THE $\mathbf{B}^{(3)}$ FIELD: ITS ROLE IN THE RAYLEIGH-JEANS LAW, PLANCK LAW, AND EINSTEIN COEFFICIENTS

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The role of the novel longitudinal vacuum field $\mathbf{B}^{(3)}$ is discussed in relation to fundamental radiation laws: the Rayleigh-Jeans law; the Planck law; and the Einstein coefficients. The circular index (3) of $\mathbf{B}^{(3)}$ causes electromagnetic energy density to be redistributed from the other indices (1) and (2) of the circular basis, but the presence of $\mathbf{B}^{(3)}$ in the vacuum does not change the value of the Planck constant $\hbar$. The $\mathbf{B}^{(3)}$ field does not affect, furthermore, the understanding of quantized radiation absorption first proposed by Einstein. Therefore, the experimental observable $\mathbf{B}^{(3)}$ does not imply modification of these fundamental, radiation laws, and experimental isolation of $\mathbf{B}^{(3)}$ must take place through its characteristic square root power density dependence when used to magnetize an electron plasma.

~~Keywords: $\mathbf{B}^{(3)}$ Field, Fundamental laws~~

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1. INTRODUCTION

The emergence ~~[1–9]~~ (1-9) of the novel longitudinal magnetic flux density, $\boldsymbol{B}^{(3)}$, of electromagnetic radiation in the vacuum means that a systematic re-appraisal must take place of the various branches of contemporary field theory in order to check that $\boldsymbol{B}^{(3)}$ is not in conflict with experimentally verifiable laws. Much of this has been reported in detail elsewhere, ~~[1–9]~~ (1-9), but in this Letter, we demonstrate that $\boldsymbol{B}^{(3)}$ does not affect the Rayleigh-Jeans law, Planck law, and Einstein coefficients. For example, the value of the Planck constant remains the same when $\boldsymbol{B}^{(3)}$ is taken into account, because $\boldsymbol{B}^{(3)}$ simply causes the total electromagnetic energy density to be *redistributed* among the indices (1), (2), and (3) of the complex circular basis used to represent three-dimensional space. Section 2 discusses the effect of $\boldsymbol{B}^{(3)}$ on the classical Rayleigh-Jeans law; Sec~~tion~~. 3 deals with the Planck law, and Sec~~tion~~. 4 with the fundamental law of absorption of quantized electromagnetic radiation as described in the Einstein coefficients.

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2. THE EFFECT OF $\boldsymbol{B}^{(3)}$ ON THE RAYLEIGH-JEANS LAW

The classical Rayleigh-Jeans law is based on the representation [10] of electromagnetic radiation by an ensemble of radiation oscillators, each one corresponding to a frequency. The classical, defining algebra of $\mathbf{B}^{(3)}$ is based on the cyclically symmetric relation between components of the magnetic flux density of vacuum electromagnetic radiation:

$$\mathbf{B}^{(1)} \times \mathbf{B}^{(2)} = iB^{(0)}\mathbf{B}^{(3)*}, \quad \mathbf{B}^{(2)} \times \mathbf{B}^{(3)} = iB^{(0)}\mathbf{B}^{(1)*}, \quad \mathbf{B}^{(3)} \times \mathbf{B}^{(1)} = iB^{(0)}\mathbf{B}^{(2)*}, \tag{1}$$

Here $\mathbf{B}^{(1)} = \mathbf{B}^{(2)*}$ is a plane wave represented in a circular basis (1-9) ~~[1-9]~~, or representation, of three-dimensional space:

$$\mathbf{B}^{(1)} = \frac{B^{(0)}}{\sqrt{2}}(i\mathbf{i} + \mathbf{j})e^{i\phi}, \tag{2}$$

where the unit vectors of the circular basis are related to the usual $\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$ unit vectors of the Cartesian basis by

$$\mathbf{e}^{(1)} = \mathbf{e}^{(2)*} = \frac{1}{\sqrt{2}}(\mathbf{i} - i\mathbf{j}), \quad \mathbf{e}^{(3)} = \mathbf{k}. \tag{3}$$

