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Hidden Variables: The Elementary Quantum of Light

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ABSTRACT

Re-examination of the work of Max Karl Planck has revealed hidden variables in his famous quantum work, consistent with Einstein's famous sentiment that quantum mechanics is incomplete due to the existence of "hidden variables". The recent discovery of these previously hidden variables, which have been missing from the foundational equations of quantum theory for more than one hundred years, has important implications for all the sciences as well as for understanding the interactions of electromagnetic radiation with matter.

Planck's quantum formula, E = hν, is missing the variable for measurement time. Planck had included the missing time variable in his earlier electromagnetic work, but omitted it in his famous work that sparked the quantum revolution. Restoration of measurement time to Planck's quantum formula produces the more complete, $E = \tilde{h}\, \nu\, t$. The numerical value Planck calculated for his action constant "h" takes on new meaning as an *energy* constant "$\tilde{h}$" for light. Planck's energy constant is the mean energy of a single oscillation of light, namely 6.626 X 10^{-34} J/oscillation. The mean oscillation energy of light is *constant*, and does not vary with frequency or wavelength. The photon, as historically defined, is a time dependent packet of energy, based on the arbitrary measurement time of one second. An arbitrary, one second increment of energy cannot be a truly indivisible and elementary particle of nature.

Omission of the time variable from Planck's quantum formula contributed to numerous paradoxes in quantum mechanics, such as uncertainty relating to formulations involving time, wave-particle duality, the need for normalization of wave functions, lack of dimensions for the fine structure constant, and irreconcilability of quantum mechanics and general relativity (Einstein's gravitational theory). Many of these paradoxes are simplified or eliminated altogether with a re-interpretation of quantum mechanics with Planck's hidden time variable and *energy* constant.

Keywords: Planck, Hidden variable, Light, Time, Photon

1. INTRODUCTION

There is an elementary quantum of light. It is *not* the photon. Max Karl Planck glimpsed the elementary quantum of light briefly, but did not recognize it. So for more than one hundred years, the elementary quantum of light has remained hidden in the dusty pages of history.

To understand how this could be, one must look back in time to Berlin in the 1890's. Planck was a Professor of theoretical physics at the University of Berlin and focused much of his work on his favorite subject - the irreversibility of entropy (the natural increase of disorder that occurs in the absence of work). While Planck was busy trying to establish a comprehensive mathematical foundation for irreversible processes, many other new and exciting discoveries were being made. Heinrich Hertz had succeeded, for the first time in history, in transmitting and receiving Maxwell's "*mysterious electromagnetic waves*", and had published both his experimental successes as well as his electromagnetic theories. Planck embraced Hertz's "*resonant oscillations*" whole-heartedly, and began developing additional theories on electromagnetic (EM) waves[1,2]. Planck then used his own electromagnetic theories in an attempt to prove the

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irreversibility of entropy. When Planck presented his first work on this subject at a large scientific meeting in 1897, however, Ludwig Boltzmann loudly and publicly criticized his conclusion. Planck had failed to consider certain effects of time said Boltzmann, and had thus failed to prove the irreversibility of an increase in entropy. Planck was forced to admit that Boltzmann was correct, and that time was a stumbling block to his proof of the irreversibility of entropy. Planck turned next to the black-body radiation experiments as a way to prove entropy's irreversibility.

Black-body radiation is the light emitted by a theoretical "black-body" or perfect light absorber (e.g. a black object). Scientists were trying to find a formula to describe changes to the wavelengths of light emitted by a black-body object, as a function of its temperature. Black-body radiation devices were the super-colliders of their time, and Planck had ready access to the experimental data generated from the device located at the PTR (physics experimental institute) in Berlin. The device had an inner chamber lined with the natural black-body material graphite and a second outer chamber which could be filled with either ice or steam. After the graphite chamber reached equilibrium at either 0° C (273° K) or 100° C (373° K), a window in the chamber was opened, allowing the black-body radiation (that had been spontaneously emitted by the graphite) to leave the chamber and to be measured as a function of time. The intensity of various wavelengths could then be obtained to determine the distribution of energy at various wavelengths and at a given temperature.

Among the many equations that had been suggested for black-body radiation, Planck was attracted to Wien's law, which coincidentally eliminated time as a variable. Planck built on his earlier electromagnetic theories and developed an early version of his quantum relationship. He set internal energy ("E") proportional to the product of a generic constant ("a"), the frequency ("ν"), and the measurement time ("t_m"):

$$E \approx a \nu t_m \tag{1}$$

He then used Wien's mathematical methods of converting the experimental time-based energy measurements (ergs/second) to energy density values (ergs/cm^3), eliminating the variable for measurement time in the process. Planck wrote four (4) theoretical papers on black-body radiation and the irreversibililty of entropy, using Wien's law as the basis.[3] By early 1900, Planck used his combined entropy/electromagnetic theory to publish a proof of Wien's law.[4] Interestingly, Planck's "proof" of Wien's law also contained a derivation and calculation for what later came to be known as Planck's constant "h".

