Rethinking the Photon: A Power-Based Model of Electromagnetic Radiation

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Abstract

The historical formulation of Planck's energy equation, $E = hf$, arose from blackbody radiation experiments that measured power as a function of frequency. These experiments recorded spectral intensity (W/m^2/Hz), not discrete photon events. In this paper, Planck's relation is re-examined through the lens of *Modified Unit Analysis* (MUA), in which frequency retains its dimensional form [cycles/second]. Within this framework, Planck's constant h no longer carries units of action (J s), but instead takes on the units [s/cycle × W], representing the power of a single wave period—analogous to a power cycle in AC electronics. This leads naturally to the relation $P = fh$, where power varies directly with frequency. Integrating over a measurement interval t yields $E = hft$, the total energy radiated during that time. The conventional expression $E = hf$ thus corresponds to the energy emitted in a one second time interval, not the energy of a single photon. Within this approach, the photoelectric effect is reinterpreted as a resonance between the wave's per-cycle power and the electron's binding power; Compton scattering arises from a continuous redistribution of wave power and momentum; and blackbody radiation emerges from the interplay between per-cycle power transfer and the density of available oscillatory modes in thermal equilibrium. This reinstates light as a continuous oscillatory phenomenon within a medium, where energy exchange occurs through power thresholds and resonant interactions rather than particle collisions. The reinterpretation of Planck's constant as a scaling factor of wave power bridges the conceptual gap between classical and quantum physics, suggesting that apparent quantization may arise from resonance geometry within a continuous field. This framework offers a unified, mechanically consistent, and physically intuitive description of electromagnetic phenomena that reconnects quantum behavior to its classical wave foundations.

1 Introduction

The blackbody experiments that gave rise to Planck's radiation law measured *power density* as a function of frequency. The data were expressed as spectral intensity, $I(f)$, with units of W/m^2/Hz. When Max Planck analyzed these results in 1900, he introduced the relation $E = hf$ as a mathematical device to fit the observed curve, associating frequency f with discrete energy elements of size hf. At that time, Planck did not claim that light itself was quantized. Rather, the quantization applied to the microscopic oscillators within the walls of the cavity.

Later, Einstein extended this concept to the photoelectric effect, interpreting $E = hf$ as the energy of a discrete light quantum or "photon". While this view became central to quantum mechanics, it obscured the original experimental context: blackbody radiation was measured as a *continuous power spectrum*, not as a count of photons. This suggests that Planck's constant may be more naturally interpreted as a proportionality constant linking power and frequency, rather than energy and frequency.

The present work revisits Planck's relation using *Modified Unit Analysis* (MUA), a dimensional framework that explicitly preserves the cyclic nature of wave phenomena. By restoring the dimensionality of "cycles," we find that Planck's constant can be reinterpreted as the power of one wave period, bridging the classical wave model of light with the quantum relationship between frequency and power.

2 Reformulating Planck's Relation in MUA

In conventional dimensional analysis, frequency is expressed as [1/s], effectively treating "cycles" as dimensionless. In MUA, frequency retains its full form:

$$[f] = [\text{cycles/second}] = \left[\frac{\Delta}{s}\right]$$

Accordingly, Planck's constant h must carry units that, when multiplied by frequency, yield power:

$$P = fh.$$

To satisfy dimensional consistency, the units of this equation are as follows:

$$P = fh \left[\frac{\Delta}{s}\right] \left[\frac{s}{\Delta} W\right] = [W]$$

where the first term in square brackets are the units for frequency and the second term are the units for the proportionality constant, h. Thus, in the above formalism, the units of h are:

$$h \left[\frac{s}{\Delta} W\right]$$

where $[s/\Delta]$ corresponds to the time period of one wave. The units of this constant interprets as the power OF one wave period. An extended unit analysis of the power equation maps out as follows:

$$P = fh \left[\frac{\Delta}{s}\right] \left[\frac{s}{\Delta} W\right] = \left[\frac{\Delta}{s}\right] \left[\frac{s}{\Delta}\frac{J}{s}\right] = \left[\frac{\Delta}{s}\right] \left[\frac{J}{\Delta}\right] = \left[\frac{J}{s}\right] = [W]$$

This mapping of units is rich with information that conceptually connects this equation to the power equation associated with electronic systems, $P = IV$ with units [C/s J/C]. In this context, Planck's constant, h, corresponds to the power OF one wave period and/or the energy per cycle analogous to the power cycle in electronic systems. Integrating over an arbitrary time interval t yields the total emitted energy in said time inerval:

$$E = Pt = hft.$$

For $t = 1$ second, this reduces to the familiar form $E = hf$. Under this interpretation, the conventional expression represents the energy emitted in one second of continuous radiation, rather than the energy of a single photon.

3 Implications for the Origin of the Photon Concept

Historically, the concept of the photon arose from Einstein's 1905 interpretation of the photoelectric effect, in which he proposed that light consists of discrete quanta of energy, each of magnitude $E = hf$. This idea followed directly from Planck's earlier formulation of blackbody radiation, in which the constant h entered as a proportionality factor between energy and frequency. Yet, it is important to note that Planck himself did not propose light quanta; he viewed his quantization as a mathematical device applied to resonant oscillators in matter, not as a physical discontinuity in the electromagnetic field.

