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Article

Re-Examination of Blackbody Radiation Theory and Elimination of the Ultraviolet Catastrophe Based on a Revised Classical Electrodynamics Framework

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Abstract

The blackbody radiation problem gave rise to Planck's hypothesis of energy quantization, which is regarded as the inception of quantum theory and ultimately led to a fundamental conceptual schism **between the emerging quantum description and the established classical framework** of physics. This paper argues that this historical turning point stems from a profound misunderstanding of the concept of the "quantum". Through a systematic critique of the three fundamental errors in the Rayleigh-Jeans formula, we propose, based on a **revised classical electrodynamics framework**, that the elimination of the ultraviolet catastrophe **does not require the introduction of the assumption of energy discreteness**. The key lies in recognizing that **continuous energy transfer** occurs only when electrons undergo accelerated or decelerated motion, and that the essence of the **minimum energy unit ϵ** is a natural **measurement benchmark** for this continuous process, rather than a physically discrete "energy packet". Building on this, we have derived a blackbody radiation formula that fully matches experimental data. This formula is consistent with the Rayleigh-Jeans formula in the low-frequency region and naturally exhibits exponential decay in the high-frequency region, successfully eliminating the ultraviolet catastrophe. **This research fundamentally clarifies the physical origin of the "quantization" feature: it arises from the measurement discreteness of the energy transfer process and the constraints of thermodynamic statistics, rather than a change in the intrinsic nature of energy itself.** This achievement not only fulfills Planck's unfulfilled desire for a classical explanation but also demonstrates that blackbody radiation, and even a series of "quantum phenomena", can be fully explained within a **purely self-consistent classical physics framework**. This lays a crucial foundation for bridging the "classical-quantum" divide and reconstructing a unified theoretical system in physics.

Keywords: blackbody radiation; Rayleigh-Jeans formula; ultraviolet catastrophe; Planck constant h ; minimum energy unit ϵ

Introduction

The blackbody radiation problem was a core challenge faced by theoretical physics at the end of the 19th century. The radiation formula derived by Rayleigh and Jeans based on classical electromagnetic theory and the equipartition theorem diverged in the high-frequency region, leading to the "ultraviolet catastrophe" [1]. Planck solved this problem by introducing the energy quantization hypothesis, but this also gave rise to quantum theory, which is fundamentally at odds with classical physics [2]. In fact, Planck himself maintained reservations about this hypothesis throughout his life; he dedicated his career to finding a classical physical explanation for the energy quantum concept, attempting to incorporate it into the traditional physics framework, but ultimately did not succeed [2]. In recent years, we proposed a revised classical electrodynamics theory, which reinterprets electron motion and radiation mechanisms, successfully explaining a series of "quantum phenomena" such as hydrogen atom spectra and the photoelectric effect without introducing quantum hypotheses [3]. Subsequently, this theory was further extended to derive the quantization

of electron elliptical orbits in hydrogen-like atoms [4], verifying its consistency in explaining microscopic systems. Based on this theoretical framework, this paper systematically analyzes the derivation errors of the Rayleigh-Jeans formula and further clarifies the physical significance of the continuity of energy transfer and the unit of measurement ϵ , clearly distinguishing the essential differences between "measurement discreteness" and "physical discreteness". This paper aims to explore the possibility of explaining blackbody radiation within the framework of classical physics, attempting to respond to Planck's original inquiry into the classical origins of the quantum concept, and to provide a theoretical pathway for understanding the connection between macroscopic and microscopic physics.

1. Classical Derivation of the Rayleigh-Jeans Formula and Its Theoretical Defects

1.1. Overview of the Classical Derivation

The Rayleigh-Jeans formula is based on cavity electromagnetic standing wave mode statistics and the equipartition theorem. Assuming the electromagnetic mode density within the cavity is:

$$g(v) = \frac{8\pi v^2}{c^3}$$

The average energy of each mode under thermal equilibrium is:

$$\langle E \rangle = k_B T$$

Thus, the radiation energy density is obtained:

$$u(v, T) = g(v) \cdot k_B T = \frac{8\pi v^2}{c^3} k_B T$$

This formula agrees with experiments in the low-frequency region but diverges in the high-frequency region [3].

1.2. Fundamental Conflict with Revised Classical Electrodynamics

Our theory [3,4] points out that electrons in uniform circular motion or periodic elliptical motion experience a centripetal force that does no work (zero torque), conserving the system's mechanical energy; thus, they neither radiate nor absorb energy. Energy exchange occurs only when the electron's motion frequency changes (i.e., during acceleration or deceleration). This process is *continuous*: electrons move in a spiral around the nucleus, their frequency changes continuously, and energy is transferred continuously as a result.

We introduce ϵ as the minimum *unit of measurement* for quantifying this continuous energy flow. Its physical meaning corresponds to the amount of continuous energy transferred per unit change in electron frequency [3]. This differs fundamentally from Planck's energy quantum as a discrete "energy packet". ϵ is merely a measurement standard, akin to using a "bucket" to measure a continuous flow of water, without altering the inherent continuity of the energy itself.

2. The Three Fundamental Errors of the Rayleigh-Jeans Formula

2.1. The Energy Equipartition Assumption Contradicts Electron Motion Mechanism

The Rayleigh-Jeans formula assumes all standing wave modes share the energy $k_B T$ equally. However, according to the revised classical electrodynamics [3,4], "stationary modes" corresponding to uniform motion do not participate in energy exchange, and their radiated energy should be zero. Allocating $k_B T$ to all modes leads to a severe overestimation of energy in the high-frequency region. This assumption violates the law of energy conservation, as electrons in stationary modes are in force equilibrium and lack the physical basis for energy radiation or absorption [3].

2.2. Mode Density Fails to Distinguish Between Radiative and Stationary States

The classical mode density $g(\nu)$ does not distinguish between "stationary modes" ($\Delta f = 0$) and "radiation modes" ($\Delta f \neq 0$). The revised theory clarifies that only radiation modes actually participate in energy exchange, and high-frequency modes are suppressed because the required energy $\Delta E = k\varepsilon$ far exceeds the thermal energy $k_B T$ [3]. The Rayleigh-Jeans formula ignores this quantization constraint, leading to an inflated count of high-frequency modes and, consequently, ultraviolet divergence [1].

2.3. The Applicability Condition of the Equipartition Theorem Is Not Satisfied

The equipartition theorem requires system energy to be in a continuous quadratic form and the system to be in thermal equilibrium. However, electromagnetic field energy exchange is achieved through continuous changes in electron frequency [3]. Here, it is crucial to distinguish between "continuous energy transfer" and "classical continuous energy flow"; their core differences lie in three aspects: physical carrier, constraint conditions, and transfer mechanism (Table 1).

Table 1. Comparison between "continuous energy transfer" and "classical continuous energy flow".

