Entangled Double-Helix Superluminal Photon Model Defined by Fine Structure Constant Has Inertial Mass $M=E/c^2$

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Abstract

Two spin-½ charged half-photons, each composed of one helically-circulating electrically-charged superluminal energy quantum, compose a double-helix photon model of total spin $1\hbar$ and of diameter $D=\lambda/\pi$ where λ is the photon's wavelength. The opposite electric charges Q and $-Q$ on the two superluminal energy quanta are calculated to have magnitude $Q=e\sqrt{2/\alpha}=16.6e$ where $\alpha=1/137.04$ is the fine structure constant of quantum electrodynamics (QED). The two charged half-photons are quantum mechanically entangled, creating the unity of the composite photon model. The composite photon model suggests a mechanism for electron-positron pair production, while the predicted charges Q and $-Q$ provide a strong experimental test of the composite photon model. The inertial mass of the double-helix photon model is calculated to be $M=E/c^2=h\nu/c^2$ even though a photon's invariant mass m equals zero.

Key words: photon, spin, double helix, superluminal, model, entanglement, electron-positron pair production, fine structure constant, quantum, inertial mass, invariant mass

Introduction

> "All these fifty years of conscious brooding have brought me no nearer to the answer to the question, 'What are light quanta?' Nowadays every Tom, Dick and Harry thinks he knows it, but he is mistaken." (Albert Einstein, 1954)

There has been a continuing interest in the possibility of a composite model of the photon since de Broglie (1) proposed this hypothesis. Since de Broglie is not well-known for his composite photon hypothesis, here is a two-paragraph excerpt from p. 285-286:

"From these general remarks, we concluded that in order to set up a theory of the photon it was necessary above all to use a relativistic form of wave mechanics having elements of symmetry like polarization and, secondly, to introduce *something more* in order to differentiate the photon from other corpuscles. The first part of this program is immediately realized by having recourse to Dirac's theory of the magnetic electron that we previously discussed. We know as a matter of fact that Dirac's theory is relativistic and that it has elements of symmetry which present a marked relationship with those of the polarization of light. Nevertheless it is not enough to suppose that the photon is a corpuscle of negligible mass obeying the equations of Dirac's theory, for the model of the photon thus obtained would have, as you might say, only half the symmetry of the actual photon; in addition, it would obey, it would seem, the Fermi statistics, as the electron does and would not be capable of being annihilated in the photoelectric effect. Something more is very much needed.

And this something more we have tried to introduce by supposing that the photon is made up not by one Dirac corpuscle, but by two. It can then be ascertained that these two corpuscles or demi-photons must be complementary to each other in the same sense that the positive electron is complementary to the negative electron in Dirac's theory of holes. Such a couple of complementary corpuscles can annihilate themselves on contact with matter by giving up all their energy, and this accounts completely for the characteristics of the photoelectric effect. In addition, the photon being thus made up of two corpuscles with a spin of $h/4\pi$ should obey the Bose-Einstein statistics, as the exactness of Planck's law of black body radiation demands. Finally, this model of the photon permits us to define an electromagnetic field connected with the probability of annihilation of the photon, a field which obeys the Maxwell equations and possesses all the characters of the electromagnetic light wave. Although it would still be premature to make a definitive pronouncement on the value of this attempt, it is indisputable that it leads to interesting results and that it strongly focuses attention on the symmetry properties of the complementary corpuscles whose existence, suggested by Dirac's theory, has been verified by the discovery of the positive electron."

In another book, de Broglie (2) gave a more extended discussion of his half-photon hypothesis, and the rationale behind it. He also suggested that the two half-photons might be two neutrinos.

Most of the quantitative research about de Broglie's spin-½ half-photon hypothesis of a composite photon has followed up de Broglie's suggestion that the two particles could be neutrinos, which at that time were hypothetical particles considered to be uncharged and massless. Now neutrinos are known to have very small but so far undetermined non-zero masses. Levitt (3) proposed that a photon consists of double-helix pair of sub-particles called neutrinos, with undefined charge, that equally share the spin of a photon. Perkins (4) reviewed various criticisms of de Broglie's two-neutrino suggestion and found that some of these criticisms do not hold up, but that problems remain with the two-neutrino model. Múnera (5) describes a 4D hydrodynamic model of the photon as a source-sink dipole consisting of an electron-positron pair. You (6) proposes two ways to construct a composite photon: from an unbonded massless and uncharged fermion-antifermion pair, and from a bonded electron-positron pair.

Several charged electric-dipole double-helix photon models have been proposed. Boland (7) proposed a superluminal double-helix electric-dipole composite photon model very similar to the present one, supported by microwave resonant cavity experiments. His charged-dipole composite photon model includes linear and elliptically polarized photons as well as the circularly polarized photon in the present model. Gauthier (8) (see

Appendix) independently proposed a superluminal double-helix oppositely-charged-dipole composite photon model, with the same quantitative features as the Boland (7) spin-1 photon model and the present double-helix photon model, before learning of Dirac's spin-½ half-photon hypothesis. Caroppo (9) independently proposed the identical superluminal double-helical charged-dipole composite photon model, with the same quantitative features as the Gauthier (8) photon model. The present superluminal double-helical composite photon model updates the Gauthier (8) photon model in light of de Broglie's spin-½ half-photon hypothesis as well as Gauthier's further research on electron and photon models since then, while providing additional quantitative analysis of the Gauthier (8) model. Giertz (10) proposes a double- helix photon model composed of two oppositely charged particles. In his model, the positive and negative charges rotate in opposite directions, unlike in the Boland, Gauthier and Caroppo double-helix models mentioned above where the two opposite charges of magnitude $Q = 16.6$ e rotate in the same direction.

Evolution of the Charged Superluminal Double-Helix Photon Model

Gauthier (11) proposed his first composite model of the photon, with each photon composed of millions of sub-quantum helically-moving microvita—hypothetical living entities proposed to compose physical particles. Due to the lack of experimental evidence that a photon is composite, Gauthier (12) later proposed a superluminal uncharged single-helix spin-1 photon model and also a superluminal charged single-helix, internally-double-looping spin-½ model of a resting electron. Gauthier (13) then extended the resting electron model to become a relativistic electron model, composed of a helically-moving spin-½ charged photon that generates the electron's de Broglie wavelength. Gauthier (14) then proposed a superluminal model of a spin-½ charged photon that can be combined with the generic spin-½ charged photon model's trajectory in Gauthier (13) to form a relativistic electron model having spin-½ at highly relativistic velocities as well as at rest.