In September 1900, Planck received a new set of black-body measurements from a PTR colleague, Ferdinand Kurlbaum who had visited the Planck's for Sunday dinner. Experimental measurements had been extended down into the infrared region. Wien's law was wrong. Worse yet, Planck had just published a "proof" of Wien's law. After his guest left, Planck played with the numbers until he found a new equation that fit the data much better than Wien's equation. Planck sent the new equation to Kurlbaum the next Monday, and Planck was elated to learn that his new equation fit the new data perfectly. When Planck presented his new black-body equation at a meeting of the German Physical Society the next month, there were no loud critics.[5] His next challenge was to find a proper derivation for his empirical formula, and as Planck later recalled, *"The explanation of the... radiation law was not so easy."*[6]

After *"some weeks of the most strenuous work of my life"*, Planck completed a formal derivation for his new radiation law. He abandoned the wave theory for light, opting instead for a particle-like treatment of light. He also found it necessary to use the statistical approach championed by his nemesis Boltzmann, as well as Boltzmann's idea that energy can be divided into small amounts.[†] Planck developed Boltzmann's energy suggestion into his Quantum Hypothesis, i.e., the idea that energy is quantized into small *equal* amounts.

Planck's 1901, formal paper[7] on this topic introduced his famous quantum formula:

$$E = h \nu \tag{2}$$

where Planck's proportionality constant "h" is equal to 6.626 X 10^{-34} J sec. This fundamental formula is the foundational basis for all of quantum theory. Interestingly, Planck simply *assumed* this formula as a given, and did not

[†] "I see no reason why energy shouldn't also be regarded as divided atomically." L. Boltzmann, 1891, Cited from Flamm, D., "Ludwig Boltzmann – A Pioneer of Modern Physics", arXiv:physics/9710007 v1 7 Oct 1997.

derive or prove it. His arbitrary quantum formula yielded a proportionality constant ("h") equal to the product of energy and time, which Planck referred to as the ultimate "*quantum of action*".[‡]

Historically, Planck's paper was a *tour de force* of nineteenth century physics. He described: 1) the black-body radiation law; 2) the quantum hypothesis; and 3) Planck's constant "h". He also calculated two *more* fundamental constants, "Boltzmann's constant, k_B", for the energy of a single molecule at different temperatures, and Avogadro's number, the number of molecules per mole. Although some in the physics community were slow to comprehend Planck's monumental achievement, a young Swiss patent clerk named Einstein quickly grasped the implications of Planck's incredible feat.

In 1905 Albert Einstein published his remarkable paper on the production and transformation of light, better known as the photoelectric effect[8]. Einstein first noted that "*it is quite conceivable…that the [wave] theory of light…leads to contradictions when applied to the phenomena of emission and transformation of light*". He proposed that the interactions of light and matter "*appear more readily understood if one assumes that the energy of light is discontinuously distributed in space [in particles]*". Thus, Einstein asserted, the paradox of broadly spread out waves somehow interacting with small particles of matter disappeared. When light and matter were both thought of as small particles or quanta, their interactions followed from the rules of mechanics. Einstein began his derivations by deriving the mean energy of a single oscillation of an electron,[§] e.g., a particle of matter. He then proposed a mathematical basis for his light particles, weaving together the mathematics of his light particles with the electron (matter) mathematics. Finally, he used his new light particle hypothesis and quantum mathematics to explain various interactions between light and matter including the photoelectric effect[**] and the ionization of gases[††].

Although Einstein's light-quanta proposal was slow to gain acceptance, his successful use of Planck's quantum hypothesis to explain the photoelectric effect encouraged others to adopt Planck's work. Neils Bohr, for example, while rejecting Einstein's light-quanta hypothesis, embraced Planck's quantum formula and used Planck's proportionality constant "h" in his famous theory of the hydrogen atom. Arthur Compton's 1923 paper declaring that "*the scattering of X-rays is a quantum phenomenon*", settled the debate in Einstein's favor. A few years later the term "photon" was coined for Einstein's particles of light, and the photon came to be regarded as an elementary particle of nature defined by Planck's quantum formula, $E = h\nu$. Unlike other elementary particles defined by a constant value (such as the electron and its uniform charge) the photon was paradoxically defined by an energy value that is infinitely variable (Fig. 1).

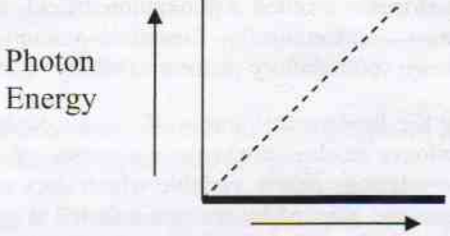

Figure 1. Direct relationship between photon energy and frequency, according to Planck's quantum formula, $E = h\nu$.

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‡ The Principle of Least Action - Nature opposes any needless expenditure of energy, and natural motions proceed along the path of shortest distance, briefest time, and minimal energy. $S = \int T - V\,dt$, where S is the action (energy • time), T is kinetic energy, V is potential energy, and t is time. Or simply, $S = \Delta E \Delta t$ (e.g., Joule seconds).

§ $\bar{E} = RT/N$, where $\bar{E}$ = mean energy of electron oscillatory motion, R = universal gas constant, T = absolute temperature, and N = Avogadro's number. Ibid 7.

** "*The simplest conception is that a light quantum transfers its entire energy to a single electron…*" Ibid 7.

†† "*We have to assume that, in ionization of a gas by ultraviolet light, one energy quantum of light serves to ionize one gas molecule.*" Ibid 7.

As frequency increases, so too does photon energy. The idea "*that light has a very large number of elementary constituents, one for each frequency*" – is an oddity that has caused countless hours of consternation for scientists the world over.[9]

After Planck and Einstein introduced their quantum concepts many questions and paradoxes arose. For example, experimental observations indicated that light behaved as both a wave and a particle. In 1922, Louis-Victor de Broglie proposed that light waves possess momentum (just like particles), and that particles are "waves" with measurable wavelengths (just like light). A few years later, in 1925, Werner Heisenberg developed matrix mechanics for particles, which was the first formal mathematical description for quantum mechanics. The next year, Erwin Schrödinger published his famous equation on wave mechanics, and after another year showed mathematically that his wave approach and Heisenberg's photon matrices were equivalent. Both struggled with the need for integral numbers in quantum mechanics.