Comparison Dimension	"Continuous Energy Transfer" Proposed in This Paper	"Classical Continuous Energy Flow"
Physical Carrier	Electron in variable-speed motion around the nucleus (accelerated/decelerated spiral motion) [3]	No specific microscopic carrier; abstracted as a continuous energy field
Constraint Conditions	Constrained by changes in electron motion frequency; transfer uses ε as the minimum measurement unit	No microscopic constraints; energy can be infinitely subdivided and flow continuously
Transfer Mechanism	Continuous change in electron frequency $\rightarrow$ continuous accumulation/release of energy; each unit change in frequency corresponds to one measurement unit ε [3]	Energy flows uninterrupted in space without relying on directed motion changes of microscopic particles

Specifically, classical continuous energy flow is an abstract concept detached from microscopic carriers, assuming energy can be infinitely divided and flows continuously. For example, in classical electromagnetic theory, the energy transfer of electromagnetic waves is treated as an unconstrained continuous field flow [1]. In contrast, the "continuous energy transfer" described in this paper is a concrete process reliant on electron variable-speed motion: electrons undergo accelerated/decelerated spiral motion between different energy levels, their frequency continuously transitions from f_n to f_m , and energy accumulates or releases continuously with the frequency change [3]. This continuity is reflected in the smoothness of the energy change, not in unconstrained infinite subdivision. The transfer process is bounded by ε as the minimum measurement benchmark, making it essentially a "continuous process subject to measurement constraints", not the "unconstrained absolute continuous energy flow" of classical theory.

The equipartition theorem is only applicable to systems with classical, unconstrained continuous energy flow. It cannot describe this type of continuous energy transfer process, which is based on electron variable-speed motion and subject to a measurement unit constraint. Its direct application leads to contradictions between theory and experiment [2].

3. Revised Model: Classical Derivation of the Energy Density Formula

3.1. Basic Assumptions and Physical Picture

Based on revised classical electrodynamics [3,4], we propose the following core assumptions:

(1) Electrons are mostly in stationary states (uniform circular or elliptical motion) under thermal equilibrium and only continuously radiate or absorb energy when their frequencies change due to disturbances;

(2) Energy transfer uses the minimum measurement unit ε , corresponding to the energy transmitted per unit change in electron frequency [3];

(3) Radiated power is constrained by energy-time, i.e., the minimum time to complete one electromagnetic oscillation cycle is $\Delta t_{min} = 1/\nu$.

3.2. Detailed Derivation of the Revised Radiation Energy Density Formula

Based on the revised classical electrodynamics theory [3,4], the physical essence of radiation within a blackbody cavity is the transition radiation of numerous "electron-nucleus bound systems" excited thermally at different frequencies. The specific derivation process is as follows:

Step 1: General Expression for Electron Transition Power

According to revised classical electrodynamics [3], when an electron accelerates and completes one revolution around the nucleus, it radiates an amount of energy ε . Therefore, within a time interval Δt , if k units of energy ε are radiated, the total radiated energy is $\Delta E = k\varepsilon$, and the radiation power can be expressed as:

$$P = \frac{\Delta E}{\Delta t} = \frac{k\varepsilon}{\Delta t}$$

The frequency ν of this radiation satisfies $\nu = k/\Delta t$. The radiation power can thus be expressed as a function of frequency ν :

$$P_k = \varepsilon \nu \quad (3.1)$$

This equation indicates that the radiation power P is directly proportional to the radiation frequency ν , with the proportionality constant being ε .

Step 2: Statistical Weight of Radiation Processes at Different Frequencies under Thermal Equilibrium

In a blackbody cavity at thermal equilibrium, there exists a vast number of microscopic systems capable of radiating. To sustain a radiation process of frequency ν , the energy that must be transferred within a time Δt is:

$$\Delta E = P_k \cdot \Delta t = \varepsilon \nu \Delta t$$

To simplify subsequent calculations, we take the unit observation time $\Delta t = 1$ s. Then, $\varepsilon \Delta t = h$, $\nu = k/\Delta t = k$ and $\Delta E = k\varepsilon = h\nu$. That is, the total energy required to generate a radiation process of frequency ν is $\Delta E = k\varepsilon = h\nu$.

In a thermal equilibrium state, there exists competition among radiation processes of different frequencies within the system: radiation processes with higher energy require overcoming higher thermal energy barriers and thus have lower probabilities of being thermally excited. This probability follows the Boltzmann distribution, whose core physical meaning is that "in a thermal equilibrium system, the occupation probability of a physical state is exponentially related to the energy of that state", with the specific form given by:

$$\text{Prob}(k) \propto \exp\left(-\frac{\Delta E}{k_B T}\right) = \exp\left(-\frac{k\varepsilon}{k_B T}\right) \quad (3.2)$$

Here, k is the energy count number (**corresponding to the radiation frequency $\nu = k$**), and $\text{Prob}(k)$ represents the "probability weight for the radiation process with frequency $\nu = k$ to be excited under thermal equilibrium". The larger k is (indicating higher frequency and higher energy), the smaller the probability weight, which fully aligns with the physical intuition of thermal statistics.

Note on Discrete Summation and Continuous Frequency

Physically, the radiation frequency ν is a continuous variable. In the following statistical summation, we discretize the continuous frequency ν into a sequence $\nu_k = k/\Delta t$, where $k = 0, 1, 2, \dots$, and take the unit observation time $\Delta t = 1$ s. This treatment is based on two points:

(1) The numerical value of the minimum energy unit ε is extremely small ($\varepsilon = h \approx 6.626 \times 10^{-34}$ J), making the error introduced by the frequency resolution $\nu = 1$ Hz negligible in macroscopic statistics.

(2) Using discrete summation allows for a clearer presentation of the physical picture where energy transfer is measured in units of ε , and facilitates subsequent asymptotic analysis. In situations

requiring strict continuous treatment, the summation can be replaced by an integral over ν , with the energy term in the integrand being $E = h\nu$.

Step 3: Calculation of Average Radiation Power

Considering all possible radiation processes at frequencies ν (**corresponding to all positive integers k**), the average radiation power of the system when in the corresponding state can be calculated via statistical summation:

$$\langle P \rangle = \frac{\sum_{\nu=0}^{\infty} P_k \cdot \exp\left(-\frac{h\nu}{k_B T}\right)}{\sum_{\nu=0}^{\infty} \exp\left(-\frac{h\nu}{k_B T}\right)} = \frac{\sum_{k=0}^{\infty} P_k \cdot \exp\left(-\frac{k\varepsilon}{k_B T}\right)}{\sum_{k=0}^{\infty} \exp\left(-\frac{k\varepsilon}{k_B T}\right)} \quad (3.3)$$

where $P_k = \varepsilon \nu = \varepsilon k$ (numerically equal).

Step 4: Asymptotic Behavior Analysis (Low and High Frequency Limits)

For ease of analysis, let $x = k\varepsilon/k_B T = h\nu/k_B T$.

Low-frequency region ($x \ll 1$): Here, $k\varepsilon \ll k_B T$, meaning the energy of the radiation process is much smaller than the thermal energy. Consequently, radiation processes of all frequencies can be sufficiently excited, and the probability weight $\exp(-k\varepsilon/(k_B T)) \approx 1$. The summation can be approximated as a continuous integral, ultimately yielding the classical statistical average power:

$$\langle P \rangle \approx k_B T \quad (3.4)$$

This is consistent with the low-frequency behavior of the Rayleigh-Jeans formula, reflecting the applicability of classical statistics.

High-frequency region ($x \gg 1$): Here, $k\varepsilon \gg k_B T$, meaning the energy of the radiation process is much greater than the thermal energy. Only radiation processes near $k \approx k_0 = k_B T/\varepsilon$ (the characteristic count number corresponding to thermal energy) have a non-negligible excitation probability. Processes far from k_0 ($k > k_0$) contribute negligibly due to the exponential decay of the probability weight $\exp(-k\varepsilon/(k_B T))$. Consequently, the average power exhibits exponential decay:

$$\langle P \rangle \approx \varepsilon \nu \cdot e^{-x} = \varepsilon \nu \cdot \exp\left(-\frac{h\nu}{k_B T}\right) \quad (3.5)$$

This behavior directly suppresses the energy divergence in the high-frequency region, thereby successfully eliminating the ultraviolet catastrophe.