The author then learned that de Broglie (1) had previously hypothesized that a photon is composed of a spin-½ "half-photon". In light of de Broglie's spin-½ half-photon hypothesis for a composite photon, a terminology change for the terminology "spin-½ charged photon" proposed by Gauthier (13,14) was needed. The term "spin-½ charged photon" therefore should be changed to "spin-½ charged half-photon" in these photon-model articles, to be consistent with de Broglie's composite photon hypothesis and also to be consistent with the fact that, experimentally, photons are uncharged and generally have spin-1. Using this new terminology, the author is here also updating the Gauthier (8) superluminal double-helix composite photon model to describe it as being composed of two superluminal spin-1/2 charged half-photons moving together to form the double-helix composite photon model.

Summary of the Superluminal Double-Helix Photon Model

The present article further analyzes the superluminal double-helix charged dipole model of the superluminal double-helix photon model proposed by Gauthier (8). As in Gauthier

(8), each spin-½ half-photon is composed of an electrically charged superluminal energy quantum moving helically at $c\sqrt{2}$ with a forward helical angle of 45° and with a helical radius of $\lambda / 2\pi$ and diameter λ / π, where λ is the wavelength of the composite photon model. The equal and opposite electric charges on the charge dipole are found by calculation to be $Q = \pm e\sqrt{2/\alpha} \cong \pm 16.6e$ where e is the electron's charge magnitude 1.602×10^{-19} Coulombs and α (alpha) is the fine structure constant $\alpha = e^2 / 4\pi\varepsilon_o \hbar c \cong$ 1/137.04 from quantum electrodynamics (QED). The superluminal energy quantum in each spin-½ charged half-photon makes two full turns of its helical trajectory for each half-photon wavelength. The present article analyzes the double-helix photon model more deeply. The calculations for the *x*, *y* and *z*-components of the photon model's spin are given explicitly, showing that the composite double-helix photon model has a calculated total spin $S = \hbar = h / 2\pi$. The forward helical angle 45° of the double-helix photon model is also calculated explicitly from the helix equations. In addition the inertial mass M of the double-helix photon model is calculated using Newton's second law of motion applied to the circulating internal momenta of the double-helix photon model, to give $M = E / c^2 = h\nu / c^2$.

The equations for one superluminal energy quantum spin-½ charged half-photon model

Here are the equations from Gauthier (14) for the trajectory of one superluminal energy quantum in the spin-½ charged half-photon model. For a right-handed spin-½ charged half-photon with energy $E = \hbar\omega = 2\pi\hbar c / \lambda$, angular frequency ω and half-photon wavelength $\lambda = 2\pi c / \omega$, traveling in the +z direction, the parametric equations for the trajectory of the superluminal quantum (neglecting a possible phase factor) that makes two helical turns per half-photon wavelength λ are:

$$\begin{aligned} x(t) &= \frac{\lambda}{4\pi}\cos(2\omega t), & p_x(t) &= -\frac{h}{\lambda}\sin(2\omega t), \\ y(t) &= \frac{\lambda}{4\pi}\sin(2\omega t), & p_y(t) &= \frac{h}{\lambda}\cos(2\omega t), \\ z(t) &= ct & p_z(t) &= \frac{h}{\lambda} \end{aligned} \tag{1}$$

for the *x*, *y* and *z*-components of the circulating superluminal quantum's position and momentum with time, respectively.

The speed $v(t)$ of the superluminal energy quantum for the spin-½ charged half-photon model is derived by differentiating the position components for the superluminal energy quantum in the spin-½ charged half-photon equations above, giving

$$v_x(t) = dx(t)/dt = -\frac{\lambda\omega}{2\pi}\sin(2\omega t) = -c\sin(2\omega t)$$
$$v_y(t) = dy(t)/dt = \frac{\lambda\omega}{2\pi}\cos(2\omega t) = c\cos(2\omega t) \qquad (2)$$
$$v_z(t) = dz(t)/dt = c$$

So

$$\begin{aligned} v(t)^2 &= v_x(t)^2 + v_y(t)^2 + v_z(t)^2 \\ &= [-c\sin(2\omega t)]^2 + [c\cos(2\omega t)]^2 + c^2 \\ &= c^2[\sin^2(2\omega t) + \cos^2(2\omega t)] + c^2 \qquad (3) \\ &= c^2 + c^2 \\ &= 2c^2 \end{aligned}$$

Therefore $v(t) = \sqrt{2c^2} = c\sqrt{2}$ for the speed of the superluminal energy quantum in the spin-½ charged half-photon model.

The equations for both helically-moving superluminal energy quanta in the spin-½ charged half-photon model

In the proposed model of the superluminal energy quantum model of a photon composed of two spin-½ charged half-photons, the two oppositely-charged superluminal energy quanta are across from each other and move together in a double helical trajectory. The equations for the superluminal energy quantum in the second spin-½ charged half-photon model are obtained by setting the *x* and *y* components of the second superluminal energy quantum equal to the negative values of the *x* and *y* components of the first superluminal energy quantum's position and momentum (Equation 1), while the *z*-component of position and momentum is the same for both superluminal energy quanta.

The parametric coordinates for the pair of helically-moving superluminal energy quantum 1 and superluminal energy quantum 2 are given below. Now it will be made explicit that the wavelength of a half-photon is called λ_{half} to distinguish this wavelength from the wavelength λ of the photon model composed of the two half-photon models. The angular frequency of the half-photon will be called ω_{half} to distinguish it from the angular frequency ω of the photon model.

Half-photon Helix 1

$$x_1(t) = \frac{\lambda_{half}}{4\pi}\cos(2\omega_{half}t) \qquad p_{x1}(t) = -\frac{h}{\lambda_{half}}\sin(2\omega_{half}t)$$

$$y_1(t) = \frac{\lambda_{half}}{4\pi}\sin(2\omega_{half}t) \qquad p_{y1}(t) = \frac{h}{\lambda_{half}}\cos(2\omega_{half}t) \qquad (4)$$

$$z_1(t) = ct \qquad p_{z1}(t) = \frac{h}{\lambda_{half}}$$

Half-photon Helix 2

$$x_2(t) = -\frac{\lambda_{half}}{4\pi}\cos(2\omega_{half}t) \qquad p_{x2}(t) = \frac{h}{\lambda_{half}}\sin(2\omega_{half}t)$$

$$y_2(t) = -\frac{\lambda_{half}}{4\pi}\sin(2\omega_{half}t) \qquad p_{y2}(t) = -\frac{h}{\lambda_{half}}\cos(2\omega_{half}t)$$

$$z_2(t) = ct \qquad p_{z2}(t) = \frac{h}{\lambda_{half}} \qquad (5)$$

What is the relationship of the wavelength λ_{half} of a half-photon to the wavelength λ of the photon composed of two half-photons? A photon of energy E is composed of two half-photons each of energy E/2. The wavelength of the composite photon of frequency ν is found from $E = h\nu = hc/\lambda$, or $\lambda = hc/E$ while the wavelength of each half-photon is given by $E/2 = h\nu_{half} = hc/\lambda_{half}$ or $\lambda_{half} = 2hc/E = 2\lambda$. This gives $\lambda = \lambda_{half}/2$. The wavelength of the photon composed of two half-photons is one-half of the wavelength of each half-photon. Since each wavelength of a half-photon is composed of two helical turns, then each helical turn of a half-photon is the same length $\lambda_{half}/2 = \lambda$ as the wavelength λ of the photon composed of the two half-photons. Similarly, the angular frequency ω_{half} of the half-photon model is half of the angular frequency of the photon model that is composed of the two half-photon models, or $\omega_{half} = \omega/2$. This gives $\omega = 2\omega_{half}$. When the photon model's helically moving superluminal energy quantum's coordinates are expressed in terms of the photon model's wavelength λ and angular frequency ω rather than the half-photon's wavelength λ_{half} and angular frequency ω_{half}, we get the parametric coordinates of the two helices of the double-helix photon model as