A revolution in quantum mechanics had begun. Meeting in Copenhagen in 1927, Bohr and Heisenberg developed the Copenhagen Interpretation, which became the "standard" interpretation of quantum mechanics. Bohr proposed his Complementarity Principle, postulating that light had a wave-particle duality, and that either a wave aspect of light could be measured, or a particle (photon) aspect could be measured, but not both at the same time. Heisenberg proposed his Uncertainty Principle suggesting that there is always uncertainty in the measurement and determination of any two paired and complementary quantities, such as momentum and position, or energy and time, e.g., $\Delta E \cdot \Delta t \geq h$. A mysterious dimensionless constant - the fine structure constant - was discovered, and it defied all explanation.[‡‡] Paradoxes multiplied like rabbits and as Einstein later wrote:[10]

> *"But what is light really? Is it a wave or a shower of photons? There seems no likelihood for forming a consistent description of the phenomena of light by a choice of only one of the two languages. It seems as though we must use sometimes the one theory and sometimes the other, while at times we may use either. We are faced with a new kind of difficulty. We have two contradictory pictures of reality; separately neither of them fully explains the phenomena of light, but together they do."*

The concepts embodied by the Copenhagen Interpretation evolved into the Standard Model of Particle Physics, and the paradoxes evolved as well. For example, the Standard Model can explain most forces associated with light and matter, however it cannot explain gravity. This is a significant issue since gravity is a fundamental aspect of our reality. By 1916, Einstein had developed his general theory of relativity and gravity, relying primarily on mechanical features of matter such as mass and velocity, without relying on quantum features such as frequency or Planck's action constant. Einstein assumed that only the mass and energy of matter excited a gravitational field, and that together gravity and matter satisfied the law of conservation of energy. Unfortunately, Einstein's attempts to unify his quantum and gravitational theories were unsuccessful, and *two more* contradictory pictures of reality resulted.

Many attempts have been made to unify the fundamental forces of nature, explaining both gravitational and quantum features of matter. Invariably more paradoxes resulted. Heisenberg's matrix mechanics can unify gravity and quantum mechanics only with the addition of a mysterious matrix variable which does not correspond to any known aspect of reality. Similarly, quantum gravity theories are plagued by an issue referred to as the "Problem of Time", i.e., there seems to be a missing time factor. Solutions include a "two-time-physics" which attempts to resolve the Problem of Time by adding another time dimension to the quantum equations.[11]

Both Planck and Einstein were deeply troubled by the paradoxes and uncertainties that their quantum work had spawned. Einstein voiced his concerns formally in 1935, in his famous "EPR" paper, proposing that quantum mechanics is incomplete because it does not provide a theoretical element corresponding to each element of reality.[12] He suggested that "hidden variables" are responsible for this incomplete state of affairs. In the 1950's David Bohm further

‡‡ The fine-structure constant *"has been a mystery every since it was discovered more than fifty years ago, and all good theoretical physicists put this number up on their wall and worry about it. Immediately you would like to know where this number for a coupling comes from: is it related to pi or perhaps to the base of natural logarithms? Nobody knows. It's one of the greatest damn mysteries of physics: a magic number that comes to us with no understanding by man"* Feynman, R. [QED. The Strange Theory of Light and Matter], Princeton Univ. Press, 129, (1988).

championed the idea that quantum mechanics is incomplete due to hidden variables, and numerous physicists since then have expressed their similar dissatisfaction with quantum physics.

Recent research has revealed the identities of some of the hidden variables hypothesized by Einstein.[13-15] In the course of performing some experimental work related to light, Einstein's concept for considering the mean energy of a single oscillation (of an electron) was used. Rather than calculating the energy for a single *electron* oscillation, however, the mean energy of a single oscillation of *light* was calculated instead. Calculations of mean light oscillation energy at various photon energies were performed, anticipating that high energy photons would possess higher oscillation energies than low energy photons. The startling result, however, was the finding that the mean oscillation energy for light is *constant*. Equally startling was the finding that the *numerical value,* of light's constant mean oscillation energy, is equal to the numerical value of Planck's action constant "h". The question immediately arose - had Planck's action constant been misinterpreted so long ago? Was it really an *energy* constant? If true, then a time variable was missing from Planck's quantum formula.

An extensive foray into the historical records provided answers in the affirmative. Planck's constant is an *energy* constant, and not an action constant. As for the missing time variable, it had been present in earlier versions of Planck's quantum relationship but he omitted it from his black-body derivation. Planck probably did this for what he thought were sound reasons at the time, but which in hindsight, led to needless paradoxes and misinterpretations.

Upon restoration to Planck's quantum formula, the hidden time variable suggests a far richer interpretation of quantum mechanics. Modeling an elementary quantum of light represented by an invariant and universal energy constant – the mean oscillation energy – banishes many of the uncertainties and paradoxes of earlier quantum mechanics.

2. DERIVATIONS AND CALCULATIONS

§ 1. Derivation of the Mean Energy of a Single Oscillation of Electromagnetic Energy

Start with the mathematical relationships from Planck's quantum formula for photon energy, "$E = h\nu$", where "$\nu = N\ t^{-1}$", and "N" is the total number of oscillations measured per unit time. To obtain the mean energy per oscillation ("$\bar{E}$"), divide mean photon energy ("E_N") by the number of waves "N" comprising the photon:

$$\bar{E} = \frac{E_N}{N\ osc} = \frac{h\nu}{N\ osc} = \frac{(6.626 \times 10^{-34}\ J\ sec)\ (N\ sec^{-1})}{N\ osc} = 6.626 \times 10^{-34}\ J/osc \qquad (3)$$

The mean energy for a single oscillation or wave of light is *numerically equal* to the value of Planck's proportionality constant "h" (and can be alternatively represented as "$\bar{h}$").