Step 5: Unified Expression and Energy Density Formula

Integrating the above limiting behaviors, the average power can be expressed piecewise as:

$$\langle P \rangle \approx \begin{cases} k_B T, & h\nu \ll k_B T \\ \varepsilon \nu \cdot \exp\left(-\frac{h\nu}{k_B T}\right), & h\nu \gg k_B T \end{cases} \quad (3.6)$$

Classical electromagnetic theory gives the mode density per unit volume per unit frequency interval as: $g(\nu) = \frac{8\pi\nu^2}{c^3}$. Substituting the average power yields the revised radiation energy density formula:

$$u(\nu, T) = g(\nu) \cdot \langle P \rangle = \frac{8\pi\nu^2}{c^3} \cdot \begin{cases} k_B T, & h\nu \ll k_B T \\ \varepsilon \nu \cdot \exp\left(-\frac{k\varepsilon}{k_B T}\right), & h\nu \gg k_B T \end{cases} \quad (3.7)$$

This formula is consistent with the Rayleigh-Jeans formula in the low-frequency region, naturally exhibits exponential decay in the high-frequency region, thereby successfully eliminating the ultraviolet catastrophe, and is in complete agreement with experimental observations.

3.3. Detailed Derivation and Physical Meaning of High-Frequency Asymptotic Behavior

Step 1: Specific Expression in the High-Frequency Region

When $h\nu \gg k_B T$, from Eq. (3.7) we obtain:

$$u(\nu, T) = \frac{8\pi\nu^2}{c^3} \cdot \varepsilon \nu \cdot \exp\left(-\frac{h\nu}{k_B T}\right)$$

Rearranging gives:

$$u(\nu, T) = \frac{8\pi\varepsilon}{c^3} \cdot \nu^3 \cdot \exp\left(-\frac{h\nu}{k_B T}\right) \quad (3.8)$$

Step 2: Define Temperature-Dependent Constant

Let:

$$c_T = \frac{h}{k_B T}$$

Then Eq. (3.8) can be written as:

$$u(v, T) \propto v^3 \cdot e^{-c_T v} \tag{3.9}$$

Step 3: Limiting Behavior Analysis

As $v \rightarrow \infty$, the exponential term $e^{-c_T v}$ decays much faster than the polynomial term v^3 grows, therefore:

$$\lim_{v \rightarrow \infty} u(v, T) = 0 \tag{3.10}$$

Step 4: Explanation of Physical Mechanism

The physical root cause of the exponential decay in the high-frequency region lies in:

Thermal Power Threshold Effect: When $h\nu \gg k_B T$, the energy $\Delta E = h\nu$ required to generate radiation at this frequency is much greater than the thermal energy $k_B T$, causing its thermal excitation probability $\propto \exp(-h\nu/k_B T)$ to decay exponentially.

Energy-Time Constraint Mechanism: The minimum time to complete one electromagnetic oscillation is $\Delta t_{\min} = 1/\nu$, and the minimum energy transfer unit is ϵ . Therefore, the theoretical maximum power is:

$$P_{\max} = \epsilon / \Delta t_{\min} = \epsilon \nu$$

Even given this power upper limit, the actual average power is still suppressed by the thermal excitation probability, manifesting as $\langle P \rangle \propto \epsilon \nu e^{-h\nu/k_B T}$.

Step 5: Elimination of the Ultraviolet Catastrophe

The classical Rayleigh-Jeans formula assumes all modes equally share energy $k_B T$, i.e., $u(v, T) \propto v^2 \cdot k_B T$, leading to divergence of the high-frequency integral.

In the revised model, in the high-frequency region $u(v, T) \propto v^3 \cdot e^{-c_T v}$, where exponential decay dominates, ensuring:

$$\int_0^\infty u(v, T) dv < \infty$$

The ultraviolet catastrophe is naturally eliminated.

3.4. Unified Explanation of Blackbody Radiation Phenomena by the Revised Model

The revised formula (3.7) naturally reduces to the Rayleigh-Jeans form in the low-frequency region ($h\nu \ll k_B T$), consistent with low-frequency experimental data. In the high-frequency region ($h\nu \gg k_B T$), it exhibits exponential decay, successfully eliminating the ultraviolet catastrophe. More importantly, this formula originates from a self-consistent classical physics framework and provides a unified explanation for the complete phenomenology of blackbody radiation without introducing any non-classical assumptions.

Starting from the revised formula, the empirical Wien's displacement law and the Stefan-Boltzmann law can be further derived. The physical mechanism of **Wien's displacement law** (the peak frequency $\nu_{\max}$ is proportional to temperature T) is clear and intuitive in this model: it stems from the competitive balance between the radiated power $P = \epsilon \nu$ and the thermal energy $k_B T$. When the temperature T increases, the thermal excitation energy strengthens, enabling the support of higher-frequency (higher-power) radiation processes, which shifts the spectral peak toward higher frequencies. The **Stefan-Boltzmann law** (the total radiant exitance $M(T) \propto T^4$) is a natural outcome derived first by integrating the energy density spectrum to obtain the total energy density $\int_0^\infty u(v, T) dv$, and then applying the classical radiation propagation relation $M(T) = \frac{c}{4} U(T)$. Since the dimensional chain of all physical quantities in this model—the mode density $g(v)$, the average power $\langle P \rangle$, and the energy density $u(v, T)$ —is strictly self-consistent, this integration has a clear physical meaning. The resulting T^4 law is an inevitable manifestation of continuous energy transfer modulated by thermal statistics.

3.5. Fundamental Differences from Planck's Approach: A Comprehensive Analysis from Formula to Laws

The standard form of Planck's blackbody radiation formula is:

$$u_{Planck}(\nu,T)=\frac{8\pi h\nu^3}{c^3}\cdot\frac{1}{e^{h\nu/k_BT}-1}\tag{3.11}$$

When $h\nu\gg k_BT$,

$$u_{Planck}(\nu,T)\approx\frac{8\pi h\nu^3}{c^3}e^{-h\nu/k_BT}\tag{3.12}$$

Although Planck's blackbody radiation formula (3.11) can mathematically fit experimental data and derive the same empirical laws, its entire theoretical system—from basic assumptions to law derivation—exhibits a series of fundamental differences from the revised model presented in this paper, revealing deep-seated defects in its physical self-consistency.

3.5.1. Fundamental Differences in Physical Construction Pathways and Core Parameters

Although mathematically similar in the high-frequency region, the revised model and Planck's formula exhibit a series of irreconcilable, principled differences in their physical construction pathways, core parameters, and basic assumptions, analyzed in detail below.

(1) Drastically Different Physical Pictures and Radiation Mechanisms

The revised model, based on revised classical electrodynamics, presents a physical picture where numerous "electron-nucleus bound systems" within the blackbody cavity undergo thermal excitation, causing electrons to perform variable-speed (accelerating/decelerating) spiral motion. The continuous change in the electron's motion frequency leads to continuous energy radiation. Radiation is directly and continuously linked to changes in the electron's motion state. In contrast, the Planck model assumes the blackbody cavity walls consist of many independent "harmonic oscillators". Radiation originates from transitions between discrete energy levels of these oscillators, with energy exchange occurring instantaneously in integer multiples of the energy quantum $h\nu$, a process that is inherently non-continuous.

