occupy space and store releasable energy, so occurring energy entities occupy time and store releasable mass.**

Second, informed speculation is not a bad thing. Much of physics (and the philosophy of physics) consists of speculation, some of it fruitful some of it less so.

Speculative but fruitful (at least for a time) entities or constructs within physics are numerous. When first proposed (and later) they gave little hope of being measured directly. Examples include Newton's absolute space, Faraday's fields, the aether, Minkowski's spacetime, the positron and virtual

[31] For Einstein's extensive use of symmetry between matter and radiation see: P.A. Klevgard "*Einstein and the Formal Equivalence of Mass and Energy*," https://arxiv.org/abs/1412.2060 (2014).

particles. More recent speculative entities, where progress or validity seems dubious to some, include the wave function Ψ as a physical entity, strings and Hugh Everett's many-worlds. One of the more spectacular examples of entity speculation is quantum field theory, QFT.

For every known particle – photon, electron, up-quark, gluon, etc. – QFT posits a continuous field that fills the entire universe. These fields can neither be seen nor detected; our knowledge of them is limited to the mathematical equations describing these fields. It is these equations which in turn predict experimental results. Quantum field do not exist in space and time as ordinary objects do because they are in a quantum superposition of states. Energy of the right frequency produces a wave in the correct field which we detect as a particle; the exact mechanism for this is unclear. A quantum field somehow knows all the properties of the particle it must produce: particle mass, charge, spin, etc.

Takeaway: So physicists, not just philosophers, are fairly promiscuous in proposing entities that we cannot measure. Using the "no proof" argument against the kinetic energy entity misses the point; we have many constructs in physics for which we lack "proof."
Entities (and concepts like inertia) often can neither be proved nor disproved. We judge such entities on the basis of their utility (for explanation and prediction), their plausibility and their aesthetic appeal (does an entity complement a known entity or in other ways enhance conceptual or ontological symmetry). These three criteria are the standard for judging the energy entity.

2.7 Kinetic Energy as an Entity: The Argument –

"Kinetic" means "unstored" but it also entails motion. The kinetic energy associated with matter in force-free motion is not stored energy since that would make it potential; rather it is transmitted energy. Similarly, EM wave energy is also transmitted energy.

We have seen that the kinetic energy entity by itself (as work done) resides in time so it is orthogonal to entities that reside in space. Kinetic energy has a presence in space but only as an occurrence common there for all space observers. Because kinetic energy as an entity does not occupy space (its potential identity progresses there), physicists have assumed that kinetic energy itself lacks any physical presence; an occurrence residing in time (and not a "particle") is a foreign concept for particle physicists. Hence kinetic energy is treated as a mere quantity like volts or grams. This is the

typical human preference for tangible things that exist as opposed to intangible things that occur.[32] This is a preference for space over time, for matter over radiation. But it doesn't make sense that kinetic energy should be a mere quantity devoid of occurrence and be unrelated to de Broglie wave oscillation. The view that velocity is occurrence which constitutes energy should be reversed so that velocity is seen as a consequence of kinetic energy. Both velocity and kinetic energy require a source, an origin. The source for velocity is kinetic energy and the source for kinetic energy is either release of stored energy (e.g., photon creation from an atom) or work done (e.g., acceleration of an object/particle, charged or not charged).

- **The kinetic energy of motion is dependent upon past work done and velocity follows from that.**

- **Kinetic energy of motion is not a consequence of velocity.**[33]

- **The source of de Broglie wave oscillation is the kinetic energy entity created by the work done on the rest mass.**

Our current concept of the kinetic energy of motion as a property attached to matter is both simplistic and inadequate. This concept is a simplistic nineteenth-century assumption that work done upon a material object attaches itself to that object as a property. And this concept is inadequate because it leaves kinetic energy unrelated to de Broglie radiation and it gives us two varieties of kinetic energy.

