A Significant Question in Quantum Foundations

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Abstract. Is the formalism of quantum mechanics complete? Examination of Max Karl Planck's original quantum work suggests the answer is "***No***".[1-3] Retrospective analysis of Planck's foundational quantum derivation suggests that his action constant ("h") is actually the ***product*** of an energy constant ("h̃") and a time variable (t_m"). Planck's ground-breaking quantum formula, "$E = h\nu$" (E is energy and ν is frequency) may more appropriately be denoted as, "$E = \tilde{h} t_m \nu$". The energy constant represents the energy of a single oscillation or wave of electromagnetic (EM) energy, and is constant regardless of frequency, wavelength or photon energy. The time variable (as originally defined by Planck) is the measurement time of the electromagnetic energy. The invariance of the EM energy constant over a change in time or space suggests it represents a universal constant for light. Retrospective evaluation also reveals that Planck inadvertently fixed the EM measurement time (t_m) at a value of one (1) second, thereby significantly limiting the time variable's degrees of freedom. Implications appear to be profound for restoring infinite degrees of freedom to the EM measurement time variable. Quantum re-interpretation using the energy constant and measurement time variable suggest conservation of energy, momentum and mass for a single oscillation of light. A deeper layer of foundations in physics may yet need to be built.

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IN PLANCK'S OWN WORDS

In the late 1890's Max Karl Planck was a young professor in the physics department at the University of Berlin. He was fascinated by Hertz's recent use of resonant electrical processes to prove the existence of Maxwell's theoretical electromagnetic waves.[4] Planck began developing a complete theory of electromagnetism to explain both the resonant, non-entropic aspects of electromagnetic oscillations, as well as the thermal, entropic aspects. Titles of his papers included, *"Absorption and Emission of Electrical Waves via Resonance"*, *"Notice on the Theory of Electrical Oscillation Damping"*, and *"On Electrical Oscillations, Which via Resonance are Energized and via Emission Become Damped"*. Planck's mathematical framework relied on some basic relationships:

$$dt_m \bullet \frac{dU}{dt} = U$$

$$\frac{dS}{dt} \bullet dt_m = \frac{1}{a\,\nu} \frac{dU}{dt} \bullet \log \frac{U}{b\,\nu}$$

(where t is time, U is energy, S is entropy, v is frequency, and a and b are constants), producing a quantum rrelationship:

$$dU \approx a\, dt_m\, \nu.$$

In 1897, Planck presented his electromagnetic entropy theory for the first time. Ludwig Boltzman roundly criticized Planck conclusions on the basis that Planck had not taken time into consideration. Thereafter, Planck adopted the mathematical methods of Wilhelm Wien, who eliminated time as a variable by converting the experimental time-based energy measurements to energy density, by dividing by the constant speed of light. In early 1900, Planck published his derivation of Wien's black-body law and the ignominy of Boltzman's earlier criticism was seemingly erased.

Just a few months later, however, new experimental data declared the Wien black-body law wrong, and Planck was once more facing professional embarrassment. One autumn weekend he played with Wien's original equation and deductively found a modification which fit all the experimental data.[5] "*I have been able to derive deductively an expression for the entropy of a monochromatically vibrating resonator and thus for the energy distribution…"*. For the next few weeks Planck worked furiously to derive his empiric black-body equation from first principles,[6] and in the process found it necessary to *assume* a shortened version of his original quantum relationship, namely the familiar "E = hv". He was able to do this only by converting the time-based experimental energy measurements to energy density values:[6]

"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:

$$S_{100} - S_0 = 0.0731\ \underline{watt}/cm^2 = 7.31 \times 10^5\ \underline{erg}/cm^2\ \underline{sec}$$

…. From this one can obtain the energy density of the total radiation energy in air at the absolute temperature

$$\frac{4 \bullet 7.31 \times 10^5}{3 \times 10^{10} (373^4 - 273^4)\text{"}} = 7.061 \times 10^{-15}\ erg/cm^3\ deg^4$$

Time was seemingly eliminated and Planck had finally obtained success by deriving the correct black-body radiation formula. But did he really eliminate time from the time-based energy measurements? Typically, one would multiply a time-based energy measurement by the measurement time, to obtain the total energy [$(dU/dt)dt_m = U$]. Planck however, divided by the speed of light, $3X10^{10}$ cm/sec. Arithmetically, dividing by a quotient such as the speed of light, is equivalent to multiplying by its inverse, 1 sec/$3x10^{10}$ cm:

$$\frac{E}{t} \times \frac{1\ sec}{3x10^{10}\ cm} \qquad (1)$$

Planck multiplied the time-based energy measurement by the constant one second of the speed of light, and what should have been an infinitely variable measurement time became fixed at one second, "$t_m \equiv 1$ sec". In addition, due to the cancellation of time units the measurement time variable was hidden as well. Restoring the measurement time variable in accordance with Planck's original quantum formula, "$dU \approx a\ dt_m v$", restores infinite degrees of freedom to the time variable.

Solving for Planck's generic constant "a", reveals it to be an energy constant. Specifically, the energy constant is the energy of a single oscillation of EM energy:

$$a = E / (dt_m\ v) = 6.626 \times 10^{-34} \text{ Joules/oscillation} \qquad (2)$$

A BALANCING ACT

The units in Planck's shorter version of the quantum formula, ($E = hv$), did not balance, i.e. Joules ≠ (Joule seconds) (oscillations/second). A few decades after Planck presented this abbreviated quantum relationship to the world, the official nomenclature of cycles per second was abandoned in favor of mathematically incomplete nomenclature for EM frequency. The designation seconds^{-1} was adopted, thereby allowing the units of the quantum formula to balance.