If Planck had instead expressed his relation in terms of power,

$$P = fh,$$

the conceptual foundation of quantum theory might have evolved very differently. In this formulation, h represents a per-cycle power constant—analogous to a fixed "voltage" in an alternating-current system—while the frequency f determines the number of oscillations (or power cycles) per second. The product $P = fh$ therefore expresses a continuous rate of energy transfer, not a discrete packet of energy.

Within this framework, the quantized appearance of light–matter interactions arises naturally from the threshold behavior of matter rather than from any intrinsic granularity of light itself. When the per-cycle power of the incident electromagnetic wave exceeds the binding power of the electrons in the material, emission occurs. The process is inherently continuous in the field but discrete in the material's response—just as an electrical diode conducts only when the instantaneous voltage surpasses its barrier potential.

Had this interpretation been adopted at the beginning of the twentieth century, it is unlikely that the notion of the photon as a fundamental particle of light would have emerged. The photoelectric effect would have been understood as a resonance phenomenon: a continuous power flow from an oscillating field into a discrete electronic system with a well-defined threshold. The apparent quantization would then be recognized as a property of wave–matter coupling, not of the field itself.

This power-based view also restores conceptual continuity between classical electromagnetism and modern field theory. In quantum electrodynamics, what we now call a "photon" is already interpreted as a quantized excitation mode of a continuous field, not a literal particle. The relation $P = fh$ anticipates this understanding by emphasizing the continuous nature of the field and the cyclic character of its interactions.

In retrospect, Planck's use of energy rather than power inadvertently steered physics toward a particle-based interpretation of light. By expressing the same relationship in its rate form, the power equation provides a more conventional, wave-centric interpretation that preserves all experimental observations while avoiding the conceptual difficulties associated with light quanta. The photon thus becomes unnecessary as a fundamental entity, replaced by a continuous electromagnetic process whose interactions are governed by power thresholds and resonance conditions.

4 Discussion

This dimensional reinterpretation restores the continuity inherent in the original blackbody measurements. The relation $P = fh$ parallels the electrical power equation $P = IV$, where current I represents a rate (charges per second) and voltage V represents an energy per charge. In the same way, frequency f represents cycles per second, while h represents the power associated with one wave period and/or the energy per cycle:

$$\begin{array}{lll} \text{Electrical system:} & P = IV & [\mathrm{W}] = [\mathrm{C/s}]\,[\mathrm{J/C}] \\ \text{Wave system:} & P = fh & [\mathrm{W}] = [\Delta/s]\,[J/\Delta]. \end{array}$$

The structural analogy is exact. In both systems, a rate term multiplied by a per-event quantity yields power.

From this perspective, the photon concept becomes unnecessary as a fundamental entity. Instead, light can be modeled as a continuous oscillation in a physical medium, where power is distributed across frequencies according to Planck's spectral law. Quantization then reflects the *discrete nature of oscillation cycles*, not of energy packets.

5 Reinterpreting the Photoelectric Effect Without Photons

One of the strongest historical arguments for the quantization of light was the photoelectric effect. Classical wave theory, as it was framed at the time, could not explain why light below a certain frequency failed to eject electrons, regardless of intensity, nor why emission occurred without measurable delay. Einstein resolved these puzzles by introducing the concept of the photon, a discrete energy packet of size $E = hf$. In the present framework, however, these same experimental results follow directly from the continuous-wave relation $P = fh$, without the need for photons.

In this view, the electromagnetic field delivers power continuously to the surface electrons of a metal. Each oscillation of the field carries a characteristic power per cycle h, so that the total power delivered by a monochromatic wave is proportional to its frequency:

$$P = fh.$$

The electrons in the metal are bound by a restoring force that can be characterized by a binding power P_{bind}. This represents the rate at which the lattice potential can absorb or oppose energy transfer from the external field. When the per-cycle power of the incident radiation is less than this binding power, i.e.

$$hf < P_{\text{bind}},$$

the electromagnetic field cannot impart enough instantaneous power during each oscillation to overcome the binding force. The electrons simply oscillate in place with the field, and no emission occurs.

As the frequency increases, the per-cycle power hf grows linearly until it exceeds the binding power threshold at

$$f_{\text{th}} = \frac{P_{\text{bind}}}{h}.$$

Beyond this threshold, the field delivers sufficient power within a single oscillation to dislodge an electron from the metal. Because this process depends on instantaneous power rather than accumulated energy, emission occurs without measurable time delay, consistent with experimental observations.

The dependence on frequency, rather than intensity, also follows naturally. Increasing the intensity of sub-threshold light only increases the amplitude of oscillation, not the per-cycle power delivered to each electron. No amount of amplitude can compensate for insufficient per-cycle power, just as increasing current in a sub-threshold AC signal cannot overcome a diode's voltage barrier. Only an increase in frequency, which raises hf, can cross the threshold and result in electron emission.

Once an electron is released, any excess power above the binding threshold appears as kinetic power of the ejected electron:

$$P_{\text{kinetic}} = h(f - f_{\text{th}}).$$

Over a one-second observation interval, the corresponding kinetic energy is

$$E_{\text{kinetic}} = h(f - f_{\text{th}}),$$

which is numerically identical to Einstein's photoelectric relation $E_k = hf - \Phi$, but is here derived from a continuous power transfer process rather than discrete photon absorption.

This power-based interpretation preserves all observed characteristics of the photoelectric effect:

1. A threshold frequency arises because hf must exceed the metal's binding power.
2. Emission is independent of intensity below the threshold.
3. Electron release is instantaneous once the threshold is crossed.
4. The kinetic energy of emitted electrons increases linearly with frequency.