Here $B^{(0)}$ is the scalar flux density amplitude of the electromagnetic plane wave in the vacuum, and ϕ is the electromagnetic phase

$$\phi = \omega t - \boldsymbol{\kappa} \cdot \mathbf{r}, \tag{4}$$

where ω is the angular frequency and $\boldsymbol{\kappa}$ the wave vector at an instant t and position $\mathbf{r}$ in space. The algebra (1) vector multiplies $\mathbf{B}^{(1)}$ with its complex conjugate $\mathbf{B}^{(2)}$ to form the physical spin field $\mathbf{B}^{(3)}$, which has no dependence on ϕ. In nonlinear optics, (7) ~~[7]~~, $\mathbf{B}^{(1)} \times \mathbf{B}^{(2)}$ is the conjugate product, the experimental observable basically responsible for magneto-optic effects such as the inverse Faraday effect, (11) ~~[11]~~, at second order in $B^{(0)}$.

The radiation oscillator must therefore be associated at each angular frequency ω for a radiation volume V, by the total energy density,

$$
\begin{aligned}
U &= \frac{1}{\mu_0}\mathbf{B}\cdot\mathbf{B} \\
&= \frac{1}{\mu_0}\left(\mathbf{B}^{(1)}\cdot\mathbf{B}^{(1)*} + \mathbf{B}^{(2)}\cdot\mathbf{B}^{(2)*} + \mathbf{B}^{(3)}\cdot\mathbf{B}^{(3)*}\right)
\end{aligned}
\tag{5a}
$$

(thin #)

$$\hbar\omega = \int U dV \tag{5b}$$

which is split into three components involving $\mathbf{B}^{(1)}$, $\mathbf{B}^{(2)}$, and $\mathbf{B}^{(3)}$ in the circular basis at each frequency. Obviously, $\mathbf{B}^{(3)}$ is not explicitly dependent on ω, but is implicitly dependent through its definition in terms of $\mathbf{B}^{(1)}$ and $\mathbf{B}^{(2)}$, which are both ω dependent. In the pre-$\mathbf{B}^{(3)}$ description, Eq. (5a) is represented by only two indices, (1) and (2):

$$\underline{U} = \frac{1}{\mu_0}(\boldsymbol{B}^{(1)} \cdot \boldsymbol{B}^{(1)*} + \boldsymbol{B}^{(2)} \cdot \boldsymbol{B}^{(2)*}) \tag{6}$$

It is of key importance to realize, however, that the following occurs when the sense of circular polarization (handedness) is switched from right (+) to left (-):

$$\boldsymbol{B}_+^{(1)} = \boldsymbol{B}_+^{(2)*} \rightarrow \boldsymbol{B}_-^{(1)} = \boldsymbol{B}_-^{(2)*} = \frac{B^{(0)}}{\sqrt{2}}(-i\boldsymbol{i} + \boldsymbol{j})e^{i\phi}$$
$$\boldsymbol{B}_+^{(3)} \rightarrow -\boldsymbol{B}_-^{(3)} . \tag{7}$$

Therefore the total field is defined in right circular polarization by three circular indices:

$$\boldsymbol{B}_+ = \boldsymbol{B}_+^{(1)} + \boldsymbol{B}_+^{(2)} + \boldsymbol{B}_+^{(3)} \tag{8}$$

and the total field in left circular polarization is *also* defined by three circular indices:

$$\boldsymbol{B}_- = \boldsymbol{B}_-^{(1)} + \boldsymbol{B}_-^{(2)} + \boldsymbol{B}_-^{(3)} \tag{9}$$

The premultiplier (factor of ~~two~~ 2) in the density of states calculated from the Rayleigh-Jeans law is therefore still *two* in the presence of $\boldsymbol{B}^{(3)}$, the fundamental reason being that electromagnetic radiation propagating in $\boldsymbol{e}^{(3)} = \boldsymbol{k}$ can spin either clockwise or anticlockwise, giving two senses of circular polarization.