§ 2. Mean Oscillation Energy is Constant and Independent of Frequency

Consider three different frequencies $\nu_{1\text{-}3}$, such that:

$$\nu_1 << \nu_2 << \nu_3$$

$$\nu_1 = 1 \times 10^3\ sec^{-1}\ (Radio); \qquad \nu_2 = 2 \times 10^9\ sec^{-1}\ (MW); \qquad \nu_3 = 3 \times 10^{15}\ sec^{-1}\ (UV). \qquad (4)$$

Next, obtain the mean photon energy at each frequency $\nu_{1\text{-}3}$ according to Eq. 2 above:

$$E_1 = 6.626 \times 10^{-31}\ J \qquad E_2 = 1.325 \times 10^{-24}\ J \qquad E_3 = 1.988 \times 10^{-18}\ J \qquad (5)$$

The photon energies are all different and are directly proportional to the frequency for each photon (i.e. proportional to the number "N" oscillations of electromagnetic energy in 1 second, comprising each photon). Next, to determine the mean energy of a *single* oscillation in each photon, one must divide the mean photon energy by the number of oscillations in that photon:

$$
\begin{aligned}
E_{osc1} &= 6.626 \text{ X } 10^{-31}\text{ J} / 1 \text{ X } 10^{3}\text{ osc} = 6.626 \text{ X } 10^{-34}\text{ J / osc} \\
E_{osc2} &= 1.325 \text{ X } 10^{-24}\text{ J} / 2 \text{ X } 10^{9}\text{ osc} = 6.626 \text{ X } 10^{-34}\text{ J / osc} \\
E_{osc3} &= 1.988 \text{ X } 10^{-18}\text{ J} / 3 \text{ X } 10^{15}\text{ osc} = 6.626 \text{ X } 10^{-34}\text{ J / osc}
\end{aligned} \quad (6)
$$

The mean energy of a single wave of light is the same for all three frequencies $\nu_{1\text{-}3}$, namely $6.626 \text{ X } 10^{-34}$ J/osc. Performing the same calculations for wavelength, it becomes clear that the mean energy of a single wavelength of light is also $6.626 \text{ X } 10^{-34}$ J for all three different wavelengths $\lambda_{1\text{-}3}$. The mean oscillation energy of light is *constant*, and does not vary with frequency or wavelength.

§ 3. The Photon

Substituting mean oscillation energy, "$\tilde{h}$", for the action constant in Planck's quantum formula:

$$\tilde{h}\,\nu = E_N / t \quad (7)$$

produces an energy rate. To obtain total energy one must multiply the energy rate by the period of time during which the energy is measured (measurement time, "t_m"):

$$E_N = \tilde{h}\ \nu\ t_m \quad (8)$$

This expanded quantum formula can be compared with the traditional condensed quantum formula. Set measurement time equal to a value of "one second":

$$E_N = \tilde{h}\ \nu \cdot 1 \text{ sec} = (6.626 \text{ X } 10^{-34}\text{ J})\, N = h\,\nu \quad (9)$$

A one second measurement time yields the familiar photon energy value of classical quantum mechanics. Referring to Equation 9, above, it can be seen that:

$$h = \tilde{h}\ t_m \quad \text{when} \quad t_m = 1 \text{ sec} \quad (10)$$

One second time intervals are arbitrary, however, so consider measurement times of differing durations such as three (3.0) seconds or one-half (0.5) second, for light with the frequency, "ν", of "N oscillations per second:

$$E_{N3.0} = \tilde{h}\ \nu \cdot 3.0 \text{ sec} = (1.988 \text{ X } 10^{-33}\text{ J})\ N \quad (11)$$

$$E_{N0.5} = \tilde{h}\ \nu \cdot 0.5 \text{ sec} = (3.313 \text{ X } 10^{-34}\text{ J})\ N \quad (12)$$

When measurement time equals some value other than "one second", the photon energies are different, even though the frequency is the same. A longer measurement time measures more oscillations, resulting in greater total energy. When the measurement time equals a numerical value of "one", the photon energies of traditional quantum mechanics are obtained. The photon, as historically defined, is a time dependent packet of energy, based on the arbitrary measurement time of one second.

An arbitrary, *one second* increment of energy cannot be a truly indivisible and elementary particle of nature.

3. THE HISTORICAL RECORD

The true brilliance of Planck was in suggesting that energy is quantized in small *equal* amounts, and in calculating the numerical value - $6.626 \text{ X } 10^{-34}$ J - for that quantum of energy. As Planck commented to Paul Ehrenfest, "*Now it seems to me not completely impossible that there is a bridge from this assumption (of the existence of an* *elementary quantum of electric charge e) to the existence of an elementary quantum of energy*".[16] Interestingly, it seems that although Planck conceptualized his constant as an *energy* constant, he formulated it as an *action* constant. Planck's publications leading up to his famous black-body and quantum formula paper, reveal important clues as to why he formulated the numerical value of "h" as an action constant rather than an actual *energy* constant.