Helix 1 for Spin 1 Composite Photon Model for Photon of Wavelength λ

$$x_1(t)=\frac{\lambda}{2\pi}\cos(\omega t) \qquad p_{x1}(t)=-\frac{h}{2\lambda}\sin(\omega t)$$
$$y_1(t)=\frac{\lambda}{2\pi}\sin(\omega t) \qquad p_{y1}(t)=\frac{h}{2\lambda}\cos(\omega t) \tag{6}$$
$$z_1(t)=ct \qquad p_{z1}(t)=\frac{h}{2\lambda}$$

Helix 2 for Spin 1 Composite Photon Model for Photon of Wavelength λ

$$x_2(t)=-\frac{\lambda}{2\pi}\cos(\omega t) \qquad p_{x2}(t)=\frac{h}{2\lambda}\sin(\omega t)$$
$$y_2(t)=-\frac{\lambda}{2\pi}\sin(\omega t) \qquad p_{y2}(t)=-\frac{h}{2\lambda}\cos(\omega t) \tag{7}$$
$$z_2(t)=ct \qquad p_{z2}(t)=\frac{h}{2\lambda}$$

where λ and ω are now the wavelength and angular frequency of the spin-1 photon composed of the two helically-circulating superluminal energy quanta of the two spin-½ half-photons.

From the above two sets of parametric equations for the coordinates of the superluminal energy quanta in the two half-photons, it is easily calculated that the distance D between the two superluminal quanta as they move helically opposite to each other, each with a helical radius $R=\lambda/2\pi$, is the photon model's helical diameter $D=2R=\lambda/\pi$.

Calculation of the total momentum $p=h/\lambda$ of the double-helix electron model.

This result can easily be found by calculating the total *x*, *y* and *z* momentum components for the two helical particles in equations (6) and (7).

$$p_{xtotal}(t)=p_{x1}(t)+p_{x2}(t)=-\frac{h}{2\lambda}\sin(\omega t)+\frac{h}{2\lambda}\sin(\omega t)=0$$
$$p_{ytotal}(t)=p_{y1}(t)+p_{y2}(t)=\frac{h}{2\lambda}\cos(\omega t)+[-\frac{h}{2\lambda}\cos(\omega t)]=0 \tag{8}$$
$$p_{ztotal}(t)=p_{z1}(t)+p_{z2}(t)=\frac{h}{2\lambda}+\frac{h}{2\lambda}=\frac{h}{\lambda}$$

The total momentum p_{total} of the composite photon model is then given by

$$
\begin{aligned}
p_{total} &= \sqrt{p_{xtotal}(t)^2 + p_{ytotal}(t)^2 + p_{ztotal}(t)^2} \\
&= \sqrt{0^2 + 0^2 + (h/\lambda)^2} = h/\lambda
\end{aligned} \tag{9}
$$

which is the experimental value of a photon's momentum *p*.

Calculation of the 45^{O} forward helical angle of the double-helix photon model

To show this result is to show that the forward angle of the helical trajectory of each spin-½ charged half-photon composing the double-helix composite photon model is 45^{o}. The two superluminal charges move opposite each other and both charges move counterclockwise (as seen from the front) to form a spin $+1\hbar$ composite photon, described by the parametric equations (6) and (7), or both charges move clockwise (as seen from the front) to form a spin $-1\hbar$ composite photon.

The parametric equations for the first spin-½ half-photon's helical trajectory are given in equation (6), where *z* is the direction of the composite photon's velocity.

The forward helical angle θ of the first composite-photon helical trajectory, given by equation (6), is calculated from

$$
\begin{aligned}
\tan\theta &= v_{transverse} / v_{longitudinal} \\
&= \sqrt{v_x(t)^2 + v_y(t)^2} / v_z(t) \\
&= \sqrt{[dx_1(t)/dt]^2 + [dy_1(t)/dt]^2} / [dz_1(t)/dt] \\
&= \sqrt{[(\frac{\lambda}{2\pi})^2(-\omega\sin(\omega t)]^2 + [(\frac{\lambda}{2\pi})^2(\omega\cos(\omega t)]^2} / d(ct)/dt \\
&= \sqrt{[(\frac{\lambda\omega}{2\pi})^2(\sin^2(\omega t) + (\frac{\lambda\omega}{2\pi})^2(\cos^2(\omega t)]} / c \\
&= \sqrt{(\lambda v)^2[\sin^2(\omega t) + (\cos^2(\omega t)]} / c \\
&= \sqrt{(c)^2[\sin^2(\omega t) + (\cos^2(\omega t)]} / c \\
&= \sqrt{(c)^2[1]} / c \\
&= c/c \\
&= 1
\end{aligned} \tag{10}
$$

This gives $\theta = \tan^{-1}(1) = 45^{o}$. The same 45^{o} result is obtained for the forward helical angle of the second superluminal particle's helical trajectory, given parametrically in equation (7).

Calculation of the *x*, *y* and *z*-components of the spin of the composite photon model

The *x, y* and *z*-components of spin of the composite photon model can also be calculated from equations (6) and (7).

