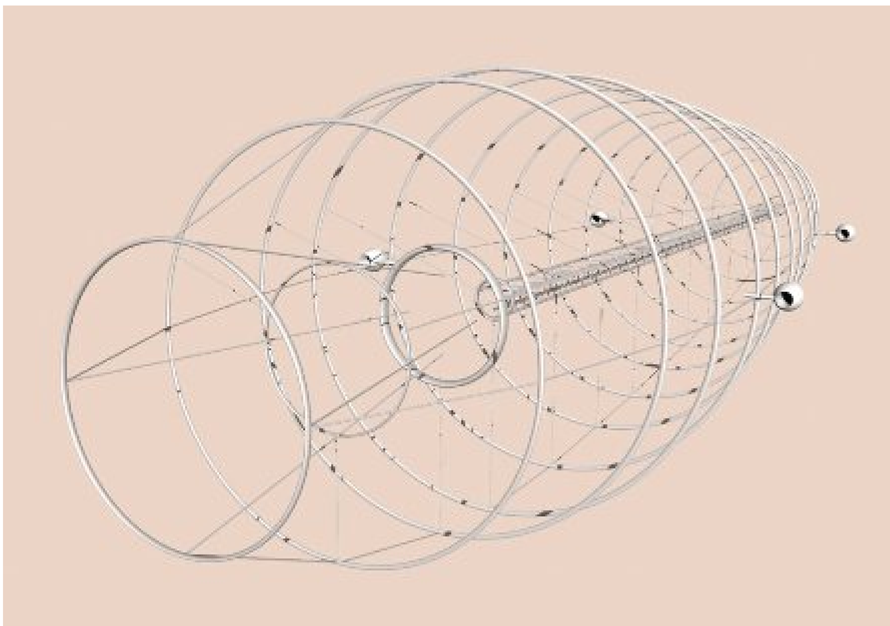
# THE PHOTON DEMYSTIFIED



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**THE-FOUNDATION-IS-THE-FRONTIER-SERIES**

Essays on Twenty-first Century Physics

**The following article is based on a paper documented in an online journal in June/July 2001*, following a five year-long and unsuccessful struggle to publish it in the standard journals of the physics establishment. It is presented here again in a clear, concise form.**

**Through certain circumstances Princeton physicist Russell M. Kulsrud – a renowned expert in the field – came to study the paper most diligently. Upon my last contact with him, he agreed that I issue the following statement on his study**:**

**"To this author's knowledge, the only sincere and objective attempt to examine the paper has been conducted by R. M. Kulsrud of Princeton University (Kulsrud, 2001; personal communication), a recognized authority in EM Theory. However, in spite of a detailed and lengthy study, he has been unable to reach any definitive conclusions. His current opinion, quoted here with his permission, is that neither he has been able to disprove the idea nor has this author been able to prove it."**

*http://www.journaloftheoretics.com/articles/3-3/bibhas-pub.htm
**http://www.bibhasde.com/kulsrud.html;
See also http://www.bibhasde.com/crux.html

## I. INTRODUCTION

The photon is the sole constituent of light. Light is electromagnetic wave. Therefore, the photon is made of electromagnetic fields. When the photon is at rest and there are no time variations, the electromagnetic fields reduce to just static magnetic field or static electric field.

I examine below my idea that the photon at rest is made of static magnetic field. I show that the photon is a very specific thing - as specific a thing as the frame of a dirigible airship. The photon is a free-floating structure ("frame") made of a constituent substance ("steel".)

## II. CONSTRUCTION STEP I: THE STRUCTURE $\Sigma_o$

First we look for a magnetic structure that is source-free and force-free. Therefore, the magnetic field **b** there must satisfy the following conditions:

(i) The Maxwell's equation $\nabla.\mathbf{b} = 0$;

(ii) For a force-free and stress-free structure, $\partial\mathbf{b}/\partial t = 0$;

(iii) Hence from Maxwell's equations $\nabla x\mathbf{b} = 0$;

(iv) **b** is uniquely defined everywhere; and

(v) $b \neq \pm \propto$; $b \rightarrow 0$ at large distances in every direction.