In the years just prior to his black-body derivation, Planck published a series of papers on his electromagnetic theory, in relation to the irreversibility of an increase in entropy. In those papers, one finds an earlier version of his quantum relationship:[3]

$$\text{``}\ \frac{dS}{dt} \cdot dt = \frac{1}{a\,\nu}\,\frac{dU}{dt} \cdot \log \frac{U}{b\,\nu}\ \text{''} \tag{13}$$

where "U" is internal energy, and which simplifies to the equivalence:

$$dU \approx a\ \nu\ dt \tag{14}$$

Clearly Planck was familiar with the mathematical relationship described in Eq. 8 above, $E_N = \bar{h}\ \nu\ t_m$.

This was the same work, however, which caused Boltzmann to publicly criticize Planck for his inappropriate assumptions related to time and electromagnetic radiation. Planck turned to the methods of Wien and the black-body radiation puzzle to achieve his goal of establishing the mathematical foundations for entropy. He combined his previous electromagnetic work with Wien's method for converting the experimental, time-dependent energy measurements into energy densities. This resulted in data that was thus independent of time. This approach may have been especially appealing to Planck, as it eliminated the source of Boltzman's earlier criticisms. It also allowed Planck to derive a "proof" of Wien's black-body radiation law, relying heavily on formulations related to entropy and its irreversibility.

Unfortunately, Wien's equation and Planck's derivation were incorrect. Planck later admitted in his famous black-body paper:[7]

"... the law of energy distribution in the normal spectrum, first derived by W. Wien from molecular-kinetic considerations and later by me from the theory of electromagnetic radiation, is not valid generally."

Although his derivation of Wien's equation from his theory of electromagnetic radiation was not generally valid, Planck used his theory once again to derive his new black-body equation:[7]

'In any case the theory requires a correction, and I shall attempt in the following to accomplish this on the basis of the theory of electromagnetic radiation which I developed."

Not surprisingly, Planck found that his black-body derivation required a somewhat arbitrary approach, as well as a certain willingness to overlook simple, practical details:[5]

"You will find many points in the treatment to be presented arbitrary and complicated, but as I said a moment ago I do not want to pay attention to a proof of the necessity and the simple, practical details. "

Turning now to Planck's mathematical assumptions, one finds in the preamble to his derivation:[7]

"§1. ... we shall refer to the average energy U of a single resonator. Then to the total energy

$U_N = NU$ *[Planck's] Equation 1."*

Planck began his black-body derivation assuming that the energy of a vibrating molecule (i.e., a resonator) was *independent* of time, consistent with the mathematical methods of the failed Wien equation. To determine whether this was an appropriate assumption, one could examine the actual laboratory measurements Planck used to calculate his constants "h" and "k". Looking near the end of his famous paper one sees that the actual laboratory measurements Planck used were quite clearly *dependent* on time. Planck cited the measurements of Ferdinand Kurlbaum (his dinner guest of that fateful Sunday). Kurlbaum reported his measurements as ergs/second per square centimeter:[7]

> *"§11. The values of both universal constants h and k may be calculated rather precisely with the aid of available measurement. F. Kurlbaum, designating the total energy radiating into air from 1 sq cm of a black body at temperature t° C* *in 1 sec* *by S_t found that:*
>
> $$S_{100} - S_0 = 0.0731 \ \underline{watt}/cm^2 = 7.31 \times 105 \ \underline{erg/cm^2} \ \underline{sec}"$$ *(Underlines added)*

If the experimental data was dependent on time, how could Planck begin his black-body derivation assuming that resonator energy was independent of time? It appears that Planck made this mathematical assumption in reliance on Wien's mathematical procedure. Ordinarily, if one wished to convert this time-based measurement into an absolute energy value, one would multiply ergs/(cm² second) by the measurement time in seconds, obtaining ergs/cm². In other words, energy per unit time (power), multiplied by the variable for measurement time, equals energy. Using a measurement time of one second, the average and total energy could then be introduced as Planck's Equation 1., recognizing that the derivation was premised on the assumption of one second measurement intervals. That would have meant however, that Planck had not eluded the foibles of time, which he knew were fatal to his quest to prove the irreversibility of an increase in entropy.

Planck used Wien's mathematical procedure instead, and converted the time dependent experimental energy measurements into values for energy density. Planck had seemingly escaped the clutches of time by using Wien's procedure:[7]

> *"From this one can obtain the energy density of the total radiation energy in air at the absolute temperature*
>
> $$\frac{4 \cdot 7.31 \times 10^5}{3 \times 10^{10} \ (373^4 - 273^4)"} = 7.061 \times 10^{-15} \ erg/cm^3 \ deg^4$$

But did Planck really avoid time? Or did Wien's procedure merely provide an illusion of timelessness ? This point is worth pondering in some further detail. Wien's mathematical method for eliminating time was to divide the time-based experimental energy data by the constant "c", the speed of light. The units for time cancelled out and a simple energy value was left. Now on its surface this procedure may seem harmless in itself, and even quite acceptable. There was one small problem however. Dividing by the speed of light (3×10^{10} cm/second) is essentially the same thing as multiplying by "1 second/3×10^{10} cm". Setting aside the distance portion of the constant, look closely at the time portion (1 second). Wien and Planck multiplied energy per unit time by a one second time interval, essentially setting what should have been a variable measurement time, at a constant value of one second.

The derivation was never premised on the assumption of one second measurement intervals, however. The fact that Wien's procedure substituted the measurement time variable, with a constant and fixed value for time, was never recognized. The time *variable* in Planck's original quantum relationship, $dU \approx a \, v \, dt$, thus became unknowingly *fixed* at a constant value of "one second", and was omitted from the black-body formulations. When Planck calculated his proportionality constant, the hidden measurement time variable became condensed with his original constant "*a*" into a single product, the action constant "h". The inherent fixed value of the time variable hidden in Planck's action constant "h", became one second. That is why Planck's *energy* constant was formulated as an *action* constant, i.e., the product of energy and time.