The vector equation for the calculation of the spin of an object is $\vec{s} = \vec{R} \times \vec{P}$. In terms of vector components, the vector equation for spin becomes

$$\begin{aligned} s_x &= yp_z - zp_y \\ s_y &= zp_x - xp_z \\ s_z &= xp_y - yp_x \end{aligned} \qquad (11)$$

In the case of the double-helix model, both helices are included in the calculation:

$$\begin{aligned} s_{x\ total}(t) &= \{y_1(t)p_{z1}(t) - z_1(t)p_{y1}(t)\} + \{(y_2 p_{z2}(t) - z_2(t)p_{y2}(t)\} \\ &= \frac{\lambda}{2\pi}\sin(\omega t)\frac{h}{2\lambda} - ct\frac{h}{2\lambda}\cos(\omega t) + (-\frac{\lambda}{2\pi}\sin(\omega t))\frac{h}{2\lambda} - ct(-\frac{h}{2\lambda}\cos(\omega t)) \\ &= 0 \end{aligned}$$

$$\begin{aligned} s_{y\ total}(t) &= \{z_1(t)p_{x1}(t) - x_1(t)p_{z1}(t)\} + \{(z_2 p_{x2}(t) - x_2(t)p_{z2}(t)\} \\ &= ct(-\frac{h}{2\lambda}\sin(\omega t)) - \frac{\lambda}{2\pi}\cos(\omega t)\frac{h}{2\lambda} + ct\frac{h}{2\lambda}\sin(\omega t) - (-\frac{\lambda}{2\pi}\cos(\omega t))\frac{h}{2\lambda} \\ &= 0 \end{aligned} \qquad (12)$$

$$\begin{aligned} s_{z\ total}(t) &= \{x_1(t)p_{y1}(t) - y_1(t)p_{x1}(t)\} + \{(x_2 p_{y2}(t) - y_2(t)p_{x2}(t)\} \\ &= \frac{\lambda}{2\pi}\cos(\omega t)\frac{h}{2\lambda}\cos(\omega t) - \frac{\lambda}{2\pi}\sin(\omega t)(-\frac{h}{2\lambda}\sin(\omega t)) \\ &\quad + (-\frac{\lambda}{2\pi}\cos(\omega t))(-\frac{h}{2\lambda}\cos(\omega t)) - (-\frac{\lambda}{2\pi}\sin(\omega t))\frac{h}{2\lambda}\sin(\omega t) \\ &= \frac{h}{4\pi}(2\sin^2(\omega t) + 2\cos^2(\omega t)) \\ &= \frac{h}{2\pi}(\sin^2(\omega t) + \cos^2(\omega t)) \\ &= \frac{h}{2\pi}(1) \\ &= \frac{h}{2\pi} \\ &= \hbar \end{aligned} \qquad (13)$$

The z-component of the spin of the double-helix photon model is calculated to be $\hbar = h/2\pi$, the experimental value of the spin of the photon, while the x and y-components of the composite photon's spin are both calculated to be zero. If the double-helix composite photon model has the opposite direction of helicity from the present double-helix formulas, the z-component of spin of the composite photon model is found to be $-\hbar$, while the x and y-components of spin remain zero.

Calculation of the electric charge on each helically-circulating superluminal energy quantum in the composite photon model

In this composite photon model, the two helically-moving superluminal quanta carry an electric charge Q and –Q respectively, whose Coulomb attractive force keeps them moving in their double-helical trajectories. At the same time, each charge's x,y coordinates move in a circle with radius $\lambda/2\pi$ and angular frequency ω . As seen from equation (2), the transverse component of momentum of each superluminal energy quantum of each half-photon is $p_{trans} = h/\lambda_{half} = h/2\lambda = \frac{1}{2}h/\lambda = \frac{1}{2}p_{photon}$ where λ is the composite photon's wavelength and $\lambda_{half} = 2\lambda$ is the half-photon's wavelength.

The transverse momentum vector of each superluminal energy quantum is rotating in a circle at the composite photon's angular frequency ω . This produces a rate of change with time dp_{trans}/dt of this rotating transverse momentum vector. If a momentum vector of magnitude p_{trans} rotates in a circle with angular velocity ω , then the rate of change of vector momentum equals a centripetal force of value $F_{cent} = dp_{trans}/dt = \omega p_{trans}$. The Coulomb attractive force F_{coul} between the two opposite superluminal charges Q and –Q, separated by the distance D, produces this centripetal force F_{cent} on each charged superluminal energy quantum. We set these two forces equal in the following calculation and solve for Q. We use the relations $\omega = 2\pi\nu = 2\pi c/\lambda$ and $D = \lambda/\pi$, and also the relation $\alpha = e^2/4\pi\varepsilon_o\hbar c = 1/137.04$ in the following calculation to give

$$
\begin{aligned}
&F_{coul} = F_{cent} \\
&F_{coul} = dp_{trans} / dt = \omega p_{trans} \\
&\frac{Q^2}{4\pi\varepsilon_o D^2} = \omega p_{trans} \\
&\frac{Q^2}{4\pi\varepsilon_o (\lambda/\pi)^2} = (2\pi \frac{c}{\lambda})(\tfrac{1}{2}\frac{h}{\lambda}) \\
&\frac{Q^2\pi^2}{4\pi\varepsilon_o \lambda^2} = \frac{\pi ch}{\lambda^2} \\
&\frac{Q^2\pi}{4\pi\varepsilon_o} = ch \\
&\frac{Q^2\pi}{4\pi\varepsilon_o} = ch(\frac{2\pi}{2\pi}) = 2\pi c\hbar \\
&\frac{Q^2}{4\pi\varepsilon_o \hbar c} = 2 \\
&\frac{e^2}{4\pi\varepsilon_o \hbar c} = \frac{2e^2}{Q^2} \\
&\alpha = \frac{2e^2}{Q^2} \\
&Q^2 = \frac{2}{\alpha} e^2 \\
&Q = e\sqrt{\frac{2}{\alpha}} = e\sqrt{\frac{2}{1/137.04}} = e\sqrt{274.08} \\
&Q = 16.6e
\end{aligned}
\qquad (14)
$$

The electrical potential energy of the composite photon model

The double-helix photon model has point charges Q and –Q (where $Q = e\sqrt{2/\alpha}$ as above) separated by their double-helix diameter $D = \lambda / \pi$ as shown earlier. So the two charges will have an electrical potential energy $U = -Q^2 / 4\pi\varepsilon_o D$. A photon of wavelength λ also has energy $E = h\nu = hc/\lambda$. Let us now calculate the ratio U/E of these two energies in the electron model.

$$
\begin{aligned}
U / E &= \frac{-Q^2 / 4\pi\varepsilon_o D}{hc/\lambda} \\
&= \frac{(-2e^2/\alpha)/4\pi\varepsilon_o(\lambda/\pi)}{hc/\lambda} \\
&= (1/\alpha)(e^2/4\pi\varepsilon_o hc)(-2\pi) \\
&= (1/\alpha)(e^2/4\pi\varepsilon_o \hbar c)(-1) \\
&= (1/\alpha)(\alpha)(-1) \\
&= -1
\end{aligned} \qquad (15)
$$

This means that the electrical potential energy of the two electric charges forming the double-helix photon model is the negative of the energy of the photon being modeled. Since potential energy is a relative quantity, this calculation assumes that the potential energy of the two opposite electric charges in the model would be zero if they were infinitely far apart.

