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PHOTON: ZERO "REST" MASS?

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Abstract. The goal of this article is to show that the "rest" mass of a photon is finite, and different than zero. It can be calculated from experimental data gathered by:
a) F. Kurlbaum, O. Lummer and E. Pringsheim; and,
b) A. H. Compton.

Contents

1. Introduction

"Before this discovery of Australia, people in the Old World were convinced that all swans were white, an unassailable belief as it seemed completely confirmed by empirical evidence. The sighting of the first black swan might have been an interesting surprise for a few ornithologists, but that is not where the significance of the story lies. It illustrates a severe limitation to our learning from observations or experience and the fragility of our knowledge. One single observation can invalidate a general statement derived from millennia of confirmatory sightings of millions of white swans (all you need is one single black bird).[1]"

2. Calculation of the "rest" mass of a photon from experimental data obtained by F. Kurlbaum, O. Lummer, and E. Pringsheim

We recently made an article available on this website with the title "Would $\epsilon = h\,\nu = \frac{m_0\,v^2}{\sqrt{1-(\frac{v}{c})^2}}$?", and in it, deduced the equation 23, on item "2.2. Quantification of the physical phenomen", which informs us that the "action constant"[2], $h = m_0\,v^2\,t$.

[1]This is an excerpt from "The Black Swan: The Impact of the Highly Improbable" by Nassim Nicholas Taleb (Hardback published by Random House (US) and Allen Lane (UK), 2007. Paperback published by Penguin, 2008).

[2]Important to mention that the action constant, h:
a) is directly related to the context of the experiment in which it was produced, that is, the radiation of a black body. Thus, we need to admit that the particle involved in the experiment is the photon; and,
b) that it was obtained from experimental data produced in the Physikalisch Technische Reichsanstalt, in Berlim, by F. Kurbaum, O. Lummer and E. Pringsheim.

Thus, considering the arguments contained on the footnote 2, we can write that

$$(m_0)_f = \frac{h}{(v_f)^2\ t} \tag{1}$$

where $(m_0)_f$ is the "rest" mass of the photon, v_f, its velocity, h, the "action constant", and t equal to 1 second[3].

In such way, if we apply the value used in the article "On the Law of Distribution of Energy in the Normal Spectrum" by Max Planck to the "action constant", h, the speed of light[4], c, and, using $t = 1$ second in the equation, we are able to calculate the approximate "rest" mass of the photon:

$$(m_0)_f = \frac{6,55\,.10^{-27}\,erg\,.\,s}{(29.979.245.860)^2\,(\frac{cm}{s})^2\,.\,1\,s} = 7,28\,.\,10^{-48}\,g. \tag{2}$$

3. Calculation of the "rest" mass of a photon from experimental data obtained by A. H. Compton

In 1917, A. H. Compton and P. Debye "deduced independently the known equations of the kinematics of scattering of an electron initially at rest. Compton obtained not only the consequent variation $\Delta\lambda$ in the wavelength of the diffused radiation of an angle θ:

$$\lambda_0 - \lambda_1 = \frac{h}{m\ c}\ (1 - cos\theta), \tag{3}$$

as he verified that the equation is entirely satisfied by the results of the experiments, concluding: *"The experimental support of the theory indicates very convincingly that a radiation quantum carries with it directed momentum as well as energy".*

Compton's results helped us accept, definitively, the idea that the quantum of light is a particle - one which chemist G. Lewis would call "photon", in 1926.[5]".

Thus, if $h = (m_0)_f\ (v_f)^2\ t$, we have

$$\lambda_0 - \lambda_1 = \frac{h}{(m_0)_e\ c}\ (1 - cos\theta) = \frac{(m_0)_f\,(v_f)^2\,t}{(m_0)_e\ c}\ (1 - cos\theta), \tag{4}$$

where $(m_0)_f$ is the "rest" mass of the photon, v_f is, in this case, its approximate velocity, t equals 1 second, $(m_0)_e$ is the "rest" mass of the electron[6] and c, is also the approximate velocity of the photon.

If we cancel the velocity, we can conclude that:

$$\Delta\lambda = \frac{(m_0)_f\ v_f\ t}{(m_0)_e}\ (1 - cos\theta), \tag{5}$$

where

$$\frac{(m_0)_f\ v_f\ t}{(m_0)_e} = 0,02426\,.\,10^{-8}\,cm \tag{6}$$

is the "Compton Wavelength".

From which,

$$(m_0)_f = \frac{(m_0)_e\ .\ 0,02426\ .\ 10^{-8}\ cm}{v_f\ t} = \frac{9,0183\ .\ 10^{-28}\ g\ .\ 0,02426\ .\ 10^{-8}\ cm}{29.979.245.860\ \frac{cm}{s}\ .\ 1\ s} = 7,29\ .\ 10^{-48}\ g. \tag{7}$$

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[3]Notice that the bound velocity used corresponds to the space of 29.979.245.860 cm in 1 second.

[4]The value chosen to calculate the numerical values was 299.792, 4586 km/s, with an uncertainty of approximately 0,0003 km/s (30 cm/s), obtained in 1983 by the U.S. National Institute of Standards and Technology as the speed of light using in lasers.

[5]This is an excerpt from the article "O Centenário do Quantum de Luz" by Eduardo Lage.

[6]Notice that we changed the name convention referring to the "rest" mass of the electron from m to $(m_0)_e$.

About the last path used to obtain the approximate "rest" mass of the photon, I put forth the following considerations:

a) note, initially, that before we executed the calculations that resulted in the finite, and different than zero "rest" mass $(7,29 \,.\, 10^{-48} g)$, we canceled the velocity, c, contained in the denominator of the original equation by the velocity, v_f, which was inserted after substituting h by $(m_0)_f\,(v_f)^2\,t$. This operation clearly strengthens a possible validation of the theoretical deduction that $h = m_0\, v^2\, t$, as well as the hypothesis contained in item a, on footnote 2;

b) in addition, observe that using this path, the value obtained for the "rest" mass of the photon is rather close to that resulted from experimental data concerning black body radiation, and coherent with measurements obtained from astronomic observations[7]; and,

c) that the equation and interpretation presented by A. H. Compton become more acceptable when we admit that the photon has a finite "rest" mass, different than zero.

4. Conclusion

When analyzing the logic underlying both cases, which calculate the "rest" mass of the photon, *finite and different than zero*, from available experimental data, we are driven to conclude that these values are far from being a mere coincidence and that we are *facing a "Black Swan"*, as the Theory of Restrict Relativity does not admit this possibility.

On the other hand, these values make it clear that the "velocity of light" cannot be used as a bound referential.

In view of these results, and considering the importance of additional data indicating that *The Theory of Special Relativity is only partially valid and requires a revision*, I request special attention of the research community in order to direct experiments that can measure the velocity associated with electromagnetic waves whose frequencies are near 10.000 Hz, to either validate, or refute the proposition contained in "Table 1. Electromagnetic Spectrum Fragment", column $c - v$, of the article "Would $\epsilon = h\,\nu = \frac{m_0\, v^2}{\sqrt{1-(\frac{v}{c})^2}}$?", published recently on this website.

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[7]There have been occasional speculations that the photon might have a tiny nonzero mass. Direct experimental information on the photon mass is therefore a matter of interest. The best determinations of this mass come from astronomical observations. The present upper bound is $8\,x\,10^{-49}$ g [D1].]. In what follows, the photon mass is taken to be strictly zero. A footnote on page 407, from the book "Subtle Is the Lord: The Science and the Life of Albert Einstein, by Abraham Pais.