Without a separate variable for measurement time, Planck's quantum relationship became condensed as well. Instead of the more complete, $E = \bar{h} \, v \, t_m$, Planck made the mathematical *assumption* that the quantum formula was simply, E = hv. It was the only way he could derive the black-body equation using Wien's method. The unpalatable alternative was to assume a fixed value for measurement time, spoiling his efforts to prove the irreversibililty of increased entropy. The variable for measurement time was thus relegated to an implicit and fixed value of "one second", becoming one of Einstein's hidden variables.

The contradictory assumptions in Planck's black-body work about energy and time did not go unnoticed by his peers, including Debye:[17]

> *"Planck's Law is verified entirely by experience; and yet the derivation has a weak spot, to the extent that the basic assumptions of both parts on which the proof of the law of radiation is constructed differ from one another. Namely, on the one hand, as is generally known, a connection is established between the average energy of the resonator, using a formulation that is completely determined by its dependence on its momentum and its rate of change [in time] ... But then for the second part of the proof, the pioneering assumption of the existence of elementary energy quanta is made, which nevertheless is in no way connected to the energy description of the resonator which is assumed in the first part; indeed, it virtually contradicts the latter."*

Likewise, at the first Solvay Congress in Brussels a year later Poincare cautioned:[18]

> *"On the other hand, it struck me in the discussion we have just heard to see the same theory sometimes applying to the principles of the old mechanics, sometimes to the new hypotheses which negate them; we should not forget that any proposition can be easily proved if you allow two contradictory premises to enter into the proof as well."*

Neither Debye nor Poincare noted that Wien's procedure, for converting the time-based black-body energy measurements into energy densities, resulted in the unseen measurement time variable being fixed at a value of one second. Without a clear alternative, Planck's incomplete quantum formula was adopted as the basis of quantum mechanics.

4. DISCUSSION

Planck's famous black-body radiation work sparked the entire quantum revolution. It appears, however, that his quantum formula was incomplete, and that in the absence a clear recognition that the formula assumes a one second measurement time, early quantum concepts were obscured and limited, affecting the subsequent development of quantum mechanics.

It is tempting to conjecture as to why Planck adopted Wien's procedure and the particular assumptions that he did. Planck was certainly familiar with the expanded form of his quantum formula that included time as a separate variable, having used that relationship in his earlier papers. Boltzmann's harsh critique may have predisposed Planck to avoid time altogether in his black-body derivation and his quest to prove the irreversibility of an increase in entropy. An accepted mathematical approach such as Wien's, that did away with the dependence of energy on time, could have been very appealing.

Planck may have also realized that his original quantum relationship would have defined his proportionality constant as energy per oscillation (or wave). Significantly, the wave and particle theories for light were thought at that time to be mutually exclusive, and an understanding of wave-particle duality did not yet exist. Light was believed to be a wave, and matter to be a particle. Planck found it necessary to break with prevailing beliefs, and model light as a particle in order to use Boltzmann's statistical methods. It is easy to imagine that he may have wished to avoid introducing even more contradictions in his derivation by using wave-related nomenclature to describe an energy constant for particles of light. Little supposition is required to understand that Planck's peers would have viewed such a construct as nonsense. It is not surprising therefore that Planck avoided the use of wave or oscillation nomenclature in his quantum formula and determination of "h", because to do otherwise would have contradicted the very premise upon which his derivation was based.

Unbound by such restrictions, one can now consider concepts that would have seemed quixotic a century ago. It has been shown that if one logically extends Einstein's model for the energy of an electron's single oscillation, to the energy of a single electromagnetic oscillation, hidden meaning is revealed in Planck's work. Planck actually found the *energy* constant for light, and not an action constant. Planck's energy constant is the mean energy of a single oscillation or wave of light, 6.626×10^{-34} J/osc. This value is constant and does not change with the frequency or wavelength of the light. A light wave one meter long possesses the same amount of energy as a light wave one nanometer long. Light waves do not come in high energy and low energy varieties, as photons do.

Although the photon has long been held to be the elementary quantum of light, that understanding must be re-examined. It appears to have arisen from limitations in Planck's abbreviated quantum formula. The hidden time variable in Planck's condensed quantum formula was fixed at a value of one second. The photon was subsequently interpreted as a packet of light, with its energy defined by Planck's quantum formula, $E = h\nu$. Use of this condensed quantum formula to calculate photon energies, inadvertently defined the photon as an increment of light of one second's duration. The photon energies to which we are all accustomed, are thus the amount of energy in a one second measurement of light, regardless of the light's frequency or wavelength. The unsatisfying result of this definition was a fundamental particle of light whose energy was infinitely variable. Dissatisfaction with prior interpretations of the "photon" as an indivisible and elementary quantum of light appear to have been well-founded. An arbitrary, one second measurement of energy cannot be a truly indivisible and elementary particle of nature.

What is the elementary particle of light then? Planck hypothesized that the electron was associated with "*an elementary quantum of electric charge e*", and suggested that light was associated with "*an elementary quantum of energy*". Accordingly, the single electromagnetic wave or oscillation is the true elementary particle of light, defined by its "*elementary quantum of energy*", the mean oscillation energy. Consider further the fact that the energy of a single oscillation of light is constant regardless of it frequency or length, i.e., it is conserved over time and space. This too suggests that Planck's *energy* quantum, invariant under a shift in time or space, is the true elementary particle of light. Just as the electron is an elementary particle with its fundamental unit of charge, the single electromagnetic oscillation appears to be an elementary particle with its fundamental unit of energy.