This result may be more meaningful if it is compared with the ratio of the electrical potential energy U to the total kinetic energy KE_{total} of two circling oppositely charged particles each with mass *m*, such as an electron and a positron with charge –e and +e forming an atom of positronium. The oppositely-charged particles circle around each other as a result of their mutual Coulomb force of attraction. Their U / KE_{total} is calculated below.

Each charged particle circles with a radius R and a centripetal acceleration $a_{cent} = v^2 / R$ produced by the mutually-attractive Coulomb force $F_{coul} = ke^2 / (D)^2 = ke^2 / (2R)^2$, since $D = 2R$ is the separation of the two charged particles. The electrical constant k is the same as $1/4\pi\varepsilon_o$. Using Newton's 2nd law:

$$
\begin{aligned}
&F = ma \\
&F_{coul} = ma_{cent} \\
&ke^2 / (D)^2 = mv^2 / R \\
&ke^2 / (2R)^2 = mv^2 / R \\
&ke^2 / 4R^2 = mv^2 / R \\
&ke^2 / 4R = mv^2
\end{aligned} \qquad (16)
$$

The electrical potential energy of the two circling charges is $U = -ke^2 / D = -ke^2 / 2R$. The total non-relativistic kinetic energy of the two circulating electron charges is $KE_{total} = 2 \times \frac{1}{2} mv^2 = mv^2$. The ratio of the electrical potential energy U to the total kinetic energy KE_{total} of the two circling charges is therefore

$$
\begin{aligned}
U / KE_{total} &= \frac{-ke^2 / 2R}{mv^2} \\
&= \frac{-ke^2 / 2R}{ke^2 / 4R} \\
&= -2
\end{aligned} \tag{17}
$$

This means that the ratio of the electrical potential energy to photon energy in the composite photon model composed of two superluminal helically-moving electric charges is only half of the ratio of the electrical potential energy to total kinetic energy of the circling electron-positron pair.

In the case of the present photon model, the opposite electric charges on the two half-photons are "contained" by their mutually attractive Coulomb forces to move at superluminal speed along a double helix and form a composite photon. In the circling electron-positron example, the two particles are "contained" by the attracting Coulomb force to form an atom of positronium. In fact, a positronium atom only exists for a tiny fraction of a second before the electron and positron mutually annihilate to yield two or three photons. In the case of the present photon model, the two helically-circulating charges would remain the same distance apart until the photon interacted with a nucleus (as in electron-positron pair production), an electron (as in the photoelectric effect or the Compton effect) or with another charged particle.

The above superluminal energy quantum model of a photon composed of two spin-½ charged half-photons is consistent with de Broglie's hypothesis for a two-particle composite photon composed of two spin-½ half-photons. De Broglie (2) proposed that the two spin-½ half-photons forming a photon might consist of two neutrinos having a zero or very small mass and zero or very small electric charge, compared with an electron. He also proposed that the two half-photons should have a correspondence and symmetry with each other, like the electron has with the positive hole in Dirac's relativistic electron theory. If the two spin-½ half-photons in a composite photon were not oppositely charged, what force would hold them together as the composite photon moves through space?

No magnetic force between the two superluminal double-helix charged particles.

The magnetic force between two moving charged point-particles whose velocities are perpendicular to each other is zero. This is because each charge acts like a small electric current that produces a magnetic field making concentric rings whose magnetic field direction along the rings is at right angles to the velocity of the moving charge. If a nearby second point charge has a velocity vector that is perpendicular to the velocity vector of the first charge, the angle between the magnetic field of the first charge and the velocity vector of the second charge will either equal 0° or 180°. The force on the second charge from the magnetic field of the first charge (which is proportional to the sine of the angle between the magnetic field of the first charge and the velocity vector of the second charge), will then equal zero since $\sin 0^\circ = \sin 180^\circ = 0$.

It was shown above that the forward helical angles of the double-helix photon model are both 45°. The two helical particles are moving opposite to each other in a double helical trajectory. So their two 45° forward helical angles are directed in opposite directions away from the longitudinal direction of the composite photon model. The total angle θ_{total} between the velocity vectors of the two helically-circulating superluminal particles is therefore $\theta_{total} = 45^\circ + 45^\circ = 90^\circ$. By symmetry, this total angle between the velocity vectors of the two particles will remain 90° through each full helical cycle. So the magnetic force on each of the two helically-moving superluminal charged particles from the other particle in the photon model is always zero. The total force between the two helically-circulating superluminal charged particles is therefore only due to the Coulomb attractive force.

Calculation of the inertial mass *M=E/c²* of the double-helix photon model

The invariant mass *m* of a photon is zero. Whether or not photons carry inertial mass *M*, defined by Newton's second law $\bar{F} = M\bar{a} = d\bar{p}/dt$, has been a subject of debate because photons travel with constant speed *c* and so don't accelerate in the direction of their motion. However, Gauthier (15) shows that in simple mirror-reflection and in Compton scattering of a photon from an electron, where the photon's vector velocity $\bar{c}$ changes direction, the calculated inertial mass *M* of a photon, using Newton's second law $\bar{F} = M\bar{a} = Md\bar{v}/dt = d\bar{p}/dt$, is $M = (d\bar{p}/dt)/(d\bar{v}/dt) = d\bar{p}/d\bar{c} = h\nu/c^2 = E_{photon}/c^2$. Gauthier (16) also uses Newton's second law to calculate the inertial mass $M = (d\bar{p}/dt)/\bar{a} = E_o/c^2$ of a resting electron model composed of light-speed circling momentum $p = E_o/c$, where E_o is the electron's rest energy. This same method will now be used below to calculate the inertial mass *M* of the proposed double-helix photon model.

Newton's second law is $\bar{F} = m\bar{a} = d\bar{p}/dt$ where $\bar{F}$ is the net force on an object, here m is the object's inertial mass, $\bar{a}$ is the acceleration of the object, and $d\bar{p}/dt$ is the rate of change of the object's momentum. If a particle with momentum $\bar{p}$ has circular motion, the rate of change $d\bar{p}/dt$ of the vector momentum can be calculated, as well as the centripetal acceleration $\bar{a}_c$ of the object towards the center of the circle that the particle is moving around. In the case of the double-helix composite photon model with wavelength λ, each half-photon moves in a helix with a transverse momentum component $p_t = h/2\lambda$ (see equation 6 above). The radius of the helix is $R = \lambda/2\pi$ (see equation 6 above). The transverse momentum component p_t rotates circularly with the angular frequency ω of the composite photon. For a photon, $\omega = 2\pi\nu = 2\pi c / \lambda$ since $\nu = c / \lambda$. For the circularly rotating transverse momentum component p_t, vector analysis gives $d\bar{p}_t / dt = \omega p_t$ directed towards the center of the circle. The centripetal acceleration a_c of the energy quantum is given by $a_c = R\omega^2$, also directed towards the center of the circle. The inertial mass m_{half} of each of the half-photons is then given by

$$m_{half} = (d\bar{p}_t / dt) / \bar{a}_c \tag{18}$$

The total inertial mass *M* of the double-helix composite photon model is given by

$$\begin{aligned} M &= 2m_{half} \\ &= 2(d\bar{p}_t / dt) / a_c \\ &= 2(\omega p_t) / (R\omega^2) \\ &= 2p_t / R\omega \\ &= 2(h / 2\lambda) / (\lambda / 2\pi \times 2\pi c / \lambda) \\ &= h / c\lambda \\ &= h / (c \times c / \nu) \\ &= h\nu / c^2 = E_{photon} / c^2 \end{aligned} \tag{19}$$

The photon model's inertial mass is calculated to be the energy of the photon divided by the square of the speed of light. This is the case even though a photon has no invariant mass.