When work is done on a material object the resulting kinetic energy has to reside somewhere; it has to occupy a dimension and therefore have a form if it is going to be a player that can interact as an

[32] Existence takes over physics: high energy physics becomes "particle physics;" forces are mediated by virtual particles; occurring EM radiation becomes the (existing) electromagnetic field of QFT; EM waveform quanta get a particle name (photon) and are treated as such. Much of this is driven by the limitations of mathematics: you can write equations involving space and time only for material entities (particles and fields) plus energy but the latter only as a quantity acting on something that exists.

[33] Textbooks (and the web) state that (kinetic) energy is a consequence of motion. But they also argue that motion is a consequence of work done on an object. Combining these two arguments, motion drops out and kinetic energy becomes a consequence (actually an entity with its own form) of work done. Giving up on motion as a main actor (viewing motion instead as a consequence) is not easy and it stands in the way of granting kinetic energy entity status and ontological equality with kinetic/unstored mass (matter).

equal with mass (matter) that has it own form. That dimension is time where oscillation can simply occur on it own as energy.

The kinetic energy of matter-in-motion then is a time-occurring, radiation entity just as mass is a space-existing, matter entity. This radiation-oscillation entity is joined with the mass entity but not as a subordinate property; rather it is the joining of two opposite entities, each with their own form and each as ontological valid as the other. This joining comes about through work done; there is nothing mysterious about it. The two orthogonal entities do not coexist in the literal sense of that word; one exists while the other occurs. But they do constitute a union that can only be undone by negative work.

To be clear, a matter entity (particle, object) residing in space (and progressing in time) is joined (via work done) to a work-created kinetic energy radiation entity occurring in time (and progressing in space). Each entity in this union has the same ontological status (validity) as the other, although one is usually the dominant partner in terms of form displayed (i.e., spaceform versus waveform). This runs counter to the current view which has kinetic energy as a dependent property of an entity.

- **Kinetic energy in general is an occurring entity. It is a constituent of physical reality in the time dimension just as matter is the same in the space dimension.**

- **Kinetic energy entails pure oscillation in the time dimension. Kinetic energy of matter-in-motion is not a property that has attached itself to an object.**

- **De Broglie wave oscillation and EM wave oscillation are both manifestations of kinetic energy as an oscillatory radiation entity created by work done or stored energy released.**

It makes sense that matter-in-motion – which possesses active energy, i.e., unstored, kinetic energy – should have one component in the time dimension, time being the natural home of occurrence just as space is the natural home of existence. But it is conceptually difficult for us to imagine oscillation without something space-residing (particle, field) and possibly material that fluctuates. That is where energy's potential identity comes in. It is the stored (potential) mass of kinetic energy that has a presence in space since it progresses, oscillates and possibly interferes there. But unlike matter which exists-resides in space and is delimited there, potential (stored) mass occurs-progresses in space, is continuous there and can expand/rarefy indefinitely. Potential (relativistic) mass is: 1) probabilistic as it progresses (not extends) in space; 2) capable of self-interference; and 3) capable of instant collapse

because it is the potential identity of pure (energy) occurrence oscillating in the time dimension with no rest mass involved.

Section 1.5 (Mach–Zehnder discussion) pointed out that a photon's potential identity fills all available space paths but the (stored mass) content of those paths gets retracted instantly at photon termination (reception). The same thing is true of a speeding electron undergoing diffraction. Its potential identity also follows all available space paths only to undergo instant retraction upon electron reception. EM radiation and de Broglie radiation are consistent with each other in this and other regards; both depend upon, embody the kinetic energy radiation entity.

We can conceptualize mass as pure existence (matter without kinetic energy). But our thinking has yet to evolve to where we can conceptualize energy as pure occurrence; instead we make energy into a property/quantity attached to matter-in-motion and we are stuck with no satisfactory explanation for de Broglie waves, for their oscillation or for their probabilistic character.