Clearly, **b** = 0 everywhere can be considered a trivial "structure" satisfying the above conditions. But we look for a solution with nonzero b.

In cylindrical coordinates with no $\phi$-dependence, the conditions (i)-(iii) above can be expressed as two equations:

$$\partial^2 b_z/\partial r^2 + (\partial b_z/\partial r)/r = - \partial^2 b_z/\partial z^2 \qquad (1)$$

$$\partial^2 b_r/\partial r^2 + (\partial b_r/\partial r)/r - b_r/r^2 = - \partial^2 b_r/\partial z^2 \qquad (2)$$

for which an exact solution $\Sigma_o$ can be found in terms of the Bessel functions $J_o$ and $J_1$:

$$b_{zo} = b_o J_o(\gamma r) e^{\pm\gamma z} \qquad (3)$$

$$b_{ro} = b_o J_1(\gamma r) e^{\pm\gamma z} \qquad (4)$$

$$b_{\phi o} = 0. \qquad (5)$$

For the purpose of the present paper it is not necessary to ask how $\Sigma_o$ is created. However, if one wishes to make $\Sigma_o$ conform to the aforementioned theorems, one must postulate sources of infinite strength and infinite extent at infinity.

## III. CONSTRUCTION STEP II: THE STRUCTURE $\Sigma_1$

So the above solution satisfies condition (iv), but violates condition (v). But one can devise *ad hoc* methods of overcoming this mathematical roadblock. My method is as follows: By taking instead $\Sigma_o$ with the minus sign (of the exponent) in the upper half space and with the plus sign in the lower half space, a "truncation" structure $\Sigma_1$ satisfying condition (v) is found:

$$b_{z1} = b_o J_o(s\alpha r) e^{-s\alpha z} \tag{6}$$

$$b_{r1} = b_o J_1(s\alpha r) e^{-s\alpha z} \tag{7}$$

$$b_{\phi 1} = 0, \tag{8}$$

with $s = z/|z|$ a shorthand notation, and $\alpha$ an arbitrary, positive real quantity. At the z = 0 plane - the boundary plane - the field $b_{z1}$ is continuous, but $b_{r1}$ flips sign. Thus the act of truncation generates a sheet current (with $\mu_o$ = the permeability of free space.):

$$\mathbf{I}_\phi = (2b_o/\mu_o) J_1(\alpha r)\, \delta(z)\, \mathbf{a}_\phi. \tag{9}$$

## IV. CONSTRUCTION STEP III: THE STRUCTURE $\Sigma_2$

As a separately standing problem, the exact solution for the field structure $\Sigma_2$ generated by a prescribed source current $\mathbf{I}_\phi$ can be calculated in terms of the potential $\mathbf{A}_{\phi 2} = A_{\phi 2}\mathbf{a}_\phi$, and is found to be [1]:

$$b_{z2} = (1/r)\, \partial(rA_{\phi 2})/\partial r \tag{10}$$

$$b_{r2} = - \partial A_{\phi 2}/\partial z \tag{11}$$

$$b_{\phi 2} = 0 \tag{12}$$

$$A_{\phi 2}(r,z) = (b_o/\pi) \int_o^\infty \{[(2-k^2)K(k) - 2E(k)] / [k(rR)^{1/2}]\}\, J_1(\alpha R)\, R\, dR \tag{13}$$