Quantum waves generated by the composite photon model

In Gauthier's (13) spin-½ charged photon model of the electron (which now should be called the spin-½ charged half-photon model of the electron) the charged half-photon composing an electron moves forward on its helical trajectory at light speed *c* to form the electron, which travels longitudinally at sub-light speed *v*. The quantum wave emitted by the charged half-photon is proposed to be a plane quantum wave function $\Phi(\vec{r},t) = Ae^{i(\vec{k}_{total} \cdot \vec{r} - \omega t)}$ where $\vec{k}_{total}$ is the wave vector of the circulating charged half-photon forming the electron and ω is its angular frequency. That quantum plane wave function when intersecting the helical axis of the charged spin-1/2 half-photon generates the electron's relativistic de Broglie wavelength $\lambda_{db} = h / \gamma mv$ along this axis.

For the double-helix composite photon model, the same basic quantum wave function formula for a plane quantum wave function can be used: $\Phi_{photon}(\vec{r},t) = Ae^{i(\vec{k} \cdot \vec{r} - \omega t)}$ where $\vec{k} = 2\pi / \lambda$ is the wave vector of a plane wave of electromagnetic radiation for the double-helix composite photon model of wavelength λ, and ω is the angular frequency of the photon model. Each half-photon in the composite photon could emit such a wave function, producing an entangled composite quantum wave function emitted by the composite photon. The photon model generates its quantum wave function as it moves forward at light speed, and this wave function predicts the probability of finding the photon in a future place and time. This wave function would be for a photon in a coherent beam of electromagnetic radiation such as a laser beam, where such a plane quantum wave function is a good description of the distribution of photons in the laser beam as a whole.

The composite photon model and electron-positron pair production

An electron and a positron are produced most commonly when a photon of sufficient energy (greater than 1.022 MeV, corresponding to the combined mass of an electron and a positron) passes near an atomic nucleus. This is one example of electron-positron pair production. The present composite photon model lends itself to a relatively straightforward (if oversimplified) explanation of this process. When the composite photon is in the sufficiently strong electric field of an atomic nucleus, the electric field of the nucleus acts on the two helically-moving electric charges in the composite photon and causes the two spin-½ charged half-photons to reduce their electric charge from $\pm 16.6e$ to $\pm 1e$. The electric charges are now no longer large enough to attract each other sufficiently to maintain their double-helical trajectory. The two spin-½ charged half-photons, now with charges *e* and -*e*, separate and the trajectories of the two spin-½ charged half-photons curl up separately to form an electron and a positron. By curling up, the two spin-½ charged half-photons each gain the electron's invariant mass *m* of 0.511 Mev/c^2 that they did not have when travelling together as the composite photon.

The fine structure constant α = 1/137.06 in the composite photon model

A surprising result of the new composite superluminal double-helix photon model is that its two electric charges Q and –Q on the circulating superluminal energy quanta are related to the electron's charge *e* by the fine structure constant alpha: α = 1/137.06 from quantum electrodynamics (QED) by $Q = e\sqrt{2/\alpha} = 16.6e$. Alpha is the measure of the strength of interaction between an electron and a photon in QED. Whether this result can lead to a better understanding of the photon or QED or both, remains to be seen.

Is the double-helix composite photon model internally entangled?

Two particles such as two electrons or two photons are said to be quantum-mechanically entangled if they function as a single quantum object or system. The quantum wave function of an entangled pair of particles is not just the linear sum of the quantum wave functions of the two individual particles. Measurement of the quantum state of one of the two particles immediately produces a corresponding quantum state of the second particle, even if the particles are separated beyond the possibility of light-speed communication between them. The concept of quantum-mechanical entanglement was discovered by Einstein, Podolsky and Rosen (17), and given the name "entanglement" ("veänkung") by Schrödinger (18). It was first experimentally confirmed by Aspect et al (19).

When a photon is transformed into an electron-positron pair by passing near an atomic nucleus, the produced electron-positron pair is quantum-mechanically entangled since the photon's spin-1 is conserved in the process of producing two spin-½ particles. The author proposes here that the two spin-½ half-photons forming a composite photon, as suggested by de Broglie (1), are also quantum mechanically entangled. The two circulating superluminal energy quanta function together as a single quantum object—the photon. Measurement of the quantum mechanical state of one superluminal energy quantum (or one spin-½ charged half-photon) would immediately put the other superluminal energy quantum into a corresponding quantum mechanical state consistent with the quantum mechanical state of the composite photon.

If the proposed composite photon model is internally quantum-mechanically entangled, this could make it more difficult to separately detect or measure the two superluminal energy quanta composing a photon. If the two charged superluminal energy quanta are detected separately, it may be because the detection process has triggered the transformation of the composite photon into an electron-positron pair. The composite photon model makes the strong experimental prediction that two opposite entangled charges of magnitude $Q = e\sqrt{2/\alpha} = 16.6e$ will be found on close experimental examination of the photon during the process of electron-positron pair production.

Some possible criticisms of the double-helix composite photon model

The author is aware of a number of possible criticisms of the proposed internally superluminal double-helix photon model.

1) It is superluminal. No particles are known to travel faster than light speed in a vacuum.
2) It is composite. There is no current experimental evidence that a photon is a composite particle.
3) A photon doesn't radiate energy. Accelerating charges in helical motion radiate energy, according to classical electromagnetic theory.
4) Light waves easily pass through each other. The circulating internal dipole charges of different photons would interact with each other and disturb their photon trajectories, which doesn't happen experimentally.
5) What causes wave-particle duality if the photon model is composed of two helically-circulating superluminal oppositely-charged particles?
6) How does the composite photon model produce linearly and elliptically polarized light, and light with orbital angular momentum as well as spin?
7) The calculation of the Coulomb force between the two helically-circulating superluminal energy quanta at the distance of the helical diameter $D = \lambda / \pi$ does not take into account that the positions of the quantum particles are changing

during the Coulomb attraction so that there should be a speed-of-light correction in this calculation, leading to a different charge calculated than $Q = e\sqrt{2/\alpha} = 16.6e$.