We refer therefore to *two senses of circular polarization* (+ and -, or right and left) and to *three circular* *indices*, (1), (2), and (3), of a complex representation of three-dimensional space.

The Rayleigh-Jeans law determines the number density of oscillators with frequencies in the range ω to $\omega + d\omega$. For each oscillator there are two senses of circular polarization *each* of which is described by three circular indices, the former being properties of the wave and the latter properties of 3-D space. Each sense of polarization is physically distinct, and for each sense of polarization there exists the algebra (1). The two physically distinct senses of circular polarization therefore determine the premultiplying factor of ~~two~~ 2 in the Rayleigh-Jeans equation for the density of states:

$$dN = \frac{8\pi\nu^2}{c^3} d\nu \tag{10}$$

where ν is the frequency of the wave and c the conventional vacuum velocity of light. The existence of $\boldsymbol{B}^{(3)}$ does not therefore affect Eq. (10) for the density of states, but $\boldsymbol{B}^{(3)}$ does of course introduce a third index (3), which means that it is *longitudinally* directed in the vacuum. Unfortunately, the literature (12) ~~[12]~~ often refers to this as a *longitudinal polarization*, whereas $\boldsymbol{B}^{(3)}$ is an axial, or pseudo, vector which is directed in the $\boldsymbol{k}$ or $\boldsymbol{e}^{(3)}$ propagation axis of the beam, and is more properly referred to as a longitudinally directed pseudo vector. For this reason, we refer to it (1-9) ~~[1-9]~~ as the spin field of vacuum electromagnetism, in contrast to the plane *waves*, $\boldsymbol{B}^{(1)} = \boldsymbol{B}^{(2)*}$, which are transverse. When the sense of circular polarization of the beam is switched from right to left, $\boldsymbol{B}^{(3)}$ changes sign, but obviously remains a pseudo vector.

In the same way, the direction of an angular momentum pseudo vector is reversed when the sense of rotation is reversed, and it can be shown (1-9) ~~[1-9]~~ that $\boldsymbol{B}^{(3)}$ is directly proportional to beam (or photon) angular momentum. For one photon in the vacuum, this is well known to be simply $\hbar$, the Dirac constant, and for a given beam intensity, $\boldsymbol{B}^{(3)}$ is constant in the same way that $\hbar$ is constant.

3. THE EFFECT OF $\boldsymbol{B}^{(3)}$ ON THE PLANCK RADIATION LAW

The Planck hypothesis of November, 1900 (10) ~~[10]~~ asserts that a radiation oscillator can possess only discrete energies, measured in quanta, $\hbar\omega$, of radiation energy. The quantum $\hbar\omega$ is of course the dictionary definition of the photon (13) ~~[13]~~. The effect of $\boldsymbol{B}^{(3)}$ is to change the mathematical expression of the Planck hypothesis for one photon from:

$$\hbar\omega = \frac{1}{\mu_0}\int(\boldsymbol{B}^{(1)}\cdot\boldsymbol{B}^{(1)*} + \boldsymbol{B}^{(2)}\cdot\boldsymbol{B}^{(2)*})dV \tag{11}$$

to

$$\hbar\omega = \frac{1}{\mu_0}\int(\boldsymbol{B}^{(1)}\cdot\boldsymbol{B}^{(1)*} + \boldsymbol{B}^{(2)}\cdot\boldsymbol{B}^{(2)*} + \boldsymbol{B}^{(3)}\cdot\boldsymbol{B}^{(3)*})dV \tag{12}$$

Thus, classical electromagnetic energy density is expressed as a sum over three circular indices instead of two, *but the total available energy density is the same*; it has simply been redistributed mathematically among three components of $\boldsymbol{B}$ rather than two. The numerical value of the right-hand sides of Eqs. (11) and (12) are the same, and the Planck constant $\hbar$ is unchanged. The photon (the quantum of electromagnetic energy) also remains the same, and there is no change in the Planck radiation law (14) ~~[14]~~:

$$dU = \frac{8\pi h\nu^3}{c^3}\left(\frac{e^{-h\nu/kT}}{1 - e^{-h\nu/kT}}\right)d\nu \tag{13}$$