The analogy with electrical power further clarifies this process. In an AC circuit, current flows through a diode only when the instantaneous voltage exceeds its barrier potential. Similarly, the electromagnetic wave interacts with the electronic binding potential; only when the per-cycle power surpasses the threshold can current (in this case, emitted electrons) flow.

Thus, the photoelectric effect can be fully described as a resonance and threshold phenomenon of a continuous electromagnetic field acting within a material medium. The quantization observed experimentally reflects the discrete nature of oscillation cycles and binding thresholds, not the existence of light quanta. The relation $P = fh$ therefore provides a continuous, power-based account of the photoelectric effect that eliminates the need for the photon concept while remaining consistent with all known experimental results.

This continuous, power-based explanation of the photoelectric effect not only reproduces all observed experimental outcomes but also challenges the historical reasoning that led to the photon concept itself. If the relation between frequency and radiation had been originally expressed in terms of power rather than energy, the subsequent interpretation of light as composed of discrete quanta might never have arisen. This possibility invites a deeper reconsideration of the origins of the photon idea and its necessity within electromagnetic theory.

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7 Continuous-Wave Interpretation of Compton Scattering

Compton's 1923 experiments on X-ray scattering from electrons are traditionally regarded as decisive evidence for the particle nature of light. The observed wavelength shift,

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta),$$

is commonly explained by invoking photon–electron collisions, in which a photon of energy $E_i = hf_i$ transfers part of its energy to an electron, emerging at a lower frequency f_s. Yet this reasoning assumes that light consists of discrete quanta, and that Planck's constant h represents an energy per photon rather than a power constant.

Within the power-based framework $P = fh$, the Compton effect can be reinterpreted as a continuous power exchange between a propagating electromagnetic wave and a charged oscillator. The incident wave carries a power $P_i = f_i h$, while the scattered wave carries $P_s = f_s h$. The difference in power,

$$\Delta P = h(f_i - f_s),$$

represents the rate of energy transfer to the electron during the scattering process. This power difference corresponds to the electron's kinetic power gain:

$$\frac{dE_e}{dt} = \Delta P.$$

Integration over the relevant interaction interval yields the total energy imparted to the electron:

$$E_e = h(f_i - f_s)t.$$

For unit observation time ($t = 1$), this relation is numerically identical to the standard photon-based result but conceptually distinct: the interaction is continuous and wave-mediated rather than discrete and particle-like.

The frequency shift itself arises from the modulation of the scattered field by the motion of the electron. As the electron accelerates under the influence of the incident field, it re-radiates with a slight phase retardation relative to the incident wave, producing a Doppler-like reduction in frequency. The magnitude of this shift depends on the scattering angle and the inertial response of the electron, giving rise naturally to the observed relation

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta),$$

where the quantity $h/(m_e c)$ represents a characteristic resonance scale between the oscillating field and an electron of mass m_e.

In this continuous-wave interpretation, the Compton effect does not imply the existence of light quanta. Instead, it describes a resonant power redistribution between field and matter. The apparent quantization arises from the cyclic nature of wave–matter interaction and the inertial thresholds of charged particles. The same mathematical relationships hold, but their physical interpretation shifts from particle kinematics to wave dynamics. The Compton wavelength thus signifies not a particle's intrinsic size but a fundamental interaction scale in the coupling between oscillatory electromagnetic fields and matter.

8 Blackbody Radiation Reinterpreted as Continuous Power Distribution

The blackbody spectrum is historically regarded as the experiment that forced physics to accept quantization. Planck's introduction of the discrete relation $E = hf$ successfully reproduced the observed spectral distribution and resolved the ultraviolet divergence predicted by classical theory. However, when Planck's relation is expressed in its power form,

$$P = fh,$$

a continuous and physically transparent explanation of the blackbody spectrum emerges without invoking discrete energy packets.

In this reinterpretation, h represents a per-cycle power constant—the maximum transferable power of an oscillatory mode during one wave period. The radiated intensity at each frequency is then determined by two factors: the number of available oscillation modes within the cavity and the efficiency with which those modes can exchange power with the electromagnetic field. At low frequencies, many modes couple efficiently, yielding the familiar f^2 rise in intensity. At high frequencies, however, the oscillation period becomes shorter than the characteristic relaxation time of the medium. The coupling between field and matter weakens, leading to an exponential decline in the power transfer rate.

This decline naturally produces the same mathematical form as Planck's radiation law, but its origin lies in a continuous saturation process rather than in the discretization of energy. The so-called "quantum cutoff" thus corresponds to the frequency range where the rate of power exchange approaches the intrinsic limit h, and additional increases in frequency yield diminishing returns in net radiative power.

From this perspective, the shape of the blackbody curve reflects a balance between the geometric density of field modes (which increases with f^2) and the saturating efficiency of power transfer (which decreases exponentially with f). The product of these two continuous effects reproduces the observed intensity distribution.

This power-based model removes the need for quantization of light or resonator energy. The blackbody is not a source of discrete photons, but a continuum of resonant oscillations whose total emitted power is limited by the finite rate of energy exchange between matter and field. The success of Planck's empirical formula thus stems not from the existence of discrete quanta, but from the universal constraint on oscillatory power embodied in the constant h.

8.1 A simple analytic approximation: $I(f) = Af^2e^{-hf/kT}$

The qualitative argument given above, that the blackbody curve results from the product of a geometric mode density and a frequency-dependent power-transfer efficiency, can be captured by a compact analytic approximation. Begin with two physically motivated ingredients.