The kinetic energy of a moving object is an entity residing in time and common in space; hence we don't "see" it nor can we measure it directly with our material instruments. Its presence is felt in space via its potential identity of stored (relativistic) mass progressing on all available space paths. The kinetic energy (radiation) entity fulfills all the requirement of a physical entity as listed in Section 1.1. It has a quantitative measure, it has a presence in a dimension (in time where it oscillates) and it stores its opposite.[34]

- **The kinetic energy entity of matter-in-motion expresses itself as de Broglie radiation and its wave oscillation. The portion of this radiation that our instruments can detect (indirectly) is the entity's stored (relativistic) mass that governs probabilistic release (reception).**

So matter that is in motion is more complicated than classical physics assumed. We have inherited – from a simpler era without much questioning – the classical view of energy as a formless quantity that becomes a property of matter-in-motion. By keeping the concept of energy simple (i.e., simplistic) we have made the rest of physics complex. We have made energy physics disjointed and

[34] Can the kinetic energy entity be regarded as quantized? Oscillation cycles are inherently discrete in time so one can argue that de Broglie radiation is quantized just as EM radiation is quantized. But de Broglie radiation gets packetized and the packet (the effective energy) assumes values that are continuous and not discrete. So the kinetic energy entity has it both ways; discrete elements merging (superposing) to create something continuous.

asymmetric with mass physics: two types of radiation, two types of energy, the mystery of the double slit, etc. Matter-in-motion is a union of two entities and each entity has its own form, its own natural dimension to occupy/reside-in, plus a kinetic identity and a potential identity. The movement in space of the mass-based entity is entirely due to the energy-based entity; remove the latter entity (i.e., the work done) and the mass entity is motionless.

- **A rest mass entity moves because it is joined with the kinetic energy entity. The latter yields both oscillation and de Broglie waves of objective probability.**

- **Matter in motion gets its space extension (space occupying feature) from its mass-based entity; it gets its space movement from its radiation (kinetic energy) entity.**

The conservation of energy law is framed in terms of energy being a quantity, which it is. But quantitative laws do not preclude a quantity from also being an entity. Mass is a conserved quantity and it is also an entity as space-residing matter.

Kinetic energy, radiation, oscillation and probability waves are all linked together. We have seen (Section 2.3) that the oscillation of EM radiation is not the exchange of potential and kinetic energies as occurs in the classic harmonic oscillator. This is equally true for de Broglie oscillation. Radiation in general is always kinetic energy transmission. It does not cycle between stored and unstored energy; and as a time-residing entity it is ontologically distinct from space-residing rest mass.

Takeaway: Energy occurring has a physical presence in time just as mass existing has a physical presence in space; both reside in, occupy, intervals in their respective dimensions. A mass-free energy entity occurs (oscillates) in time just as an energy-free (inertial) mass entity exists in space. Matter-in-motion is the joining of these two entities via work done on an object. Matter-in-motion is then a blending of energy waveform with mass spaceform. Mass and its spaceform dominate the union except at the quantum level.

2.8 De Broglie Radiation and the Electron –

Radiation transmits work done at some location across space. Think of the work done to accelerate an electron in an electron microscope. This work (energy) manifests itself as the electron's de

Broglie wave radiation oscillation in time.[35] The electron as a rest mass particle is thus joined with the kinetic energy entity that work has created.

As the electron speeds through the microscope, its tiny rest mass entity is now dominated by the work-created kinetic energy entity and its oscillation. With two entities joined there are two kinetic identities present: rest mass and de Broglie oscillation. The potential identity of the latter is the electron's relativistic mass. This relativistic mass is important because it progresses (and rarefies) as a wave along space paths whereas the energy entity's oscillation (frequency) remains common and undiminished for all those paths; this is true of our electron just as it is true of the photon (Section 1.4 above).