Einstein voiced his dissatisfaction with quantum mechanics in his epic EPR paper asserting that quantum mechanics "*... does not provide a complete description of the physical reality*". He suggested that hidden variables were at the root of the problem. Attempts to test Einstein's hypothesis – both pro and con - invariably utilized Planck's incomplete quantum formula. It is axiomatic that an incomplete foundational equation cannot provide for a complete theory. Planck's complete quantum relationship does much to satisfy Einstein's desire for an element of reality corresponding to each mathematical element of quantum mechanics and to resolve many of its paradoxes.

As noted by David Bohm, "*the physical interpretation of the quantum theory centers around the uncertainty principle*".[19] Changes in energy and time are uncertain to the extent that their product must always be greater than or equal to Planck's constant, $\Delta E\ \Delta t \geq h$. Replacing the condensed constant "h", with the product expansion "$\tilde{h}\ t_m$" one discovers the relationship, $\Delta E\ \Delta t \geq \tilde{h}\ t_m$. Setting Δt and t_m equal to the time period of a single oscillation, one learns that, $\Delta E \geq \tilde{h}$. A change in energy related to light can never be smaller than the energy of a single wave of light. Similarly, a change in time related to light can never be smaller than its time period. When Heisenberg introduced his famous uncertainty principle in 1927, he remarked on the idea that a hidden reality might exist outside the boundaries of our experimental data, in which quantum systems have definite values and are unaffected by uncertainty relations.[20] The previously hidden time variable seems to be just such a hidden reality. It was inevitable that with the time variable hidden and its value unknowingly fixed, calculations of quantities involving *time* would yield uncertain results. Heisenberg's uncertainty principle takes on vastly different meaning with an understanding of the measurement time variable and Planck's energy constant.

The wave equation developed by Schrödinger was also affected by the missing time variable.[21] Schrödinger used Planck's condensed action constant "h", unknowingly adopting its fixed measurement time of one second. He attempted to replace the quantum conditions by a variation problem, using the Hamilton function for Keplerian motion. Schrödinger found that the variation problem had both "*a discrete and a continuous spectrum of proper values [and] the discrete spectrum corresponds to the Balmer terms and the continuous to the energies of the hyperbolic orbits*". Schrödinger struggled with the quantum rules requiring "whole numbers" and posited that he had traced the matter a step further back, and "*found the integralness to have its origin in the finiteness and single-valuedness of a certain space function.*" In his addendum, he noted the need for "the *normalizing, accessory condition,* $\int \psi^2 d\tau = 1$ *[where] d*τ *[is] the volume element of the space...The proper values of this variation problem ... yield, according to our thesis, the quantum levels of the energy.*" The fixed measurement time of one second inherent in Planck's action constant required whole number and necessitated Schrödinger's normalization procedure.

One of the great challenges that eluded Einstein was the development of a unified field theory, uniting all the forces of nature under one cohesive theoretical framework. His attempts to unify his quantum theories with his gravitational theory of general relativity must have been impacted by the missing time variable in Planck's foundational quantum formula. It is telling that both matrix mechanics and two-time physics address the irreconcilability of quantum mechanics and general relativity by using additional variables. It is reasonable to suggest that the additional variables function as proxies for the hidden time variable. It would be interesting to analyze the added nonspecific matrix variable in Heisenberg's matrix mechanics, to determine if it does indeed correspond to the hidden time variable. For two-time physics, the correspondence is self evident. With restoration of the hidden time variable, a realistic unified field theory may be quickly attainable.

Another of the quantum paradoxes - the mystery of the dimensionless fine structure constant - becomes far less paradoxical upon use of Planck's *energy* constant in quantum mechanics. Substituting the energy constant for the action constant in quantum formulations, reveals that the fine structure constant is not dimensionless. It possesses the dimensions of "osc · time". Historically, nomenclature for oscillations has not used, and thus "oscillation" was missing from the fine structure constant dimensions. The time variable was hidden as well, giving the fine structure constant the *appearance* of being dimensionless, even though it was not. Understanding that the fine structure constant has dimensions of "osc · time" one can determine the action of light: the product of the energy constant (energy/osc) and the fine structure constant (osc · time), provides the action of light (energy · time) in a one second measurement time.

Another paradox, the wave-particle duality of light addressed by Bohr in his complementarity principle, also surrenders to greater clarity. The photon, which was previously believed to be a "particle" of light, is now seen to be merely the light one second's measurement time. The artificiality of such a construct for a "particle" becomes self-evident. In its place there is the single oscillation of light as the elementary quantum and particle of light. The wave-particle duality of light suddenly becomes much less problematic. The fundamental particle of light is the single wave. And the single wave of light *is* light's fundamental particle. Wave-particle duality seems much less a conundrum when considered from this perspective. The wave and the particle of light are not simply dual, they are identical. Further, while beyond the scope of this paper, the actual three dimensional shape of light, as suggested first by Einstein and later by Schrödinger, sheds additional light on this subject, eliminating virtually all paradox.[22]

Apart from the rich theoretical implications attached to this re-discovery of Planck's complete quantum formula and his *energy* constant, there are many practical applications for this new understanding as well. Twentieth century technology was deeply affected by the interpretation of Planck's condensed quantum formula and constant. Quantum chemists of long ago, unaware of the hidden, fixed value allotted to the hidden time variable, concluded that the total energy of a "photon" had to be equal to or greater than molecular bond energy. Only "photons" in the visible and ultraviolet regions satisfied this criterion, and so infra-red, microwave and radio waves were excluded from study in photochemistry. The lower frequency electromagnetic waves were deemed to be purely thermal processes. Re-discovering Planck however, one realizes that the photon energies used by chemists did not necessarily correspond to a realistic element of chemical reality, but rather to an arbitrary measurement time. Molecules are not necessarily restricted to interactions with light of one second's duration. Freed from the earlier misunderstanding of an incomplete formulation, it is now possible to develop more realistic models for the decades of unexplained experimental phenomena related to the production and transformation of light, and the effects of electromagnetic energy and fields.[23-28]

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7. REFERENCES

[1] Planck, M., "Absorption und Emission electrischer Wellen durch Resonanz", Ann. der Phys. und Chem., 293(1), 1-14 (1896).