Mode density. The number of electromagnetic modes per unit frequency in a cavity grows as f^2. This is the geometrical factor that underlies the low-frequency Rayleigh–Jeans law. Thus the radiated intensity must contain a multiplicative factor proportional to f^2.

Per-mode transfer efficiency. Let $\Phi(f)$ denote the continuous efficiency with which a cavity mode at frequency f transfers its oscillatory power into free radiation. Physically, $\Phi(f)$ depends on the ability of the material degrees of freedom to respond to and reradiate a field that oscillates with period $T = 1/f$. As f increases the period shortens and the medium's finite relaxation time and inertia progressively reduce coupling efficiency. A simple, physically plausible model for this diminishing coupling is an exponentially decaying efficiency

$$\Phi(f) \;\propto\; \exp\bigl(-\alpha\,\hbar\omega/kT\bigr)$$

where $\omega = 2\pi f$, kT is the thermal energy scale of the material, and α is an $\mathcal{O}(1)$ dimensionless constant that encodes the precise microscopic response time of the medium. Written in frequency form and absorbing numerical constants into a single prefactor A, we may therefore approximate

$$\Phi(f) \approx \exp\bigl(-hf/kT\bigr),$$

where the combination hf sets the natural per-cycle interaction scale in the MUA picture.

Product model. Multiplying the mode-density factor by the per-mode efficiency yields the simple analytic approximation

$$I(f) \;=\; A\,f^2\,\Phi(f) \;\approx\; A\,f^2\,e^{-hf/kT}.$$

Here A is a temperature-dependent (and geometry-dependent) prefactor that collects factors such as cavity emissivity, surface area normalization, and numerical mode-count constants (e.g. $8\pi/c^3$ in the usual derivation). The exponential factor models the continuous saturation (or attenuation) of power transfer at high frequency: as f increases beyond the characteristic scale kT/h, $\Phi(f)$ rapidly tends toward zero, producing the observed exponential tail.

Connection to classical and Planck limits. This approximation recovers the correct limiting behaviors:

- **Low-frequency (classical) limit:** For $hf \ll kT$, the exponential can be expanded as $e^{-hf/kT} \approx 1 - hf/kT + \cdots$. Thus $I(f) \approx Af^2$, in agreement with the Rayleigh–Jeans $I \propto f^2$ scaling (the prefactor A must be chosen to match the classical constant $\propto kT$ when practicable).
- **High-frequency (exponential tail):** For $hf \gtrsim kT$, the exponential suppression dominates and produces the same qualitative ultraviolet cutoff observed in experiments. In the regime $hf \gg kT$ this single-exponential approximation and Planck's $(e^{hf/kT} - 1)^{-1}$ factor are numerically very similar, both producing an exponential decay of spectral intensity.

Physical interpretation and limitations. The choice of an exponential $\Phi(f)$ is phenomenological but physically natural: it encodes that the material's ability to exchange power with increasingly rapid oscillations is thermally limited and decays on a scale set by kT and the per-cycle interaction scale hf. A more detailed microscopic model would derive $\Phi(f)$ from material response functions (relaxation times, impedance mismatches, and microscopic damping), which could produce an exponential, a stretched exponential, or a Lorentzian-like attenuation depending on the mechanisms involved. Nevertheless, the simple form $I(f) = Af^2e^{-hf/kT}$ captures the essential physics of the continuum interpretation and reproduces the blackbody shape qualitatively while avoiding any appeal to discrete photons.

Practical note. For plotting or fitting, choose A so that the integrated power matches the Stefan–Boltzmann result at the desired temperature (or set A to include the usual geometrical factor $8\pi/c^3$ so as to compare directly with Planck's law). More refined fits can replace the single-exponential $\exp(-hf/kT)$ by a response-derived $\Phi(f)$ obtained from measured material permittivity and loss functions.

8.2 Computer Simulation of Blackbody Curve

Using the principles presented in this section, a computer program was developed to generate a blackbody curve similar to the blackbody curved found by experimet.