Here $k^2 = 4rR/(R^2 + r^2 + z^2 + 2rR)$, and K(k) and E(k) are the complete elliptical integrals of the First and the Second kind [2]. Since $\mathbf{I}_\phi$ has a delta-function behavior and since the above solution is exact at every point in space for which $z \neq 0$, it follows that $b_{r2}(r, z \to \pm 0) = b_{r1}(r, z = \pm 0)$, and that therefore $b_{z2}(r, z \to \pm 0)$ is a finite quantity. Thus:

$$b_{r2}(r, z \to \pm 0) = b_{r1}(r, z = \pm 0) \tag{14}$$

$$b_{z2}(r, z \to \pm 0) \neq \propto. \tag{15}$$

## V. CONSTRUCTION STEP IV: THE STRUCTURE $\mathbf{\Sigma} = \mathbf{\Sigma}_1 \sim \mathbf{\Sigma}_2$

I now propose that the structure $\Sigma$ we started out to find is the vector subtraction of the two magnetic structures. Symbolically:

$$\mathbf{\Sigma} = \mathbf{\Sigma}_1 \sim \mathbf{\Sigma}_2$$

This superposition of $\Sigma_1$ and $\Sigma_2$ causes $\mathbf{I}_\phi$ to vanish identically, leaving the source-free solution $\Sigma$:

$$b_z = b_{z1} - b_{z2} \tag{16}$$

$$b_r = b_{r1} - b_{r2} \tag{17}$$

$$b_\phi = 0 \tag{18}$$

with $b_z\ (r, z = 0)$ finite and continuous through the $z = 0$ plane, and $b_r\ (r, z = 0) = 0$. No singularities or discontinuities remain across this plane (Cf. Eqs. (14) and (15)). The above geometry satisfies all the conditions in Section II *and now stands independently of the method employed in constructing it*. Any conceptual or intuitive difficulties one has with that method itself are therefore now irrelevant. For instance, it is unnecessary to discuss how the structures $\Sigma_o$ and $\Sigma_1$ are created.

The structure $\Sigma$ may assume other geometric forms as well (obtainable by replacing the Bessel functions in Eqs. (3)-(5) by other suitable functions, or by a superposition of Bessel functions).

Now it only remains to demonstrate that $\Sigma_1 \neq \Sigma_2$ so that we end up with a structure where the magnetic field is not zero everywhere.

There are different ways to approach this question. First, we address the issue of numerical computation. Based on my first-hand experience with electromagnetic computations, I know that this is a tricky problem, not the least because of the oscillating functions. If one were to try to demonstrate that b = 0 everywhere, he will not be able to do so unless he interprets his nonzero residuals as artifacts of computation. If one were to demonstrate that b is finite in places, others may suggest that these are residual numbers resulting from computational accuracy. Such "I am not convinced"-type of assertions cannot be easily resolved. Therefore, it is not a good idea to adopt numerical computation as the primary proof. That leaves us with analytical methods.

## VI. A FIRST ANALYTICAL PROOF OF THE INEQUALITY $\Sigma_1 \neq \Sigma_2$

The exact potential $A_{\phi 1}$ for $\Sigma_1$ is found from $b_{r1} = -\partial A_{\phi 1}/\partial z$:

$$A_{\phi 1}(r,z) = (b_o/\alpha)\, J_1(\alpha r)\, e^{-s\alpha z} . \qquad (19)$$

This can be rewritten in the following *ad hoc* form by invoking, for the upper half space, a mathematically provable identity:

$$A_{\phi 1}(r,z) = b_o \int_o^\infty F_1(R)\; J_1(\alpha r)\, dR \qquad (20)$$

Here

$$F_1(R) = [\, J_1(\alpha r)/\, \alpha][\, R^2/(\, R^2 + z^2)\, z^{3/2}\, ]. \qquad (21)$$

This can now be compared with $A_{\phi 2}(r,z)$, rewritten as{(Ref. [2], §(11.4.44), § (10.2.17), § (6.1.9)}:

$$A_{\phi 2}(r,z) = b_o \int F_2(R)\; J_1(\alpha r)\, dR, \qquad (22)$$

where

$$F_2(R) = [(\, 2- k^2)\, K(k) - 2\, E(k)]R/[\pi\, k(rR)^{1/2}] \qquad (23)$$

Since for $\alpha \rightarrow \propto$, $F_1(R) \rightarrow 0$ for all values of R, but $F_2(R)$ remains unchanged, it follows that the two potential distributions are generally not equal. However, the inequality of the vector potentials does not necessarily prove the inequality of the field structures. To establish the latter inequality, one may readily verify that for $r = 0$, both potentials are zero regardless of the value of . Thus, traveling from the axis outward, the potentials are first in agreement, and then begin to disagree. Therefore the same comment applies to the two field structures.