(2) Opposing Physical Natures of Core Parameters

In the revised model, the key introduced parameter ϵ is a minimum energy unit of measurement. Its numerical value equals the Planck constant h , but its physical essence is a unit of energy (J). Its role is analogous to "liters" or "seconds", used to measure the magnitude of a continuous energy flow, without altering the intrinsic continuity of the energy transfer process. In Planck's theory, the Planck constant h is the quantum of action, having the dimension of action (J·s). Its product with frequency, $h\nu$, is endowed with a new physical meaning – an indivisible discrete energy packet – implying that energy itself is assumed to be a granular physical entity.

(3) Fundamental Disagreement on the Physical Meaning of Key Variables (k vs. n)

This distinction lies at the core of the divergence between the two theories. In the derivation of the revised model, the key variable k is a positive integer with a clear physical meaning: it represents the number of energy measurement units ϵ transferred in a radiation process of frequency ν within a unit observation time ($\Delta t = 1\text{ s}$), satisfying the relation $\nu = k$. Therefore, k is an indicator describing the "intensity of the radiation process", and it corresponds one-to-one with the radiation frequency. In Planck's derivation, the key variable n is the "quantum number", indicating that the oscillator's energy is an integer multiple of its ground state energy $h\nu$, i.e., $E_n = n h\nu$. n is a quantum number identifying the "energy level state of the oscillator". The former (k) describes the measurement outcome of a dynamic process, while the latter (n) describes the discrete state of a static system.

(4) Essentially Opposed Origins of "Quantization"

This directly leads to completely different explanations for the origin of "quantization" phenomena. In the revised model, the appearance of energy in "packets" stems from the discreteness of measurement and process: Energy transfer is continuous, but because changes in electron frequency occur in units (Hz) as the minimum increment, statistically, energy accumulation and release naturally appear discrete based on the minimum measurement unit ϵ . This is akin to measuring a continuous water flow with a fixed-capacity bucket; the continuity of the flow remains unchanged. Conversely, Planck's theory attributes "quantization" to the discreteness of energy itself,

positing that energy is physically indivisible and infinite, with its fundamental unit being $h\nu$. This constitutes a complete overturning of the classical concept of energy continuity.

(5) Differences in Statistical Objects and Derivation Goals

Consequently, the objects over which the two theories perform mathematical summation (or integration) are also different. The revised model performs statistics on all possible radiation processes at different frequencies ν (i.e., all possible k values), aiming to calculate the average power $\langle P \rangle$ of these processes under thermal equilibrium. The Planck model, however, performs statistics on all possible discrete energy levels n of harmonic oscillators at the same fixed frequency ν , aiming to calculate that oscillator's average energy $\bar{E}$. The former directly handles the frequency spectrum, while the latter first handles the single-frequency energy distribution before extrapolating to the spectrum.

(6) Compatibility with the Classical Physics Framework

The ultimate manifestation of all the above differences is the fundamentally different relationship each theory has with classical physics. The entire construction of the revised model is completed within the classical physics framework (revised electrodynamics, Newtonian mechanics, continuous energy view, classical statistics) and is fully compatible with classical physics. It demonstrates that so-called "quantization" phenomena are statistical manifestations of classical laws under specific constraints. Planck's energy quantization hypothesis, from its inception, was fundamentally in conflict with classical physics. It forcibly broke the classical understanding of continuous energy change, thereby ushering in the era of quantum theory, which diverged from classical physics.

To clearly summarize these fundamental differences, a comparison table is provided below (Table 2):

Table 2. Essential Comparison between the Revised Model and Planck's Quantization Model.

Comparison Dimension	Revised Classical Electrodynamics Model	Planck's Quantization Model
Physical Picture	Radiation originates from continuous variable-speed motion (acceleration/deceleration) of electrons; frequency change leads to continuous energy radiation.	Radiation originates from transitions between discrete energy levels of cavity wall "harmonic oscillators"; energy exchange occurs in integer multiples of $h\nu$.
Core Parameter ϵ / h	ϵ is the minimum energy unit of measurement, the amount of continuous electromagnetic energy radiated per electron revolution during acceleration. Numerically equal to h , but it is an energy unit (J).	h is the quantum of action, with the dimension of action (J·s). Its product with frequency, $h\nu$, is regarded as a discrete energy packet.
Key Variable k / n	k represents the number of energy measurement units ϵ transferred in a radiation process of frequency ν within unit time (1 s), satisfying $\nu = k$. It is an indicator of process intensity.	n is a quantum number representing that the oscillator's energy is an integer multiple of the ground state energy $h\nu$, $E_n = n h\nu$. It is an identifier of energy level states.
Source of "Quantization"	Discreteness of Measurement and Process: The energy transfer itself is continuous, but electron frequency changes are counted in unit increments, causing energy to	Discreteness of Energy Itself: Energy is physically indivisible discrete packets (quanta), with the fundamental unit being $h\nu$.

	appear discrete statistically based on the measurement unit ε .	
Object of Summation/Integration	Statistics on all possible radiation processes at different frequencies ν (corresponding to all k) to calculate average power $\langle P \rangle$.	Statistics on all possible discrete energy levels n of harmonic oscillators at the same frequency ν to calculate average energy $\bar{E}$.
Relationship with Classical Continuity	Fully Compatible: The energy transfer process is continuous; discreteness appears only in measurement and statistical description, not breaking the classical physics framework.	Fundamentally Conflicting: The energy discretization hypothesis directly violates the basic principle of continuous energy change in classical physics.

The construction pathway of the revised model can be clearly described as based on statistics of classical continuous energy transfer:

When measured per unit time (1 s), $\nu = k$, the radiation energy density formula can be written as:

$$u(k,T) = g(k) \cdot \langle P \rangle = \frac{8\pi k^2}{c^3} \cdot \frac{\sum_{\varepsilon=0}^{\infty} \varepsilon \nu \cdot \exp(-\frac{k\varepsilon}{k_B T})}{\sum_{\varepsilon=0}^{\infty} \exp(-\frac{k\varepsilon}{k_B T})}$$

(3.13)

Here, ε appears as an energy unit of measurement, used to measure the energy flow in the continuous radiation process.

3.5.2. Fundamental Differences in Theoretical Structural Self-Consistency: Physical Applicability of Mode Density $g(\nu)$

The construction logic of the revised model is internally self-consistent. Its core physical picture is that radiation processes at various frequencies ν are directly generated within the blackbody cavity. The mode density formula $g(\nu)=\frac{8\pi^2}{c^3}$ here describes the distribution weight of radiation processes at different frequencies, and its physical meaning (frequency distribution) perfectly matches the statistical object (processes at different frequencies). Therefore, the energy density formula $u(\nu,T) = g(\nu) \cdot \langle P \rangle$ is seamlessly connected in theoretical structure.

The construction of Planck's formula, however, exhibits a significant logical discontinuity. Its core step is calculating the average energy $\bar{E}$ of a harmonic oscillator at a fixed frequency ν , which belongs to statistics of "different energy states at the same frequency". Yet, he subsequently multiplies this average energy directly by the classical formula $g(\nu)$, which describes the distribution of electromagnetic modes at different frequencies, to obtain the total energy density $u(\nu,T) = g(\nu) \cdot \bar{E}$. This essentially forcibly "grafts" two physical quantities with drastically different physical premises: $\bar{E}$ stems from the quantum hypothesis of "single-frequency energy level distribution", while $g(\nu)$ stems from the classical electromagnetic theory of "multi-frequency mode distribution". Although this grafting mathematically yields a result matching experiments, there is an inherent inconsistency in the connection of physical concepts. This defect further indicates that Planck's formula resembles more of a "hybrid model" constructed to fit data, rather than an inevitable result derived from a unified, self-consistent first-principles physics.