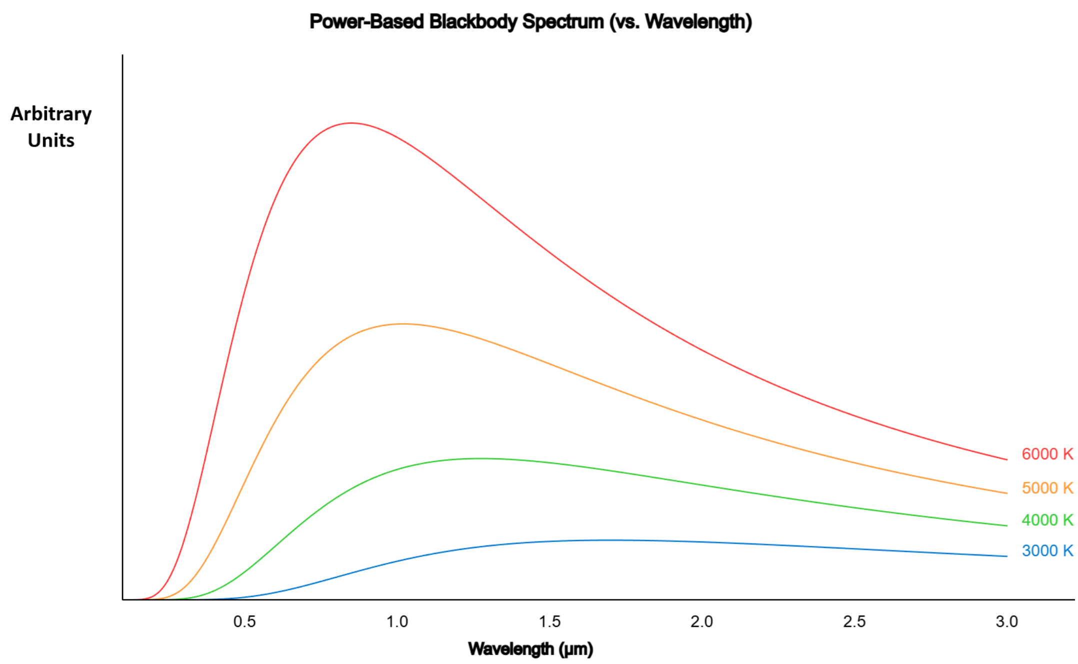

Figure 1: Qualitative comparison of spectral intensity versus frequency.

9 The Atom as a Power–Resonance System

Having reinterpreted Planck's relation in terms of per-cycle power transfer, we now extend this continuous-wave framework to the atomic domain. In this view, the atom is not a discrete energy system that emits quantized photons, but rather a *power-resonant structure* embedded within a continuous electromagnetic medium. Stable atomic states correspond to self-sustaining power resonances where the net flow of electromagnetic power into and out of the atomic field remains balanced over each oscillation cycle.

9.1 Resonant Power Balance

In the traditional Bohr model, quantization of electron orbits arises from the postulate that an integer number of de Broglie wavelengths must fit along the orbital circumference. In the power-based model, this same stability emerges naturally from a condition of power equilibrium:

$$P_{\text{in}} = P_{\text{out}}.$$

Here, P_{in} represents the electromagnetic power coupled into the electron's orbital motion, while P_{out} represents the re-radiated or dissipated field power. Stable configurations occur only when the circulating wave pattern closes on itself without destructive interference—i.e., when the orbital frequency is harmonically related to the natural frequency of the surrounding field.

Since $P = fh$, the power associated with each resonant frequency f_n is

$$P_n = f_n h,$$

and the total energy exchanged during one full cycle is

$$E_n = P_n t = h f_n t.$$

When the integration time t is set to one oscillation period, the per-cycle energy transfer remains $hf_n/f_n = h$, consistent with Planck's constant as a *per-cycle invariant of wave power.*

9.2 Atomic Emission as Power Transition

Transitions between resonant modes correspond to the rebalancing of power between two stable frequencies. The difference in per-cycle power between two resonant states,

$$\Delta P = h(f_2 - f_1),$$

drives the emission of a propagating field oscillation at frequency

$$f_{\text{em}} = f_2 - f_1.$$

This emitted wave is not a discrete photon, but a resonant pulse of electromagnetic power—an oscillatory wave packet whose duration and coherence are governed by the stability of the transition. The resulting spectrum is identical to that predicted by quantum theory, yet the mechanism is entirely continuous and wave-based. The discrete line structure of the Balmer and Lyman series thus emerges as a geometric property of resonant field modes rather than a signature of quantization.

9.3 Resonant Geometry and Stability

Within this framework, the classical condition for standing waves in the Bohr atom,

$$2\pi r_n = n\lambda_n,$$

simply ensures that the power distribution around the orbit is phase-coherent. Each integer n corresponds to a distinct resonant geometry of the electromagnetic field surrounding the nucleus. Perturbations that disturb this balance cause either a loss or gain in net power, driving the system toward the nearest stable configuration. What are conventionally interpreted as "quantum jumps" are, in this interpretation, rapid relaxations between adjacent power-equilibrium modes.

9.4 Relation to Atomic and Spectral Constants

The fine-structure constant α can be viewed as a dimensionless ratio of radiative to orbital power:

$$\alpha = \frac{P_{\text{radiative}}}{P_{\text{orbital}}}.$$

This reinterpretation restores a clear physical meaning to α: it measures the coupling efficiency between the oscillatory motion of a charge and the electromagnetic medium. Likewise, the Rydberg constant arises naturally from the geometry of resonant frequencies rather than from discrete electron energy levels.

9.5 Continuous Wave Interpretation of Atomic Structure

Under the power-resonance model, atomic structure is inherently continuous, yet it manifests discrete stability conditions due to the geometry of resonance. The apparent quantization of atomic energy levels therefore results from *standing-wave power geometry*, not from intrinsic particle discreteness. The same per-cycle power law that governs blackbody emission and Compton scattering thus extends seamlessly into atomic physics.

This unified treatment of electromagnetic power across free radiation, scattering, and bound-field resonance suggests that quantization itself may be an emergent property of a continuous medium governed by harmonic power equilibrium. The atom, in this view, is a self-stabilizing power resonator whose modes encode the structure of matter and radiation alike.

9.6 Electron Orbitals as Harmonic Power Oscillators

In the power-resonance model, electron orbitals are understood as the spatial manifestations of standing-wave power distributions within the atomic field. Each orbital corresponds to a stable harmonic of the electromagnetic potential surrounding the nucleus. Rather than being regions of probabilistic occupancy, these orbitals represent geometric loci where the oscillating power density maintains phase coherence over time.