## VII. A SECOND ANALYTICAL PROOF OF THE INEQUALITY $\Sigma_1 \neq \Sigma_2$

There is no way to cast Eq. (13) in a suitable analytical form that can be compared directly with Eq. (19). However, for the purpose of analytical demonstration of the inequality it suffices to consider the far reaches of the structures where the inequality is most pronounced. For points with $z \gg r$ (*without* assuming that $\alpha r \rightarrow 0$), $k^2 \ll 1$ and in $k^2$:

$$(R^2 + r^2 + z^2 + 2rR) \rightarrow (R^2 + z^2).$$

The neglecting of the term 2rR above can be examined for the entire range of R $(0,\infty)$ as follows: When $R \ll r$, $2rR \ll 2r^2 \ll z^2$; when $R \sim r$, $2rR \sim 2r^2 \ll z^2$; and when $R \gg r$, $2rR \ll R^2$. One can select values of r and z such that not only $k^2 \ll 1$, but also $k \ll 1$. Referring back now to the original integrand in Eq. (13), one can examine the functional behavior of the term in curly brackets for $k \ll 1$, seen as an amplitude of the oscillatory Bessel function term. It is readily seen that no information is lost in making the preceding assumption *in* k, the oscillations notwithstanding. The elliptical integrals can now be replaced by their usual approximation ([1], Eq. (5.39)). Then

$$A_{\phi 2}(r,z) \approx (b_o/2)\, r \int_o^{\propto} [R^2 / (R^2+z^2)^{3/2}]\, J_1(\alpha R)\, dR \qquad (24)$$

The integral can be evaluated to be exactly $e^{-\alpha z}$ ([2], §(11.4.44), §(10.2.17)). Thus

$$A_{\phi 2}(r,z) \approx (b_o/2)\, r\, e^{-s\alpha z}. \qquad (25)$$

The following points may now be noted:

(1). The two potentials agree for $z \gg r$ and $\alpha r \to 0$ (i.e. in the near-axis region), as can be seen by setting $J_1(\alpha r) \approx \alpha r/2$ in Eq. (16).

(2). Since the condition $z \gg r$ can be made arbitrarily strong in the far reaches of the structure, the above result can be made arbitrarily close to exactitude. It is therefore justified to compare the exact result of Eq. (19) with the result of Eq. (25) in the limit $z \gg r$ and $\alpha r \gg 0$ ($\alpha r \geq 1$, say) to prove that $A_{\phi 1}(r,z) \neq A_{\phi 2}(r,z)$ in the far reaches of the structures.

Thus, traveling from the axis outward, the two vector potentials are first in agreement, and then gradually begin to disagree. Hence $\Sigma_1 \neq \Sigma_2$.

## VII. DISCUSSION: PHOTON MATERIAL AND PHOTON MASS

So now we have a completely defined structure made of magnetic field in empty space, and nothing else. Elsewhere [3], I have shown that magnetic field in empty space ins an actual substance (hitherto undefined.) Therefore the photon is now as well-defined as the structural frame of a dirigible aircraft.

In my paper just mentioned, I have defined the mass of magnetic field. Accordingly, the mass of the photon is

$$m = 2\pi\varepsilon_o \int_{o}^{\propto}\int_{-\propto}^{\propto} b^2 \, r \, dz \, dr \, , \qquad (26)$$

$\varepsilon_o$ being the permittivity of free space.

The reader interested in my further speculation on this idea may turn to Ref. [4].

## References


1. J. D. Jackson, *Classical Electrodynamics* (Wiley, New York, 1972).

2. M. Abramowitz and I. A. Stegun, *Handbook of Mathematical Functions* (Dover, New York, 1972).

3. B. R. De, Astrophys. Space Sci**.** **239** (1996), 25.

4. http://www.journaloftheoretics.com/Links/Papers/BibhasDe.pdf