Energy transmission proceeds via oscillatory radiation and its waveform. For matter-in-motion this involves de Broglie radiation; when matter is not involved one has EM radiation. The two are closely related as their common momentum formula indicates, $p = h/\lambda$.[36] Both have a kinetic oscillation identity extending (residing) in time (occurring cycles); and a potential identity progressing in space. Because of this, both are probabilistic and both function well in microscopes. A photon encountering a double slit and a speeding electron encountering a crystal lattice produce the same interaction, namely waveform self-interference. Each has a waveform potential identity of stored mass making them probabilistic. This potential identity (space-continuous relativistic mass) interferes with itself when passing through slits or lattices and produces wavy regions of maxima and minima probable reception. In both cases the wave exiting the slit or lattice is an actual wave of **objective probability** that can be modeled (for the electron) by the wave function Ψ.

There are some differences between de Broglie and electromagnetic oscillatory energy entities due to the fact that in one case the entity is joined with rest mass. De Broglie wave packets conform to the trajectory and the speed of the rest mass while EM quanta proceed at constant velocity for all observers and have no defined trajectory. Nevertheless, both constitute radiation either transmitting released energy (e.g., photon emission from an atom) or work done (e.g., accelerated particle) across space.

De Broglie radiation waves superpose to form a wave packet accompanying the particle. For a particle of very small momentum, such as an electron, the packet resembles a wave with a relatively long packet wavelength permitting imaging and also diffraction effects. It features incomplete wave reinforcement yielding uncertainty of the particle position (an elongated, diffuse packet). For larger

[35] During acceleration a pure EM energy wave is also generated.
[36] For the electron λ is the average de Broglie wavelength.

particles with larger momentum things go the other way: shorter wavelength, greater certainty of particle position and the packet comes to resemble a spaceform, not a waveform. For moving objects at the human scale the wave packet features complete wave reinforcement; the packet wraps the object tightly in space and the packet wavelength is much too small to allow diffraction.

We have seen (Section 1.5) that "which-way" experiments on photons disrupt a photon's probability wave (relativistic mass wave). This disruption eliminates the wave interference pattern. The same is true for electrons traversing adjacent paths in a crystal lattice. In this case there is a mixed entity traversing the lattice: the electron mass entity with its spaceform joined with the kinetic energy entity and its waveform. Placing an electron detector at one lattice exit will tell if the electron mass entity chose that path or not. Even if the electron does not register, that detector will block the probability wave from one lattice passage and thereby eliminate the electron interference pattern. In this case, unlike the photon (which is not a particle), we can truly say that wave measurements and particle measurements are mutually exclusive. So if we disrupt (i.e., measure) the location of the moving rest mass entity by blocking a space path, we have also disrupted the passage of kinetic energy's waveform potential mass.

Our instruments can only measure that which has a presence in space. As already noted, the kinetic energy entity resides (as oscillation) in time and our instruments cannot record it. Its only presence in space is its potential identity of stored, probabilistic mass. Our measure of the latter is necessarily indirect courtesy of its influence on a rest mass entity such as an electron. The waveform we attribute to the electron's rest mass is actually a consequence of a different entity, namely kinetic energy.

For matter in motion it is tempting to think of the rest mass entity as physically distinct from the accompanying kinetic energy radiation entity. One of these has mass residing in space and progressing over time as spaceform; the other has oscillation occurring/residing in time and progressing over space as waveform. But this conceptual separation – wave versus particle – may be deceiving; forms certainly blend into one another. For human-scale, moving bodies the rest mass entity dominates and so the oscillatory radiation entity assumes the spaceform (via intense wave reinforcement-superposition). At the quantum scale, it is oscillatory energy that dominates and it is the subordinate rest mass that possibly alters its form. Perhaps the tunneling electron has lost most of its particle nature allowing it as wave to go where particles can't.