Use of incomplete nomenclature for frequency however, is akin to denoting speed as hours^{-1}, rather than as miles or kilometers per hour. It results in the unnecessary creation of a great deal of uncertainty and the need for additional compensatory values. With dimensional analysis and complete mathematical notation, it is clear that Planck's generic constant "*a*" is the energy of a single oscillation of EM energy, "$\tilde{h}$", with the value of 6.626×10^{-34} J/osc.

This is, in fact, more in line with Planck's original concepts, "*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.*"[7] (underline added) Likewise, the EM energy constant is consistent with De Broglie's quantum concepts as well, "*"...we have returned to statements on energy as fundamental and ceased to question why action plays a large role ... Yet it is impossib[le] to consider an isolated quantity of energy"*.[8] It was this very lack of an energy quantum that frustrated De Broglie's efforts to determine a constant and conserved value for the mass of light.

EINSTEIN, ELECTRONS AND WAVES

Few contemporary scientists appreciate that Einstein's original quantum work was based on the energy of a single oscillation, namely an electron oscillation:

$$\text{“}\bar{E} = \frac{R}{N_A} T$$

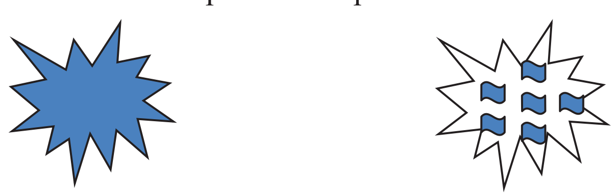
Where $\bar{E}$ is the average energy of a single oscillation of an electron, R is the gas constant, N_A is the number of real molecules in a gram equivalent, and T is absolute temperature.”[9]

Applying Einstein's model for the average energy of a single electron oscillation to EM waves, one finds complete alignment with Planck's original quantum relationship, $E = \tilde{h} t_m \nu$, and the EM energy constant, $\tilde{h}$. Assessing oscillation energy using either of Planck's quantum formulae, one finds that the energy of a single EM oscillation is constant regardless of frequency, wavelength or photon energy. Take "$E = h\nu$", where $\nu = 1 \text{ sec}^{-1}$. Solving for energy per oscillation, one finds $E/osc = 6.626 \times 10^{-34}$ J/osc. There are no high energy or low energy oscillations. The higher the frequency of a "*photon*", the greater the number of equal-energy oscillations are counted in a one second time interval.

SOME STARTLING IMPLICATIONS

Mathematically, these facts are demonstrated by simple arithmetic and are beyond dispute. *"The question now is the interpretation!"*[10] By logically following the simple arithmetic one uncovers some startling new insights:

- Planck's action constant "h", is the product of an energy constant "$\tilde{h}$" and the measurement time variable "t_m", where $h = \tilde{h}\, t_m$ and $t_m \equiv 1$ second.
- The complete quantum formula is $E = \tilde{h}\, t_m\, \nu$.
- Mean EM oscillation energy is constant regardless of frequency or wavelength.
- Oscillation energy is invariant under a shift in time or space and is conserved.
- The photon was conceptualized as an EM energy packet: $E = h\nu$, with measurement time unknowingly set equal to one second.
- Planck's complete quantum formula, $E = \tilde{h} t_m \nu$, suggests that a conserved sub-photonic particle, namely a single EM oscillation, is the fundamental particle of light, and that the classical photon is a packet of fundamental light particles.



(a) (b)

FIGURE 1. Classical photon model (a), as free-standing energy packet using Planck's abbreviated and assumed quantum formula, vs. (b) updated photon model using Planck's expanded and derived quantum formula and EM energy constant for a single EM oscillation.

- Using Heisenberg's uncertainty principle, one finds $\Delta E\ \Delta t \geq h \geq \tilde{h}\, t_{m,}$ and $\Delta E \geq \tilde{h}$. A change in EM energy can never be smaller than the energy of a single EM oscillation.
- Schrödinger's wave equation uses Planck's action product "h", "*the integralness [of quantum mechanics has] its origin in the finiteness and single-valuedness of a certain space function… [The] normalizing, accessory condition,*$\int \psi^2 d\tau = 1$ *[where] dτ [is] the volume element of the space …[whose] proper values [yield] … the quantum levels of the energy."* Schrödinger's normalization procedure was made necessary by the fixed "one second" measurement time.[11]
- According to Bohr, the *"well known dilemma between the corpuscular and undulatory character of light and matter is avoidable only by means of the view point of complementarity… experiences gained under different experimental conditions cannot be summarised in any one picture"*[12] New insights suggest complementarity is an artifact of the hidden time variable and EM energy constant.
- Fine structure constant: Using the energy constant, "$\tilde{h}$", in place of the action constant "h", reveals dimensionality for the fine structure constant "α", of α = osc · time, suggesting the fine structure constant is a coupling constant for time and EM oscillations.
- General Relativity and Gravity: Heisenberg's matrix mechanics add an unspecified matrix variable to reconcile with Einstein's gravitational theory. Two time theories add a time dimension. New insights suggest that the added variables compensate for the missing time variable and energy constant.

CONCLUSION

Examination of Max Karl Planck's original quantum work suggests that the formalism of quantum mechanics was not complete. Retrospective analysis of Planck's foundational quantum derivation suggests that his action constant ("h") is actually the ***product*** of an EM energy constant ("$\tilde{h}$") and a time variable (t_m"), and that the full quantum formula is , "$E = \tilde{h} t_m \nu$".

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