[2] Planck, M., "Ueber electrische Schwingungen welche durch Resonanz erregt und durch Strahlung gedämpft warden", Ann. der Phys. und Chem., 296 (4), 577-599 (1897).

[3] Planck, M., "Ueber irreversible Strahlungsvorgänge", Ann. Phys., 306(1), 69-122 (1900).

[4] Planck, M., "Entropie und temperatur strahlender Wärme", Ann. Dr Phys., 306(4), 719 (1900).

[5] Planck, M., "On the Theory of the Energy Distribution Law of the Normal Spectrum", Verh. Deut. Phys. Ges., 2, 237-245 (1900).

[6] Planck, M., "The Genesis and Present State of Development of the Quantum Theory", 1920 Nobel Lectures, Physics 1901-1921, Elsevier Publishing Company, Amsterdam (1967).

[7] Planck, M., "On the Law of Distribution of Energy in the Normal Spectrum", Annalen der Physik, 4, 553 (1901).

[8] Einstein, A., "On a Heuristic Point of View Concerning the Production and Transformation of Light", Annalen der Physik, 17, 132-148 (1905).

[9] Mardari, G., "What is a photon? The Nature of Light: What Are Photons?" SPIE, 6664, 66640X-1–66640X-9 (2007).

[10] Einstein, A., and Infeld, L., [The Evolution of Physics], Siimon and Schuster Inc., New York , 262-263, (1938).

[11] Bars, I., "Survey of Two-Time Physics", Classical and Quantum Gravity, 18, 3113-3130, (2001).

[12] Einstein, A., Podolsky, B. and Rosen, N., "Can a Quantum-Mechanical Description of Physical Reality be Considered Complete?", Physical Review, 47, 777-780 (1935).

[13] Brooks, J., "Hidden Variables: The Elementary Quantum of Light", 2009 Spring Meeting of the American Physical Society NES, Boston, MA, May 8 (2009).

[14] Brooks, J., "Einstein's Hidden Variables: Part A – The Elementary Quantum of Light and Quantum Chemistry", *In Press,* Materials Science and Technology 2009 Conference Proceedings, Pittsburgh, PA, October 25-29 (2009).

[15] Brooks, J., "Einstein's Hidden Variables: Part B – The Resonance Factor", *In Press,* Materials Science and Technology 2009 Conference Proceedings, Pittsburgh, PA, October 25-29 (2009).

[16] Planck, M., to Ehrenfest, P., 6 July 1905, Cited in Klein, M., "Thermodynamics and Quanta in Planck's Work", Physics Today, 19, 23-32 (1966).

[17] Debye, P., "Der Wars. in der Theorie der Strahlung", Ann d. Phys, 33, 1427-1434 (1910).

[18] Langevin, P., and de Broglie, L. (Eds.), [La Theorie du Rayonnement et les Quanta] *Rapports et discussions de la reunion tenue a Bruxelles, du 30 Octobre au 3 November, 1911,* M.E. Solvay, Paris : Gauthier-Villars, 451 (1912).

[19] Bohm, D., "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables", Phys Rev, 85(2), 166-179 (1952).

[20] Heisenberg, W., "Ueber den anschaulichen Inhalt der quantentheoretischen Kinematik and Mechanik' Zeitschrift für Physik, 43, 172-198 (1927).

[21] Schrödinger, E., [Collected Papers on Wave Mechanics], "Quantization as a Problem of Proper Values (Part I)", Chelsea Publ. Co., New York, 1-12 (1982).

[22] Brooks, J, "Hidden Variables: Part II – The Distribution of Light", submitted to Annalen der Physik, April 11 (2009).

[23] Brooks, J., and Blum, B., "Spectral Chemistry", U.S. Patent Appl. No. 10/203797 (2002).

[24] Blum, B., Brooks, J., and Mortenson, M., "Methods for controlling crystal growth, crystallization, structures and phases in materials and systems", U.S. Patent Appl. No. 10/508,462 (2003).

[25] Brooks, J., and Abel, A., "Methods for using resonant acoustic and/or resonant acousto-EM energy", U.S. Patent No. 7,165,451, Issued January 23 (2007).

[26] Roy, R., Rao, M. L., and Kanzius, J., "Observations of polarised RF radiation catalysis of dissociation of H_2O-NaCl solutions", Mat. Res. Innovations, 12(1), 3-6 (2008).

[27] Roy, R. et al., "Decrystallizing solid crystalline titania, without melting, using microwave magnetic fields', J. Amer. Ceram. Soc., 88(6), 1640-42 (2005).

[28] Roy, R., et al., "Definitive experimental evidence for Microwave Effects: Radically new effects of separated E and H fields, such as decrystallization of oxides in seconds", Mat. Res. Innovat., 6, 128-140 (2002).