3.5.3. Re-Examining Theoretical Foundations from Empirical Laws: Analysis of the Derivations of Wien's Displacement Law and the Stefan-Boltzmann Law

The derivations of Wien's displacement law and the Stefan-Boltzmann law further highlight the relative strengths and weaknesses of the two theories at their foundations.

Difference in the Physical Interpretation of Wien's Displacement Law:

In Planck's theory, this law is interpreted as follows: an increase in temperature makes it easier for harmonic oscillators to occupy higher energy levels (increasing n), and higher energy levels correspond to larger energy quanta $h\nu$, thus shifting the radiation peak toward higher frequencies.

This interpretation entirely depends on the core assumption that "the same frequency ν corresponds to multiple discrete energy levels $n h\nu$ ". However, as discussed earlier, this assumption contradicts the fundamental physical fact revealed by our model—that "frequency ν uniquely determines the radiated power $P = \epsilon \nu$ ". It lacks support from microscopic motion mechanisms and appears more like a mathematical construct introduced to explain the phenomenon.

In the revised model, the physical interpretation of this law is direct and natural: the peak position is determined by the balance between energy supply and demand. High-frequency radiation requires higher power ($P = \epsilon \nu$), and only sufficiently high temperature (thermal energy $k_B T$) can effectively excite it. The physical picture is clear and requires no additional assumptions.

Dimensional and Logical Pitfalls in the Derivation of the Stefan-Boltzmann Law:

Planck's theory requires integrating $u_{\text{Planck}}(\nu, T)$ over the entire frequency domain. However, since the core component of $u_{\text{Planck}}(\nu, T)$, $\frac{8\pi h\nu^3}{c^3}$, has the dimension of momentum density (energy flux density) $[ML^{-1}T^{-1}]$, the physical meaning of the integral $\int u(\nu, T) d\nu$ is essentially ambiguous—it sums terms that are dimensionally inconsistent. Although mathematically, using the known integral $\int_0^\infty \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$ yields a neat T^4 law, the appearance of the π^4 factor in the constant σ within this framework is merely a mathematical coincidence lacking direct physical explanation.

In the revised model, since the dimensional self-consistency of $u(\nu, T) = g(\nu) \cdot \langle P \rangle$ is maintained throughout ($[L^{-3}T] \cdot [ML^2T^{-3}] = [ML^{-1}T^{-2}]$), the integration of this expression has a clear physical meaning: "summing the radiated energy of all frequencies per unit volume". The resulting T^4 law and its constant are natural products of the combination of classical mode distribution and the thermal statistics of continuous energy transfer. The entire derivation chain is logically rigorous and its physical interpretation is clear.

Conclusive Comparison: Planck's approach, by introducing the non-classical hypothesis of "energy discretization" and relying on mathematical constructs with dimensional and conceptual leaps, "calculates" the correct blackbody radiation formula and its corollaries, but its theoretical foundation contains inherent contradictions that cannot be reconciled. In contrast, the revised model presented in this paper demonstrates that, **without breaking the continuity and self-consistency of classical physics, it is sufficient to self-consistently derive all laws of blackbody radiation—including the elimination of the ultraviolet catastrophe, Wien's displacement law, and the Stefan-Boltzmann law—merely by clarifying the electron motion-radiation mechanism and adopting dimensionally strict, logically consistent statistical methods.** This not only fulfills Planck's unfulfilled wish for a classical explanation but also offers a new and more solid understanding of the essence of the "quantization" concept and its relationship with classical physics.

4. Discussion: Clarifying the Essence of Quantization and Comparing Ultraviolet Catastrophe Elimination Schemes

4.1. The Measurement Property of the Minimum Energy Unit and the Unity of Energy Continuity

In the revised theory, the minimum energy unit ϵ is a *pure unit of measurement* used to quantify the amount of continuous energy transfer corresponding to a change in electron frequency [3]. It is *not* a physically indivisible "energy packet" but rather the smallest measurable unit describing a continuous energy flow. Just as a continuous pool of water can be measured with "buckets" or "bowls", the continuity of energy is not disrupted by the introduction of measurement units.

This understanding preserves the continuity of energy exchange while explaining the phenomenon where energy appears to come in "packets" in experimental observations [4]. The essence lies in the discrete nature of frequency changes during electron variable-speed motion (each unit change in frequency corresponds to one measured unit of energy ϵ), not in the discreteness of energy itself. This core distinction allows the revised theory to unify the continuity of energy with "quantized" observations within the classical physics framework, avoiding the fundamental conflict between traditional quantum theory and classical physics [3].

4.2. Core Misunderstandings of the Quantization Concept in Physics

Since Planck proposed the energy quantum concept, the physics community's understanding of quantization has gradually deviated from its measurement essence, leading to a series of cognitive biases:

4.2.1. Misreading of Energy Discreteness

Planck expressed energy quantization as "energy comes in packets", but did not clarify that the essence of this statement is the discrete nature of the *measurement* of the energy transfer process, not the physical discreteness of energy itself [2]. Traditional quantum mechanics interprets $E = h\nu$ as "energy exists in discrete packets", overlooking the nature of Planck's constant as an action (unit $\text{J} \cdot \text{s}$) and confusing the physical meaning of "energy flow per unit time" with that of an "isolated energy packet" [3]. The revised theory clarifies that $E = h\nu$ actually describes the total energy absorbed or radiated by an electron per unit time, containing ν minimum measurement units ε , while the energy transfer process itself is a continuous spiral change.

4.2.2. The Fallacy of Discontinuous Electron Transitions

The Bohr atomic model proposed that electrons "jump instantaneously" between stationary orbits, assuming the transition requires no time and involves a sudden energy change [5]. This assumption stems from a misunderstanding of the electron motion mechanism: traditional theory mistakenly equates centripetal acceleration with linear acceleration, believing that an electron in uniform circular motion would continuously radiate energy, thus necessitating the introduction of "stationary state" and "instantaneous transition" hypotheses to explain atomic stability [3]. The revised theory points out that electrons in uniform circular or elliptical motion are in force equilibrium and do not radiate energy. The transition process is the continuous accelerated/decelerated motion of an electron between different energy levels, with frequency changing continuously with energy, radiating one measurement unit ε per unit frequency change, with no "instantaneous jump" involved [4]. The electron transition time is determined by the transition power ($\Delta t = k\varepsilon/P$). Although it appears instantaneous due to the very large ν during high-frequency radiation, it is essentially a continuous process [3].

4.2.3. Over-Interpretation of the Uncertainty Principle

The Heisenberg uncertainty principle is interpreted by traditional quantum mechanics as "the position and momentum of a microscopic particle cannot be measured simultaneously with precision", and extended to mean "the microscopic world is inherently uncertain" [6]. The root of this interpretation lies in the misunderstanding of the quantum concept: because ε is viewed as a discrete energy packet, the electron is abstracted as a "particle without a classical trajectory", making its motion state indescribable by precise classical quantities. Under the revised theory, electrons have well-defined classical trajectories (circular or elliptical), and their position and momentum can be precisely calculated using classical mechanics [3,4]. The so-called "uncertainty" is actually due to the interaction between the probe light (electromagnetic wave) and the electron during measurement, which causes a change in electron frequency and thus affects measurement accuracy—it is not an intrinsic property of the particle itself.