The simplest orbital, the s-state, corresponds to the fundamental radial mode of the resonant field. Here, the oscillatory power is symmetrically distributed about the nucleus, with no angular variation. Higher-order modes, such as the p, d, and f orbitals, emerge as harmonic oscillations of the same underlying field, each characterized by distinct angular phase relationships that satisfy the resonance condition:

$$\nabla^2\Psi + k^2\Psi = 0,$$

where Ψ represents the complex amplitude of the oscillating power field and $k = 2\pi/\lambda$ is the wavenumber associated with the local resonance frequency.

These solutions correspond directly to the familiar spherical harmonics $Y_{l,m}(\theta, \phi)$, which in this framework describe angular distributions of power flow rather than probability amplitudes. The integers l and m label harmonic modes of the resonant electromagnetic structure, each with a characteristic power geometry:

$$P_{l,m} \propto |\Psi_{l,m}|^2.$$

The quantized appearance of atomic orbitals thus arises naturally from the boundary conditions imposed by the finite geometry of the resonant field, in exact analogy to the harmonic modes of a vibrating string or a three-dimensional cavity resonator.

In this sense, the so-called "wavefunction" does not represent the probability of finding a particle, but rather the spatial structure of oscillatory power in a stable, self-sustaining resonance. Each orbital is a harmonic oscillator in both space and time - an equilibrium between the inward and outward flow of electromagnetic power. When external perturbations shift this balance, the atom transitions to a neighboring harmonic mode, releasing or absorbing a resonant power pulse corresponding to the difference in frequency between the two modes.

This interpretation restores physical meaning to the discrete orbital patterns observed in spectroscopy and quantum chemistry. They are not arbitrary quantum abstractions, but visible expressions of the harmonic architecture of a continuous electromagnetic medium.

9.7 Deriving the Balmer and Lyman Series in the Power-Resonance Model

The familiar spectral lines of hydrogen (Balmer, Lyman, etc.) may be derived in the usual algebraic way, but here we present the derivation while explicitly framing each step in the power-resonance vocabulary developed above. The goal is to show that the same frequency-domain relations that are normally interpreted via photon energy differences arise naturally from resonant stability conditions and the per-cycle power law $P = fh$.

1. Mechanical balance. Consider an electron of mass m orbiting a nucleus of charge $+e$ at radius r with tangential speed v. Coulomb attraction provides the centripetal force:

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}.$$

This standard mechanical balance is agnostic about whether energy is carried by particles or waves; it simply constrains orbital kinematics.

2. Resonant (standing-wave) condition. Replace the historical semiclassical postulate (quantized angular momentum) with an explicitly resonant statement: the circulating field closes coherently after an integral number n of field cycles. Algebraically this condition can be written in the same functional form as Bohr's de Broglie argument:

$$2\pi r = n\lambda_n,$$

where λ_n is the wavelength associated with the resonant oscillation supporting the mode. Using a phase-frequency relation $\lambda_n = v_n/f_n$ (with v_n the local phase speed along the orbit), one may equivalently express the resonance as

$$mvr = n\hbar,$$

where $\hbar \equiv h/2\pi$. In the power–resonance interpretation this relation does not assert a primitive quantization of action but instead encodes the geometric requirement for a self-consistent standing-wave power distribution around the orbit.

3. Algebraic consequences. Combining the mechanical balance with the resonant condition gives the standard Bohr expressions for orbital radius r_n and speed v_n. Eliminating v from the two relations and solving for r_n yields

$$r_n = \frac{4\pi\varepsilon_0\hbar^2}{me^2}\,n^2 \equiv a_0 n^2,$$

where a_0 is the Bohr radius. The kinetic and potential energies follow as usual; the total (bound) energy of the n-th resonant mode is

$$E_n = -\frac{me^4}{8\varepsilon_0^2 h^2}\frac{1}{n^2} = -\frac{(R_\infty\, c)\, h}{n^2},$$

where R_∞ denotes the Rydberg constant. In MUA, the units of R_∞ are cycles/meter or $[\Delta/m]$ (instead of 1/m) and $(R_\infty\, c)$ has the units of frequency, $[\Delta/m \times m/s] = [\Delta/s]$.

4. Emission in the frequency domain. Under a transition from an upper resonant mode n_i to a lower mode n_f, the net change in (per-cycle integrated) energy is

$$\Delta E = E_{n_f} - E_{n_i} = h\,\Delta f_{\text{em}},$$

where Δf_{em} is the frequency of the emitted resonant wave. Rearranging,

$$\Delta f_{\text{em}} = \frac{E_{n_f} - E_{n_i}}{h}.$$

Substituting the expression for E_n gives the standard Rydberg form in the frequency domain:

$$\boxed{f_{\rm em} \;=\; R_\infty c\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)}$$

Numerically, for hydrogen

$$R_H \approx 1.0967758 \times 10^7 \text{ m}^{-1},$$

so $f_{\rm em} = R_H c(\, 1/n_f^2 - 1/n_i^2\,)$ reproduces the observed spectral frequencies.

5. Balmer and Lyman series as special cases. The Balmer series corresponds to transitions terminating at $n_f = 2$:

$$f_{\rm Balmer} = R_H c\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right), \qquad n_i = 3, 4, 5, \ldots$$

The Lyman series corresponds to transitions terminating at $n_f = 1$:

$$f_{\rm Lyman} = R_H c\left(1 - \frac{1}{n_i^2}\right), \qquad n_i = 2, 3, 4, \ldots$$

These forms are identical to the textbook expressions but here are interpreted as the frequencies of continuous resonant power waves emitted when an atom relaxes from one standing-wave power mode to another.