8) In quantum mechanics, a photon's total spin is given by $S_{total} = \hbar\sqrt{l(l+1)} = \hbar\sqrt{2}$ since for a photon, $l = 1$. However, in the double-helix photon model here, $S_{total} = \hbar$.
9) In the double-helix photon model, the position and momentum coordinates are given precisely, which is a violation of Heisenberg's uncertainty principle $\Delta x \Delta p_x \geq \hbar / 2$ etc. for the corresponding position and momentum components of a particle.

The above basic criticisms and questions (there may be many others) can be briefly responded to:

1) The proposed superluminal energy quanta composing the photon model are not particles in the traditional sense but are fundamental quantum entities proposed to compose the known particles like photons and electrons and give them their quantum wave-particle nature. Particles composed of superluminal energy quanta, such as the photon and the electron, do not themselves travel faster than light, or even at light speed (in the case of an electron or other particles with non-zero invariant mass.)
2) There are other composite particles such as protons, neutrons and mesons that are composed of quarks. It took time to establish this experimentally.
3) The ground state of a hydrogen atom does not radiate energy although it contains an accelerating electron, which should radiate according to the classical laws of electromagnetism. New quantum laws about radiation may also apply to the charged-dipole superluminal energy quanta composing photons.
4) When electromagnetic waves pass through each other, the average interaction between the charged dipole pairs of the different composite photons composing the electromagnetic waves may be negligible. Composite photon trajectories may therefore be unaffected by other nearby composite photons.
5) The superluminal energy quanta composing the two spin-½ charged half-photons are proposed to generate an entangled quantum wave function that statistically predicts where the photon will be found in the future. The quantum wave functions from these superluminal energy quanta are the source of the quantum wave-particle nature of matter and energy.
6) Light comes in a variety of polarization states. However, when a single photon is detected, it is in only one of two states, either spin 1 or spin -1. Other polarization states of light are quantum mechanical combinations of these two basic photon states. The composite photon modeled here is the spin 1 or spin -1 state of circularly polarized light, not the superposition of quantum-mechanical states describing other states of a photon. Boland (7) describes other motions of the charged dipole pair of a double-helix composite photon model that could describe other polarization states of light such as elliptical or linear polarization.

7) The Coulomb force calculation assumes that this force is produced instantaneously between the two circulating transluminal energy quanta. If these two circulating charges in the photon model are quantum-mechanically entangled, this may actually be the case. Otherwise a correction in the calculation would be required which could give a different value for the circulating charges $\pm Q$ in the photon-model's charge dipole.
8) The double-helix photon model is that of a single spin-1 photon, not a statistical average for many photons, which quantum mechanics describes.
9) Heisenberg's uncertainty principle is a statistical principle applied to measurements on a set of many particles, while the position and momentum coordinates of the double-helix photon model are for a single photon.

There may be other criticisms of the proposed superluminal double-helix model of the photon, and the author would like to hear them. Perhaps an even better model of the photon and its underlying energy/momentum/spin structure will be the outcome.

One intriguing idea of Caroppo (20), who independently proposed the superluminal double-helix model of the photon in Caroppo (9), is that the double-helix photon model may be compatible with Maxwell's equations for electromagnetic waves in a way that Maxwell himself (and others that followed him) overlooked. This is Caroppo's proposed "Maxwell's error". In the internally-superluminal double-helix photon model there are dipole charge carriers closely associated with electromagnetic waves even in a vacuum. If a light-speed oppositely-charged-dipole photon model accompanying and generating electromagnetic waves in a vacuum had been conceived of by Maxwell, the discovery of the photon would not have come as such a shock as it did, and would not have had such difficulty finding general acceptance. Physical theories, such as quantum mechanics and quantum electrodynamics (QED) that were developed since Maxwell, based on the no-oppositely-charged-dipole photon, may need to be reexamined in light of this new possibility.

Conclusions

An internally-superluminal double-helical quantum-mechanically self-entangled oppositely-charged-dipole model of the photon is proposed. It is composed of two oppositely-charged spin-½ half-photons moving side-by-side in internally-superluminal double-helical trajectories, consistent with de Broglie's hypothesis of a composite photon composed of two spin-½ half–photons. The photon model has a calculated inertial mass $M = E / c^2 = h\nu / c^2$ based on Newton's second law $\vec{F} = M\vec{a} = d\vec{p} / dt$, applied to the rotating internal momenta of the superluminal energy quanta composing the photon model. This composite photon model suggests a new approach to explaining electron-positron pair production. Due to the calculated dipole charge $Q = \pm e\sqrt{2/\alpha} = \pm 16.6e$ on the two helically-circulating superluminal energy quanta composing this photon model, a possible connection of the photon model to quantum electrodynamics (QED) is suggested, and a strong experimental test of the composite photon model – the detection of this charge Q -- is provided. Physics theories developed after Maxwell's equations may have to be reformulated in light of the superluminal dipole double-helix photon model.

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Appendix

This is my earlier article “Dumbons and Photons” on the superluminal double-helical model of the photon. It was copyrighted in 2002 and published on-line in 2005 on a Dutch free energy website blog nulpuntenergiewatisdat.pdf. I was working in Poland and using the name Richard Richardson when the article was first published. The present article is the latest update of the article below.

Dumbons and Photons
by Richard Richardson, Ph.D. (richard@sfo.pl)

Summary: A new model of the photon is proposed which has the unique and experimentally testable property of containing two equal and opposite electric charges of magnitude Q = e * sqrt (2/alpha) = e * sqrt (274.)

= 16.55..e (where e is the electron charge and alpha is the fine structure constant) moving in a double helical path. If experimentally confirmed, the model could shed new light on the nature of the photon/electron coupling in quantum electrodynamics (QED) and deepen our understanding of the physical world.

What object has the following properties?

*1. It consists of two equal and opposite point charges Q and -Q, with Q = e * sqrt (2/alpha) = e * sqrt (274.) = 16.55..e, where e is the charge of the electron and alpha is the dimensionless fine structure constant of physics: alpha (in cgs units) = (2 pi * e squared)/hc = 1/137.. , where h is Planck's constant, c is the speed of light, and pi =3.14.. The two charges Q and -Q are separated by a distance D (or 2R) like a dumbbell. Different such objects can have different values of D, but for a particular object, D (which is related to the energy of the object) remains constant during the lifetime of the object.*

*2. It moves forward like the tips of a propeller of a small airplane, rotating in a 45 degree double helix through space at the speed of light c, giving it a physical wavelength (by geometry) of L = pi*D (or 2pi *R) and a rotational frequency f = c/L. So the individual point charges Q and -Q are moving along the double helix paths with speed c*sqrt 2=1.414..c .*

3. It has no physical rest mass, but it has energy of motion E = hf (where h is Planck's constant) and electrical potential energy V= -(Q squared) / D due to the separation of the charges Q and -Q.