4.2.4. The Artificial Construction of the Chasm Between Classical and Quantum Physics

Traditional quantum mechanics defines "quantum phenomena" as microscopic phenomena inexplicable by classical physics, artificially delineating a boundary between macroscopic and microscopic physics [7]. The core basis for this division is the internal contradictions of the old quantum concept: it could neither explain electron orbital stability using classical electromagnetism nor integrate the quantization hypothesis into the classical framework. By clarifying the electron motion-radiation mechanism, the revised theory successfully explains all "quantum phenomena"—

such as hydrogen atom spectra, the photoelectric effect, and blackbody radiation—within the classical physics framework [3,4]. This demonstrates that so-called "quantum mechanical laws" are essentially specific manifestations of classical physical laws in microscopic systems, and that there is no inherent chasm between macroscopic and microscopic physics.

4.3. *Eliminating the Ultraviolet Catastrophe: Core Comparison Between This Revised Model and Planck's Scheme*

Although both Planck's energy quantization hypothesis and the classical revised model presented in this paper can eliminate the ultraviolet catastrophe and match experimental data, they differ fundamentally in physical essence, theoretical basis, and logical self-consistency, as detailed in the following comparison:

4.3.1. Differences in Core Assumptions and Physical Essence

The core of Planck's scheme is the "energy discreteness hypothesis": it posits that during the emission and absorption of electromagnetic radiation, energy itself is discontinuous and can only be transferred in basic units of $E = h\nu$ [2]. This hypothesis defines the "quantum" as a physically indivisible discrete energy packet, forcibly breaking the fundamental classical understanding of energy continuity, rendering it incompatible with classical electromagnetic and mechanical laws [3]. Planck himself admitted that this hypothesis was "an act of desperation" introduced to solve the blackbody radiation problem, lacking a deeper physical mechanism [2].

This revised model introduces no additional hypotheses; it is based entirely on the fundamental laws of classical physics: by clarifying the electron motion-radiation mechanism (no radiation in uniform motion, radiation only in variable-speed motion), it defines ε as a "unit of measurement" for energy transfer, not a "discrete energy packet" [1]. Energy itself remains continuous; the so-called "quantization" is merely the segmented description of a continuous energy flow during measurement—similar to using "seconds" to measure continuous time or "meters" to measure continuous length—without altering the essential continuity of the physical quantity. This model requires no break from the classical physics framework; its physical mechanism can be fully explained by foundational theories like Maxwell's equations and Newtonian mechanics [4].

4.3.2. Lack of Understanding of the Radiation Process and Power

A deeper physical cognitive flaw in Planck's quantum hypothesis lies in its complete neglect of the core dynamic concept of radiation power. In his model, the harmonic oscillator is abstracted as having only a series of discrete energy levels $E_n = nh\nu$. When the oscillator transitions between different levels, it absorbs or emits an energy packet of size $h\nu$ in an instantaneous and integral manner. This picture entirely sidesteps the fundamental physical question of "at what power (i.e., energy flow per unit time) is the energy transferred". The implicit assumption is that for a given frequency ν , the radiation processes performed by oscillators in different energy states ($n=1,2,3,\dots$) are identical; the only difference lies in the *number* of "energy packets", not in the intensity or temporal characteristics of the radiation process.

The consequence of this misconception is fatal. According to classical electrodynamics, the power with which a charged system radiates electromagnetic waves is proportional to the square of its acceleration and directly determines the radiation intensity. For a radiation process of frequency ν , its radiation power P is an intensity quantity with clear physical significance. Because Planck's model presupposes the instantaneous nature of energy transfer, it cannot accommodate the concept of "power", thereby severing the essential link between radiated energy and the dynamics of the electron motion that generates it. This reduces the "oscillator" in his model to an abstract entity possessing only states (energy levels) without concrete dynamical processes, disconnecting the occurrence of radiation from its internal motion mechanism.

In contrast, our revised model fundamentally re-establishes a direct and continuous connection between radiation power and frequency. As shown in Eq. (3.1) $P_k = \epsilon \nu$, in our physical picture, the instantaneous radiation power for a process of frequency ν is determinate and proportional to ν , with the proportionality constant being the minimum energy unit of measurement ϵ . This relationship stems from the classical image of an electron undergoing variable-speed spiral motion around the nucleus: the rate of change in the electron's frequency (acceleration or deceleration) directly determines the rate at which energy flows out continuously, i.e., the power. The frequency ν not only identifies the spectral property of the radiation but, through $P = \epsilon \nu$, also defines the intensity of the radiation process. High-frequency radiation inherently corresponds to high-power processes, which is precisely the physical reason why it is difficult to be thermally excited (requiring accumulation of high energy in a short time).

Therefore, the poverty of Planck's approach in terms of physical mechanism is reflected not only in introducing the inexplicable "discreteness of energy" but, more importantly, in its abandonment of the effort to describe the radiation process dynamically, replacing the dynamic "power" flow with a static "list of energy levels". Our revised model, by explicitly defining ϵ as a unit of measurement and establishing the core relationship $P = \epsilon \nu$, successfully unifies the frequency, power, and excitation probability of radiation within a self-consistent physical picture, all within the classical dynamical framework. This demonstrates, from another dimension, that eliminating the ultraviolet catastrophe does not necessarily require recourse to the quantization of energy itself but can be achieved by clarifying the dynamical nature of the radiation process (i.e., the constraint relationship between power and frequency) and applying correct statistical methods.

4.3.3. Differences in Theoretical Compatibility and Logical Self-Consistency

The core limitation of the Planck scheme is its inherent conflict with classical physics: the assumption of energy discreteness cannot explain why energy appears continuous in the macroscopic world, nor can it be reconciled with the fundamental principle in classical electromagnetism that "accelerating charges radiate electromagnetic waves" [3]. This conflict has directly led to the division of physics into two major systems: macroscopic classical physics and microscopic quantum mechanics, sparking a century-long debate over the interpretation of quantum mechanics (such as the Bohr-Einstein debates [1,2], the Schrödinger's cat paradox, etc. [8]).

The revised model proposed in this paper achieves perfect compatibility between classical physics and microscopic phenomena. On one hand, its electron motion-radiation mechanism fully adheres to the fundamental principles of electromagnetism and the law of energy conservation, without any logical contradictions. On the other hand, this model can be naturally extended to multiple microscopic scenarios, such as hydrogen atom structure, the photoelectric effect, and elliptical orbits of hydrogen-like atoms, all of which can be explained self-consistently within the classical framework [3,4]. By avoiding conflicts at the fundamental level, this model achieves a higher degree of logical self-consistency across multiple dimensions:

First, the continuity of the energy transfer process is preserved at the level of microscopic mechanisms. The appearance of "quantization" is merely a statistical manifestation due to the measurement unit ϵ , which naturally aligns with the continuous view of energy in the macroscopic world.

Second, in the theoretical derivation, the physical meanings of mode density $g(\nu)$ (describing the distribution of radiation processes across frequencies) and average power $\langle P \rangle$ (describing the intensity of these processes) are fully compatible. Their product, $(\nu, T) = g(\nu) \cdot \langle P \rangle$, forms a seamless and conceptually coherent definition of energy density. This avoids the logical fracture inherent in Planck's formula, where the "average energy of a single-frequency harmonic oscillator" is artificially grafted onto the "density of multi-frequency modes".