6. Interpretation and remarks. Algebraically the derivation follows the same steps as the semi-classical Bohr model, but the physical interpretation is different. The quantity E_n is understood as the net per-cycle integrated power-time exchanged by a stable resonant mode, and the transition frequency $f_{\rm em}$ is the frequency of the emitted *resonant power wave* generated by the rebalancing of the atomic power distribution. No appeal to indivisible photons is required: the discrete spectral lines arise from allowed resonant geometries and power equilibria of the bound-field system.

Finally, because the Rydberg expression is expressed directly in frequency units, it is particularly transparent in the MUA picture: frequency is the fundamental observable (cycles per second), and the per-cycle power scale h converts differences in resonant mode power into emitted-wave frequency in a dimensionally consistent manner.

10 Discussion

The reinterpretation of Planck's relation as a power law rather than an energy law provides a compelling bridge between classical electromagnetism and modern quantum phenomena. By framing h as a proportionality constant linking frequency to power rather than energy, we restore a continuous description of radiation that remains fully consistent with experimental observations. This approach reintroduces the concept of a medium or field substrate through which electromagnetic oscillations propagate and exchange energy continuously over time.

In traditional quantum theory, the introduction of the photon was necessary to resolve the ultraviolet catastrophe and to account for discrete photoelectric thresholds. However, these phenomena can be equally well explained if one recognizes that the radiative power of a wave increases linearly with its frequency. The key insight is that interactions between electromagnetic waves and matter occur not as instantaneous impacts, but as continuous exchanges of power over the duration of a wave cycle. The concept of "quantization" then becomes an artifact of measurement limits and discrete resonance conditions within the medium, rather than a property of nature itself.

This perspective aligns naturally with the principles of classical field theory, where energy transfer is mediated through continuous oscillatory fields. In the photoelectric effect, the threshold frequency corresponds to the point at which the wave's per-cycle power matches the local binding power of the electron. In Compton scattering, power and momentum are redistributed between wavefronts in accordance with resonance geometry, without invoking particle collisions. And in blackbody radiation, the spectral distribution arises from the statistical distribution of continuous wave modes in equilibrium, each contributing according to its intrinsic per-cycle power and damping characteristics.

The conceptual advantage of the power-based interpretation is that it reestablishes a coherent physical picture in which light, matter, and space are all part of a single dynamic continuum. Rather than imagining photons as discrete entities traveling through empty space, this framework envisions electromagnetic radiation as a structured oscillatory process in a medium whose response defines the apparent quantization of interaction. This restores mechanical intuition to the understanding of radiative phenomena while retaining the predictive precision of Planck's constant and related empirical laws.

Ultimately, this reinterpretation does not discard quantum theory, but rather embeds it within a broader wave-mechanical context. By viewing Planck's constant as a scaling constant of wave power, we open a path toward unifying quantum and classical descriptions under a single continuous formalism—one that honors both the successes of quantum mechanics and the physical coherence of field theory.

11 Summary and Outlook

The reinterpretation of Planck's constant as a per-cycle power coefficient offers a coherent and unified foundation for understanding electromagnetic phenomena within a continuous wave framework. By restoring the role of frequency as a direct measure of radiative power, we dissolve the conceptual divide between classical and quantum descriptions. The relation $P = fh$ becomes the central expression of energy exchange in the electromagnetic medium, linking oscillation rate to power transfer in a physically intuitive and dimensionally consistent way.

Through this reinterpretation, phenomena traditionally regarded as evidence for quantization—such as the photoelectric effect, Compton scattering, and blackbody radiation—can all be understood as manifestations of continuous power resonance between oscillating fields and matter. The apparent discreteness of energy exchange arises not from indivisible quanta, but from resonance thresholds and boundary conditions that regulate the flow of wave power across media. In this view, nature remains fundamentally continuous, yet capable of producing sharply defined, quantized outcomes as a consequence of its resonant geometry.

This framework invites a reconsideration of other domains where quantization and continuity have long appeared irreconcilable. For instance, atomic emission spectra may be reinterpreted as the result of stable standing-wave configurations within atomic or molecular structures, where each allowed frequency corresponds to a resonant mode that balances power flow between bound and radiative states. Similarly, polarization, interference, and diffraction phenomena can be understood as direct expressions of the vectorial and geometric properties of the medium itself, with Planck's constant setting the scale of power transfer per cycle.

At larger scales, the same principles of oscillation, resonance, and power distribution may extend to the structure of spacetime and the dynamics of the cosmos. If the universe exhibits fractal or self-similar organization across scales, then the laws governing electromagnetic power transfer at the quantum level may reflect deeper structural symmetries of the medium underlying both radiation and gravitation. In such a picture, h represents not the granularity of light, but a universal scaling constant linking oscillation, geometry, and power across the hierarchy of physical systems.

Future work will aim to formalize this continuous-wave power model, exploring its implications for atomic structure, field quantization, and cosmological dynamics. By uniting the precision of Planck's constant with the continuity of classical wave mechanics, this approach offers the possibility of a more complete and physically coherent understanding of the universe—one in which quantization emerges naturally from resonance and geometry, rather than from fundamental discreteness.