The total energy density of black body radiation is obtained ~~[14]~~ by integrating dU over all frequencies. Since $\hbar\omega$ is redistributed among three circular indices, so is black body radiation, but it is not possible to isolate the specific effect of $\boldsymbol{B}^{(3)}$ from that of $\boldsymbol{B}^{(1)} = \boldsymbol{B}^{(2)*}$ simply through the study of black body radiation. The experimentally measurable quantity obviously remains the same, but our *understanding* of it has been extended to include $\boldsymbol{B}^{(3)}$. The specific effect of $\boldsymbol{B}^{(3)}$ must be measured through its ability (6,8) ~~[6, 8]~~ to magnetize an electron plasma. The measurable magnetization is expected to be proportional to the *square root* ($I_0^{1/2}$) of the beam power density (i.e., its intensity I_0) in watts per square meter under well-defined and experimentally accessible conditions (15) ~~[15]~~. This is a direct result (6,8) ~~[6, 8]~~ of the classical Hamilton-Jacobi equation of motion of one electron in a circularly polarized electromagnetic beam.

4. EFFECT OF $\boldsymbol{B}^{(3)}$ ON THE EINSTEIN COEFFICIENTS AND THE PROCESS OF ABSORPTION

The equilibrium between radiation and matter was shown by Einstein to be made up of several distinguishable processes, described by the well-known Einstein coefficients (14) ~~[14]~~. The rate of absorption of electromagnetic radiation is described in terms of the Einstein B coefficient:

$$W_{f \leftarrow i} = B_{if} \rho \tag{14}$$

angle bracket

From an initial quantum state $|i\rangle$ to a final quantum state of higher energy $|f\rangle$. Here ρ is the energy density of at the absorption frequency ν_{fi}. The energy density of states in this expression must be evaluated at the transition frequency. For electric dipole transitions $W_{f\leftarrow i}$ is proportional to $En(\nu)\hat{\rho}_N/V$, where $En(\nu)$ is the energy of the field at frequency ν and $\hat{\rho}_N$ is the frequency density of states for a given volume V occupied by the electromagnetic radiation. The specific effect of $\boldsymbol{B}^{(3)}$ on these calculations is as in Sec~~tion~~s 2 and 3, to cause the electromagnetic energy to be mathematically redistributed among three circular indices without changing its numerical value. As argued in Sec~~tion~~ 2, the density of states is unaffected by $\boldsymbol{B}^{(3)}$, and so the rate of absorption $W_{f\leftarrow i}$ is also unaffected.

We conclude that the absorption of a photon of energy $\hbar\omega$ by an atom at a frequency ν_{fi} defined by a transition from $|i\rangle$ to $|f\rangle$ is affected by $\boldsymbol{B}^{(3)}$ only insofar as ~~that~~ the definition of $\hbar\omega$ is modified by $\boldsymbol{B}^{(3)}$ as in Eq. (12). The angular momentum conservation rules which apply (14) ~~[14]~~ in the absorption of a photon are not changed by the existence of $\boldsymbol{B}^{(3)}$, which is already proportional to the intrinsic (or spin) angular momentum of the photon, $\hbar$. Since $\boldsymbol{B}^{(3)}$ is not directly visible through any of the phenomena of absorption in spectroscopy, and since its characteristic $I_0^{1/2}$ profile (6, 8) ~~[6, 8]~~ can be isolated only under specific conditions, it has evaded experimental detection to date except insofar as it contributes at second order in magneto-optics through the conjugate product, (1-9) ~~[1-9]~~, which is now recognizable as $iB^{(0)}\mathbf{B}^{(3)}$. For these reasons we have referred to it in the past (9) ~~[9]~~ as the *ghost field*, but the terminology *spin field* is more transparent even than a ghost.

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