Atomic scale particles display wave behavior when traversing a crystal lattice. Some physicists (de Broglie – Bohm) characterize this as the wave "guiding" the rest mass; others rely on superposition (particle replication) to explain electron diffraction. More likely the real answer is that the rest mass of a moving electron is so dominated (and altered?) by its joined kinetic energy entity that it really acts like a wave; no particle guiding is required.[37]

Section 2.6 lists three criteria for judging proposed physics entities: utility, plausibility and aesthetic appeal. Aesthetic appeal is surely a strong point for the kinetic energy entity. Matter and radiation – mass and energy – are now seen as ontologically equal and symmetrical in formal terms: residing and quantized in a dimension, progressing in a dimension, having kinetic and potential identities, etc.

As for utility, i.e., explanation and prediction, the verdict is perhaps mixed. No new predictions emerge but then none were sought or expected. On the other hand, explanation should rank very high providing the reader values theories that coalesce divergent phenomena: two energies treated as one; two radiations treated as one. While such unification is always a goal of science, it would be much easier for the reader if there were fewer new concepts to master and fewer traditional ideas and assumptions to overcome (reject). We are paying a heavy price for issues surrounding energy that were never addressed during the quantum revolution.

Takeaway: We now have a coherent explanation for the electron's unusual attributes: its dualism, its probabilistic nature, it tunneling ability and its relation to EM waves.

3.0 Our Concept of Radiation –

The concept of matter-in-motion as a joining of two distinct pure entities (quantized mass and quantized energy) with their two distinct forms has never been considered. Physicists have always assumed that entities only exist, they only reside in space (particles or fields) and energy is merely a formless quantity. But de Broglie's intuition about wave-particle duality and then Davisson and Germer's confirmation convinced physicists that moving bodies (particles) indeed had two forms, waveform and spaceform (for them the opposition was wave versus particle, see footnote #2).

[37] A separate wave guiding a separate particle is a model drawn from common experience (e.g., a cork bobbing on the ocean waters). One would expect Nature to be more subtle than that, especially at the quantum level.

Having a single entity possessing two opposite forms was a real paradox that defied explanation. It became common either to embrace the contradiction as a quasi-explanation and regard the problem as "solved" (Bohr) or to set it aside. This model of one entity with two forms has become so thoroughly embedded into consciousness and textbooks that one may despair of changing minds on this score. This model can't be disproved, it defies rational explanation and it is certainly well-received by physics mystics and by anti-realists.

Wave-particle duality has come to be seen as a fundamental principle; something like the postulates of special relativity. This has had some serious consequences. First, it convinced almost everyone – despite a lack of evidence – that the in-flight photon was a particle. And second, by comparing a pure entity (the photon) with a hybrid/mixed entity (moving electron) any chance of seeing the electron as a union of two entities – rest mass and kinetic energy – was lost. "Wave-particle duality" has become a mantra invoked when required and never questioned.

This model of matter-in-motion as one entity with two opposite, contradictory forms is a conceptual dead end as the last 100 years have demonstrated; no progress can be made on it, period. In contrast the model of a moving particle as a union of two distinct entities – each with its own form – by-passes the contradiction entirely and provides for particle behavior when mass dominates energy, and wave behavior for the reverse. This model explains why particle measurement precludes wave measurement and vice versa: you are actually measuring distinct entities that are joined together but are ontologically orthogonal (occupying space versus time, possessing waveform versus spaceform, existing versus occurring, etc.).

The taxonomy of entities in physics in these pages – 1) inertial mass as pure existing entity; 2) radiation as pure occurring entity; and 3) matter-in-motion as mixed entity – is the key to clarifying various major issues in physics. If you give up the simplistic idea of one entity having two contradictory forms, if you accept that entity mass with its spaceform and entity energy with its waveform (oscillation) can join together (usually unequally), then so many problems in physics disappear.

- **Quantum mechanics is that branch of physics that deals with hybrid/mixed entities. Because it is confined to mixed entities it has no special claim for embodying fundamental truths that apply universally. It is quite useless when applied to pure**

entities which have their own physical presence and their own ontological validity: no wave function for inertial, space-stationary mass; no wave function for the photon.