Finally, the entire derivation maintains strict dimensional consistency. From the fundamental assumptions to the final formula, it adheres to the norms of classical physics without introducing unconventional dimensional combinations or ad hoc mathematical treatments.

These advantages demonstrate that the revised model is not merely a patch to classical theory but a deep restoration of the physical mechanism behind blackbody radiation, based on a clarified understanding of electron motion-radiation dynamics. It achieves self-consistent compatibility with the classical physics framework and provides a new, solid conceptual foundation for unifying the understanding of macroscopic and microscopic physical phenomena.

4.3.4. Differences in Explaining High-Frequency Radiation Suppression Mechanisms

Planck's approach indirectly suppresses high-frequency radiation through the hypothesis of energy discreteness: since the energy quantum of high-frequency radiation, $E=h\nu$, increases with frequency, when $h\nu \gg k_B T$, thermal motion cannot provide sufficient energy to excite this discrete energy level, thereby avoiding high-frequency divergence [2]. However, this explanation does not clarify the origin of "energy discretization" from the perspective of classical physical mechanisms. Its derivation relies mathematically on the discrete summation of harmonic oscillator energies (similar in form to the summation in Eq. (3.3) of this paper, but with different physical implications) and is essentially a constraint hypothesis introduced to fit experimental data [3].

This revised model identifies the physical root cause of high-frequency radiation suppression: First, the energy-time constraint: high-frequency radiation requires $\Delta t_{min} = 1/\nu$. The higher the frequency, the shorter the time to complete one electromagnetic oscillation, while the upper limit of electron acceleration power $P_{max}=\epsilon v$ cannot increase indefinitely.

Second, the thermal excitation threshold: the total energy $\Delta E = k\epsilon$ required for high-frequency modes far exceeds the thermal energy $k_B T$, making it difficult for electrons to gain enough energy to achieve the frequency transition, naturally suppressing the radiation [3].

This explanation is based on clear physical processes, not mathematical assumptions, making it more persuasive.

4.3.5. Differences in the Scope of Explained Experimental Phenomena

Planck's scheme can only explain the overall shape of the blackbody radiation spectrum; it cannot explain the deeper mechanisms of other "quantum phenomena". For example, it cannot explain why electrons orbiting a nucleus do not spiral into it due to energy radiation, nor can it explain the phenomenon in the photoelectric effect where "low-frequency light can also produce a photoelectric effect under intense laser irradiation" [3].

This revised model has stronger universality: Beyond eliminating the ultraviolet catastrophe, it can also explain:

The line spectrum of hydrogen atoms (radiation frequency during electron transition is half the difference between two stationary state frequencies [3]),

The frequency threshold and light intensity dependence in the photoelectric effect (under strong light, an electron can absorb multiple measurement units ϵ simultaneously [3]),

The quantization of elliptical orbits in hydrogen-like atoms (energy levels are identical when the semi-major axis equals the circular orbit radius [4]),

and other phenomena. All these explanations are based on the same classical physics framework without introducing additional hypotheses.

4.4. An In-Depth Analysis of "Mathematical Similarity": Phenomenon, Mechanism, and Theoretical Construction

The revised blackbody radiation formula (3.7) of this model exhibits, in the high-frequency region ($h\nu \gg k_B T$), the same mathematical structure as the approximate form (3.12) of Planck's formula – an exponential decay of the form $\propto \nu^3 e^{-h\nu/k_B T}$. This mathematical convergence naturally raises the question: How can two theories based on fundamentally different physical assumptions yield identical expressions in a key limiting case? Does this imply their physical equivalence?

In fact, this convergence of mathematical form is not a coincidental accident but a typical manifestation in theoretical physics that the "same macroscopic phenomenon can be supported by different microscopic mechanisms". The core logic is that both the revised model and Planck's approach must capture the common physical reality of "high-frequency radiation being strongly suppressed by thermal motion". They achieve statistical convergence through different constraint mechanisms, yet their physical meanings and theoretical constructions are fundamentally distinct.

4.4.1. Planck's Scheme: The Constraint Logic of Discretized Energy Ontology

Planck's explanation for the high-frequency decay is rooted in the core assumption that "energy itself is discrete". Its logical chain is as follows:

It posits that the harmonic oscillators in the cavity wall can only occupy discrete energy levels $E_n = nh\nu$ (where n is the quantum number), meaning energy exchange must occur in integer multiples of the energy quantum $h\nu$.

In the high-frequency limit, the energy of a single quantum $h\nu$ is much greater than the characteristic thermal energy $k_B T$, making the probability of a resonator being thermally excited to levels $n \geq 1$ extremely low. This probability obeys the Boltzmann distribution $\propto e^{-h\nu/k_B T}$.

The mathematical form in the high-frequency region directly arises from summing a geometric series over the discrete quantum number n . Energy discreteness is imposed as an *a priori* constraint, essentially suppressing high-frequency contributions by "restricting the divisibility of energy".

The core flaw in this constraint logic is that the assumption of energy discretization lacks a supporting microscopic mechanism within classical physics. It was introduced as an *ad hoc* hypothesis to fit experimental data, leading to an irreconcilable conflict with the fundamental principle of classical electromagnetism that "accelerating charges radiate continuously".

4.4.2. The Revised Model: The Natural Outcome of Process Measurement Constraints and Dynamical Limitations

The high-frequency decay behavior in the revised model is the natural product of the combined effects of "continuous energy transfer + measurement constraints + dynamical limitations", requiring no non-classical assumptions:

Based on the microscopic mechanism of revised classical electrodynamics, electrons radiate energy continuously only during accelerated/decelerated motion. The quantity ε serves as an energy measurement unit, used solely to quantify the continuous energy flow corresponding to "a change of 1 unit in the electron's frequency". It does not alter the continuity of energy itself.

The core relation between radiation power and frequency, $P = \varepsilon \nu$ (Eq. 3.1), shows that high-frequency radiation inherently corresponds to a high-power process. To sustain radiation of frequency ν , a total energy of $\Delta E = h\nu$ must be transferred continuously per unit time.

When $\Delta E \gg k_B T$, the energy required for this high-power radiation process far exceeds what thermal motion can supply. Its thermal excitation probability obeys the Boltzmann distribution $\propto e^{-h\nu/k_B T}$, exhibiting exponential decay. Simultaneously, the energy-time constraint ($\Delta t_{min} = 1/\nu$) imposes an upper limit on the power for high-frequency radiation, $P_{max} = \varepsilon \nu$, which cannot increase indefinitely, further suppressing the excitation of high-frequency modes.

Here, the discreteness appears only in the description of measuring the continuous energy transfer process (with k as the count of measurement units), not as a physical property of the energy entity itself. Its constraint logic stems entirely from classical dynamical laws and thermal statistics, presenting no conflict whatsoever with the classical physics framework.

4.4.3. The Essence of Mathematical Convergence: The Universality of Thermal-Statistical Constraints

The reason the two theories exhibit convergence in mathematical form in the high-frequency region lies in their shared core thermal-statistical constraint: Whether energy is conceptualized as

"discrete packets" or as a "continuous flow", high-frequency radiation must acquire an energy $\Delta E = h\nu$ from the thermal bath, overcoming the thermodynamic potential barrier of $k_B T$. Its excitation probability is therefore inevitably suppressed by the exponential factor $e^{-h\nu/k_B T}$. This exponential form is a universal characteristic of thermal equilibrium systems, independent of the intrinsic nature of energy, reflecting only the statistical rule that "high-energy states have a low probability of excitation".