4. It has linear momentum P = h/L.

5. It has total angular momentum or spin S = h/2pi.

*6. It has a probability of being absorbed or emitted by an electron (according to quantum electrodynamics-QED) given by 2 * (e squared / Q squared) = alpha = 1/137.. (the fine structure constant).*

7. It says "chirp!"

*With the possible exception of point 7, the above physical characteristics describe a dumbon (pronounced "dum-on", which is a newly proposed (Richardson 2002b) physical model for a single photon (a quantum of electromagnetic energy, or light) based on my earlier work (Richardson 2002a, 1994). The dumbon is a particular kind of electric dumbbell (hence the name) composed of two separated equal and opposite point charges of one particular magnitude, moving in a certain way that models some of the physical properties of a photon. The dumbon moves through space as a whole at the speed of light in a double helical motion, a bit similar to the movement through space of the two opposite tips of a single rotating propeller of a small flying airplane. Except that with the dumbon, one full 360 degree rotation of the electric charges Q and -Q advances the dumbon a distance pi * D, where D is the separation of the 2 charges. (Whether the two fixed charges Q and -Q are actually point charges or have a radius that is negligible compared to the distance D between the two fixed charges, is not important for the present dumbon model).*

A photon satisfies points 3-5 above. It is an electrically neutral object that moves at the velocity of light c, with energy E=hf, momentum P=h/L, and angular momentum or spin S= h/2pi. A photon also has (as in point 6) the probability of being emitted by or absorbed by an electron (in quantum electrodynamics) given by the fine structure constant known as alpha.

The dumbon also has these known characteristics of a photon (the dumbon's total charge is zero), but also carries 2 equal and opposite fixed charges (point 1) with their associated forces (described by Coulomb's law) and energies (described by the Coulomb electric potential), and moves in a particular geometrical way (point 2). Point 6 for a dumbon is based on a reasonable supposition (see point A below), since QED presently does not accept the existence of dumbons.

Some more detailed information about the dumbon, relating to points 1 and 2, makes it an interesting object:

A) the electric charges Q and -Q (where Q = e*sqrt(2/alpha) or 16.55.. units of the electron's charge) are not composed of an integral whole number of electron charges and have not so far been observed in nature in this amount. A photon is uncharged (has no net charge) and has no rest mass, while e is the fixed unit of electrical charge associated with most elementary particles with rest mass, like electrons and protons. But note that the quarks which compose nuclear particles like protons and neutrons, have fractional electric charges like 2/3 e and -1/3 e, so fractional charges in nature do exist. It is possible that the particular charges Q and -Q that might compose a photon (which the dumbon is modeling) have just not been observed yet, just as it was very difficult to experimentally observe the quarks that compose a proton because they are internal to the proton. But these charges Q and -Q could help quantitatively explain the probability of absorption or emission of a photon by an electron that is found to equal alpha (1/137..) in quantum electrodynamics (QED). We can rearrange the above formula for Q to get (e squared)/ (Q squared) = alpha/2. So it is reasonable to propose that the charges Q and -Q in the dumbon each contribute a probability alpha/2 to the probability of a photon being absorbed or emitted by an electron, that is, Prob. (total) = Prob. (Q <--> e) + Prob. (-Q <-->e) =alpha/2 + alpha/2 = alpha.

B) The individual linear momentum of each charge Q and -Q is a rotating vector quantity directed along the 45 degree helical path of these charges. So each charge Q and -Q has a longitudinal component P1 and P2 respectively of its individual vector linear momentum, in the direction of the path of the dumbon's motion, and also each charge Q and -Q has a transverse component of it's individual vector linear momentum perpendicular to the direction of the dumbon's motion. Each instantaneous total linear momentum for Q has longitudinal magnitude P1 and a rotating component vector of transverse linear momentum, also of magnitude P1 since the angle of the helix and therefore the path of Q and -Q is 45 degrees to the forward direction. This is also true for the charge -Q with corresponding longitudinal and transverse components of magnitude P2 which are equal in magnitude to P1, since the helical motion is the same for both charges Q and -Q. The total linear momentum in the direction of motion of the dumbon is given by the sum of the 2 longitudinal components of momenta of Q and -Q. So P = P1 + P2 = 2 P1 = h/L. So P1 = P2 = h/2L.

*C) The two transverse or perpendicular (to the forward direction of motion of the dumbon) components P1 and P2 of the individual linear momentum vectors of Q and -Q moving at 45 degrees to the forward direction, contribute to the total angular momentum or spin S of the dumbon, as calculated by S = s(Q) + s(-Q) = (P1 * R) + (P2 *R) (where s(Q) and s(-Q) are the contributions of Q and -Q to the total angular momentum or spin S. But from paragraph D above, P1=P2 = h/2L = h/(2*2pi*R). So S = (h/(2*2pi*R)* R) + (h/(2*2pi*R) * R) = h/2pi , which is the spin of the photon.*

D) How were the values Q and -Q obtained? They are the values of electric charge required to keep the point charge Q (and also the point charge -Q), carrying their corresponding transverse vector *components of linear momentum P1 and P2, in circular motion around the helix's axis as the dumbon moves forward at velocity c. So the electric force on the charge +Q (carrying transverse momentum P1) which is caused by the charge -Q at a distance D from +Q, is given by F= Q squared)/ (D squared) = P1 * angular frequency of rotation of the vector P1 around the circle of radius R. So F = (Q squared)/(D squared)= P1 * 2pi f where f is the frequency of rotation and 2pi f is the angular frequency of rotation of P1. (The same equation applies for rotating P2 of charge -Q due to the force of charge Q) When this force equation is solved for Q by using (from paragraph C above) P1= h/2L = h/(2*pi*D) and f = c/L = c/(pi*D) we obtain the value Q= sqrt (hc/pi). Since alpha = 2pi * (e squared)/hc (in cgs units), this gives Q = e * sqrt (2/alpha) = 16.55..e.*

*E) This same value of Q can also be obtained by setting the value of electric potential energy between the two charges Q and -Q, given by V = (Q squared) / D , equal to the energy of motion of the dumbon E = hf and solving for Q. Since f = c/L = c/(pi*D), this gives (Q squared) / D = E = hc/(pi*D). Solving for Q we find Q = sqrt (hc/pi) as before. And since alpha = 2pi * (e squared)/hc (in cgs units, this gives Q = e * sqrt (2/alpha) = 16.55..e.*

The dumbon model for a photon would be verified experimentally by establishing the existence of the unique charges Q and -Q composing the model. Such verification would help us to further understand the relationship between electric charge and light that is fundamental to quantum electrodynamics and to our physical existence.

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