- **The merging of two forms for a quantal particle yields uncertainty. The precision of a wave measure is prevented by the presence of the mass entity and its spaceform. The precision of space location is prevented by the energy entity and its waveform. Uncertainty is ontic not epistemic; uncertainty results from blending existence (with its form) and occurrence (with its form) at the quantal level.**

- **Classical physics successfully deals with pure entities; it assumes that entities have the spaceform or the waveform, but not a blend of the two. Classical physics is unfairly maligned by expecting it to cover a region where it is not valid.[38]**

This model of a moving object combining two entities and their respective forms offers several conceptual and ontological advantages. It provides:

- **Formal unity for radiation:**
  - **Radiation now has a common ontological model. Radiation is a self-sufficient energy entity that can stand alone (EM radiation) or join with rest mass (de Broglie radiation). The radiation kinetic energy entity has a kinetic/unstored identity that resides (extends) in time and whose energy (oscillation) is common to all space paths. This entity also has a potential identity that progresses in space and whose stored (relativistic) mass: 1) disperses and rarifies on all available space paths; and 2) probabilistically determines its own release.**

- **Formal unity between radiation energy and matter as entities:**
  - **Matter and radiation are the two opposite ontological constituents of physical reality. A matter entity exists with the spaceform and progresses through time, while a radiation kinetic energy entity occurs with the waveform and progresses through space. Each entity stores its opposite: mass stores energy and radiation energy stores**

[38] Most anti-realist arguments treat mixed-entity (quantum) physics (imprecision, duality) as if it is "more fundamental" than classical physics. In truth, the two versions of physics (classical, quantum) are equally valid and apply to different entity configurations. Pure entities are not subject to inherent imprecision nor to dualism (the photon is a pure entity/wave, no dualism; see Section 1.3). Pure entity (classical) physics is successful with static matter (bulk stress and strain, thermodynamics) and arguably with large, slow moving matter; none of these phenomena exhibit dualism. It is also successful with EM radiation. That is, classical electrodynamics is perfectly valid for radiation above the level of charged quanta (i.e., above the level of electron charges at small distances and low field strengths where mass and energy entities are *mixed* and QED instead becomes valid). But saving realism and classical (pure entity) physics is an argument for another day. ***Side note***: The lack of distinguishing properties (individuality) for quantal objects has been regarded as significant. But if the electron is more waveform than spaceform, why ask for any property other than frequency? Wave cycles occur and don't have individuality; nor do they have distinguishing properties (including defined space location). We keep projecting our assumptions about existing objects down to the quantal (mixed entity) level and are surprised when they don't apply

(relativistic) mass. This gives each entity a potential identity that provides for probabilistic release of what it stores.[39]

- **Resolution of electron wave-particle duality:**
  - **Unlike the in-flight photon, the in-flight electron does have dual identities because matter-in-motion is always a union of rest mass entity with kinetic energy radiation entity, each with its own form. Depending upon the experiment, only one identity (form) is revealed leading to the assumption that a single entity has a dual nature. But dualism is not fundamental; the ontological union (via work done) of an existing entity with an occurring entity is fundamental.**

- **A separation of classical and quantal reality/physics based upon physical entities rather than size:[40]**
  - **Classical physics applies to pure or near-pure entities. Quantum physics applies to mixed entities. This explains: 1) the success each physics has in it own domain; and 2) why quantum (mixed entity) physics is probabilistic and not deterministic as is classical (pure entity) physics.**

- **Promotion of energy to its rightful place:**
  - **Energy is given formal, ontological equality with mass: both are quantized; both have a form and a dimensional presence; each stores the other; etc.**

3.1 The Inertia of Settled Opinion –

We have seen (Section 2.6) that physicists and philosophers of physics are, in general, willing to consider (sometimes advocate) speculative concepts not amenable to direct proof or disproof. John Archibald Wheeler is a prime example of a physicist who enjoyed playing with concepts that could never expect to receive laboratory verification: wormhole, quantum foam, It from Bit, etc. It was Wheeler's imprimatur (later rescinded) that elevated the many-worlds interpretation into general notice.