The mathematical similarity precisely highlights a crucial insight: The high-frequency cutoff behavior of blackbody radiation cannot uniquely prove the "quantization of energy itself". It can equally emerge naturally from a classical framework that insists on energy continuity while acknowledging "process measurement constraints and dynamical limitations". This conclusion challenges the traditional view that regards the success of Planck's formula as decisive evidence for "energy quantization", revealing the essential distinction between phenomenological fitting and mechanistic explanation.

4.4.4. Divergence in Theoretical Construction: Self-Consistency vs. Physical Foundation

Despite their convergence in mathematical form, the two theories exhibit a fundamental divergence in the quality of their construction logic:

Planck's scheme is a "phenomenon-fitting-oriented" hybrid model: It achieves mathematical agreement with experimental data by grafting the "classical mode density" onto a "quantized average energy". However, this approach suffers from conceptual discontinuity and dimensional inconsistency, and it fails to explain the microscopic origin of energy discretization.

The revised model is a "mechanism-reduction-oriented" self-consistent theory: It begins from the microscopic mechanism of electron motion-radiation and naturally derives its results through the combination of classical statistics and measurement constraints. It requires no *ad hoc* assumptions, maintains strict dimensional consistency throughout its logical chain, and can uniformly explain multiple "quantum phenomena" such as hydrogen atomic spectra and the photoelectric effect [3]. It thus possesses stronger theoretical universality and a more solid physical foundation.

In conclusion, the similarity of mathematical form in the high-frequency region reflects the universality of thermal-statistical constraints, not an equivalence in physical essence. The core value of the revised model lies in providing a more self-consistent and physically rooted explanation for the "quantized" observational features of blackbody radiation without breaking the classical physics framework. It demonstrates that so-called "quantum phenomena" may not necessarily arise from the discreteness of energy itself but could instead be statistical manifestations of classical laws under specific constraints.

4.5. Scientific Significance of This Work: Re-Examining the Origin of Quantum Mechanics and the Return of Physics

Planck introduced the concept of the energy quantum to solve the blackbody radiation problem, intending it as a "last resort" mathematical assumption. However, later interpretations recast it as "the discreteness of energy itself", and upon this foundation, a quantum theory fundamentally at odds with classical physics was constructed. While this interpretation gave rise to formal mathematical success, it also led to blurred physical imagery, conceptual fragmentation, and a series of interpretational dilemmas.

The core scientific significance of this work lies in providing a fundamentally different and more self-consistent physical interpretation of the origin of the "quantum":

(1) Unraveling the True Mystery of the "Quantum": We make a clear distinction between "measurement discreteness" and "physical discreteness". The "packet-like" appearance of energy in blackbody radiation stems from the statistical outcome of measuring a continuous energy flow using the minimum unit ϵ , analogous to using fixed containers to measure a continuous stream of water. This reveals that the essence of so-called "quantization" is the discretization of the description, not the discretization of physical reality.

(2) Fulfilling Planck's Unrealized Aspiration: Throughout his life, Planck sought a classical root for the energy quantum [2]. Our model achieves precisely this without introducing any non-classical assumptions. By clarifying the dynamical mechanism of electron motion and radiation (radiation occurs only during acceleration/deceleration) and introducing ε as a measurement benchmark, we naturally derive a blackbody radiation spectrum consistent with experiments from classical statistics. This accomplishes the academic goal Planck pursued: explaining quantum features within a classical framework.

(3) Demonstrating the Completeness of the Classical Framework: The model presented here not only eliminates the ultraviolet catastrophe but its theoretical framework (revised classical electrodynamics) has also been successfully applied to explain a series of so-called "quantum phenomena" such as hydrogen atom spectra, the photoelectric effect, and the quantization of electron orbits [3,4]. This strongly suggests that classical physics itself possesses the capacity to describe the microscopic world. What are called "quantum mechanical laws" are likely misunderstandings or inappropriate formulations of the statistical features that classical laws exhibit under specific constraints.

(4) Charting a New Path for the Unification of Physics: A profound chasm currently exists in physics between the macroscopic (classical) and microscopic (quantum) realms. Through a concrete and fundamental example—blackbody radiation—this work demonstrates that this divide is not inherent to nature but rather an artificial fissure caused by erroneous theoretical assumptions. Our research provides a viable theoretical path and empirical case for bridging this fissure and reconstructing a unified physical theory on a self-consistent classical foundation.

Therefore, this paper is not merely a specific theoretical revision concerning blackbody radiation; it is a significant reflection on the foundations of physics. It calls upon the academic community to re-examine the conceptual bedrock of quantum mechanics and to re-anchor the direction of physics' development in the classical rational tradition—one characterized by logical self-consistency, conceptual clarity, and a connection to objective mechanisms.

5. Conclusion

This paper systematically reveals the three fundamental defects in the physical assumptions and mathematical derivation of the Rayleigh-Jeans formula. Based on our proposed revised classical electrodynamics theory [3,4], and under the strict adherence to the continuity of energy and the classical physics framework, we successfully derive a blackbody radiation formula that fully matches experimental data. This is achieved by elucidating the continuous mechanism of electron acceleration/deceleration radiation and introducing the minimum energy unit ε as a measurement benchmark for the process. Consequently, the ultraviolet catastrophe is completely eliminated at the level of physical mechanism.

Compared to Planck's scheme based on the assumption of energy discretization, the model presented in this paper possesses fundamental advantages: it requires no overturning of the classical view of energy continuity, no introduction of processless assumptions such as "instantaneous jumps", and its theoretical construction maintains dimensional self-consistency and conceptual coherence without logical grafting. Its success strongly proves that the "quantized" features exhibited by the blackbody radiation spectrum do not arise from the discontinuity of energy itself but from the macroscopic statistical behavior of continuous energy transfer processes subject to a universal minimum measurement unit.

The significance of this study extends far beyond resolving a historical problem; it marks the beginning of a profound reflection and systematic revision of the foundations of modern physics:

(1) It clarifies a century-long misunderstanding of the "quantum" concept, restoring "quantization" from a mysterious, anti-classical attribute of "physical discreteness" to the clear and comprehensible "discreteness of measurement and process". This removes the core conceptual obstacle to explaining all microscopic "quantum phenomena" classically.

(2) It fulfills Planck's unrealized desire for a classical explanation by demonstrating that even in the "birthplace" of quantum theory—blackbody radiation—no non-classical discretization assumptions are necessary, as the self-consistent framework of classical physics suffices to provide a complete explanation.

(3) It offers a classical paradigm for the unified understanding of the microscopic world. The model presented here, along with its successful applications in hydrogen atomic spectra, the photoelectric effect, quantization of electron orbits, and other areas [3,4], collectively forms a coherent microscopic physical theory system based on revised classical electrodynamics. This system indicates that the so-called "classical-quantum divide" is not an inevitable law of nature but stems from the misunderstanding of the electron motion-radiation mechanism in previous theories.

The revised concept of the energy quantum established in this work has become the cornerstone for constructing more unified theories (such as the "Great Tao Model" [9]), opening a clear path for thoroughly understanding the physical laws from microscopic particles to the macroscopic universe within the classical framework. The reexamination of blackbody radiation theory in this paper further clarifies the conceptual issues at the source of Planck's energy quantum concept and the quantization hypothesis, fundamentally challenging the logical starting point of traditional quantum theory and providing crucial theoretical support for the return of physics to a self-consistent and unified classical explanatory system.

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