12 Conclusion

By restoring the dimensional significance of "cycles" in the frequency term through Modified Unit Analysis (MUA), we uncover a reinterpretation of Planck's constant as a *per-cycle power coefficient* rather than an energy–time product. Within this framework, Planck's relation becomes

$$P = fh,$$

which expresses the *instantaneous power transfer* of an electromagnetic wave as directly proportional to its frequency. Here, h represents the intrinsic power conveyed during a single oscillation period of the wave—analogous to a "power cycle" in electronics—rather than a discrete packet of energy.

This reinterpretation restores a continuous, wave-based framework for understanding electromagnetic radiation. In the context of the photoelectric effect, it explains the observed frequency threshold and the linear relationship between kinetic energy and frequency without invoking photons. The threshold arises naturally when the wave's per-cycle power equals the binding power that holds electrons within the metal lattice. Beyond this point, the excess power contributes to the electron's kinetic motion, reproducing Einstein's empirical law while maintaining a purely wave-based description.

Similarly, Compton scattering can be understood as a resonant power exchange between a propagating electromagnetic wave and a charged particle, where momentum and power are transferred continuously through the medium rather than via discrete photon impacts. The observed wavelength shift then reflects a redistribution of wave power between the incident and scattered components, governed by resonance geometry and conservation principles within the wave continuum.

When applied to blackbody radiation, this same power-based framework reproduces the observed spectral distribution without resorting to quantization. The shape of the Planck curve emerges from the interplay between two continuous factors: the per-cycle power transfer and the density of available electromagnetic modes ($\propto f^2$) in thermal equilibrium. At low frequencies, the power contribution per cycle is small, while at high frequencies, the exponential damping term $e^{-hf/kT}$ suppresses the available power due to finite interaction times. The result is the characteristic asymmetric curve of blackbody radiation—steeply rising and exponentially decaying—matching experimental observations while preserving the continuity of wave behavior.

In this light (pun intended), Planck's constant no longer signifies the granularity of nature but rather a universal scaling factor that links oscillation frequency to power transfer in a continuous electromagnetic medium. This shift eliminates the need for a fundamental photon particle, offering a unified, mechanically consistent, and wave-based interpretation of radiation phenomena—including the photoelectric effect, Compton scattering, and blackbody emission—under a single, continuous power law.

A Simulation of the Power-Based Blackbody Spectrum

The following JavaScript program plots the blackbody intensity distribution as a function of wavelength for different temperatures. The simulation demonstrates how the continuous power-transfer model reproduces the shift and suppression of the blackbody spectrum as temperature varies. The code can be run in any browser at **editor.p5js.org**.

```
function setup() {
  createCanvas(800, 500);
  noLoop();

  // --- Physical constants ---
  const h = 6.626e-34;          // Planck constant (J*s)
  const c = 3e8;                // Speed of light (m/s)
  const k = 1.381e-23;          // Boltzmann constant (J/K)

  // --- Define temperatures to plot (in Kelvin) ---
  const temps = [3000, 4000, 5000, 6000];
```

```
// --- Define wavelength range (in meters) ---
const lambdaMin = 1e-7;    // 0.1 micrometers
const lambdaMax = 3e-6;    // 3 micrometers
const steps = 500;

// --- Compute intensity for each wavelength and temperature ---
let spectra = temps.map(T => {
  let data = [];
  for (let i = 0; i < steps; i++) {
    let lambda = lambdaMin + (lambdaMax - lambdaMin) * i / (steps - 1);
    let f = c / lambda;
    // Power-based spectral intensity per wavelength interval
    let intensity = (h * f * f * f) / (Math.exp(h * f / (k * T)) - 1);
    // Convert lambda to micrometers for display
    data.push({ lambda: lambda * 1e6, intensity });
  }
  return { T, data };
});

// --- Find global intensity max for scaling ---
let Imax = 0;
spectra.forEach(s => s.data.forEach(d =>
{ if (d.intensity > Imax) Imax = d.intensity; }));

// --- Axes setup ---
background(255);
stroke(0);
fill(0);
textSize(14);
textAlign(CENTER);
text("Power-Based Blackbody Spectrum (vs. Wavelength)", width / 2, 20);
textSize(12);
textAlign(RIGHT);
text("Intensity (arbitrary units)", 80, 30);
textAlign(CENTER);
text("Wavelength (micrometers)", width / 2, height - 20);
translate(100, height - 60);

// --- Plot each temperature curve ---
const colors = ['#0077cc', '#33cc33', '#ff9933', '#ff3333'];
for (let t = 0; t < temps.length; t++) {
  stroke(colors[t]);
  noFill();
  beginShape();
  spectra[t].data.forEach(d => {
    let x = map(d.lambda, lambdaMin * 1e6, lambdaMax *
    1e6, 0, width - 150);
    let y = -map(d.intensity, 0, Imax, 0, height - 150);
    vertex(x, y);
  });
  endShape();
```

```
    // —— Label each curve ——
    noStroke();
    fill(colors[t]);
    text(`${temps[t]} K`, width - 120,
      -map(spectra[t].data[steps - 1].intensity, 0, Imax, 0, height - 150));
  }

  // —— Draw axes ——
  stroke(0);
  line(0, 0, width - 100, 0);
  line(0, 0, 0, -height + 100);

  // —— Axis labels ——
  for (let lambda = 0.5; lambda <= 3; lambda += 0.5) {
    let x = map(lambda, lambdaMin * 1e6, lambdaMax * 1e6, 0, width - 150);
    noStroke();
    fill(0);
    text(lambda.toFixed(1), x, 20);
  }
}
```

References

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