Someone smarter or more learned than this writer could probably categorize speculative ideas in the history of physics and explain what makes some ideas more successful (or popular) while others fail to gain an audience. There are probably a number of factors involved, but surely speculative (non-

[39] This (wordy, dense) paragraph encapsulates the challenges of viewing physics at the abstract level of ontology. A level where space and time become dimensions, inertial matter and the photon become pure entities, wave and spaceform (particle) become forms with a dimensional presence and the release of something stored (mass or energy) becomes crossover. Thank you for your patience…

[40] Non-classical physics applies for mixed entities where the energy entity is significant relative to the rest mass entity, e.g. the electron. But this can occur for very large objects as well, e.g. a spaceship approaching the speed of light relative to some observer (it suffers space contraction).

testable) ideas have an advantage if they are relatively simple to explain and if they don't require a person to give up any of the basic physics said person has learned over many years.

Surveys indicate that currently the two most popular interpretations of quantum mechanics (and the double slit experiment) are the Copenhagen theory and the many worlds theory. Of course both have their nuances, but to an outsider each may be summed up in a short paragraph or even a catch-phrase (complementarity, many-worlds). Besides that advantage, each constitutes a meta-theory that defines the relationship of the observer to reality and the nature of wave function collapse. Both are ad hoc theories[41] and neither of them undermine or reject the textbook physics taught at the undergraduate and graduate levels; hence the cost of admission to subscribe to the Copenhagen or many-worlds theory is relatively low.

Unfortunately, that is not the case for the ideas in these pages which challenge accepted concepts of energy and entity and are not ad hoc to specific problems in physics. Viewing the kinetic energy of EM radiation or of moving matter as an entity in the time dimension that progresses in the space dimension is a very big conceptual change in fundamental physics; it entails both learning the new and unlearning the old. And those new ideas are couched in the less familiar language of ontology requiring much more explanation than a single paragraph. Arguments herein are unfamiliar and too numerous to be absorbed by a mortal in a single reading.

Nevertheless, there is good news too; the basic assumptions of this inquiry are straightforward and easy to remember:

- **Mass and energy are truly equal: both are quantized entities that may appear on their own or join together.**

- **Their stored (potential) identities have a physical reality (dimensional presence).**

Modern physics has redefined space and time and mass. Energy's turn is long overdue. Of course if that redefinition was easy or obvious it would have been done long ago. The attempt at redefinition in these pages is far from perfect. It has its conceptual defects, its technical errors, its

[41] Both theories are directed at, a response to, a specific problem. And their proposed solution involves easy-to-comprehend ideas (dualism or worlds). They combine this with irrefutability. For Bohr dualism is a mystery we can never explain. For Everett multiple worlds can never interact or have any knowledge of each other.

exposition leaves much to be desired and it does not conform to the "rigorous and closely-argued"[42] style preferred by academics. Nevertheless, many of the ideas put forth in these pages merit a wider discussion and perhaps the reader can agree that unifying two types of energy into one and two types of radiation into one would be a good thing.

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[42] "Rigorous and closely-argued" are code words for a narrow monograph that makes small distinctions on a limited topic while citing all the relevant literature on that topic; hardly the proper (or practical) approach for an original reexamination of a very broad topic: the entities of physics and the nature of energy.

Appendix A

Formal Symmetry of Matter and Radiation

Inertial mass entity	Photon entity
• Quantized.	• Quantized.
• Discrete in space (particle).	• Discrete in time (cycle).
• Pure mass.	• Pure energy.
• Stationary in space.	• Stationary in time.
• Progresses in time.	• Progresses in space.
• Extends in space.	• Extends in time.
• Spaceform.	• Waveform.
• Stores energy.	• Stores mass.

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