SUPERLUMINAL HELICAL MODELS FOR THE ELECTRON AND PHOTON

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Revised July 1, 2003

ABSTRACT

Dynamical geometrical models of the electron and the photon are proposed which are composed of sheets of electric charge moving at superluminal velocities in closed and open helical paths respectively. In both models, the sheets of electric charge always internally travel faster than the speed of light, and the size, structure, wavelengths and helical motions of these sheets of electric charge correspond to their energy, momentum and angular momentum, and the electron's magnetic moment to first order. The photon and electron models are closely related through the geometry and dynamics of electron/positron pair production from a photon, resulting in the quantum mechanical 720^{o} rotational symmetry of the electron model. When the electron model moves as a whole with velocity v, it is found that its internal structure generates the electron's deBroglie wavelength $L = h / mv$, due to internal photon-like Doppler wavelength shifts and wave interference. The electron model also increases its total energy (and therefore its mass) with its velocity in accordance with special relativity, due to the increased net energy associated with the Doppler-shifted frequency of the circulating charged photon-like entity that composes the electron model. Due to the constancy of the electron's angular momentum with velocity, a relativistically moving electron model is found to decrease in size with velocity so as to be consistent with experimental determinations of the maximum size of an electron from high energy scattering experiments. The two models illustrate a new concept of quantum wave-particle duality, where the form of the charged sheets (two in the photon and one in the electron) constitute the particle and their superluminal motion constitutes the wave. This modeling approach predicts that there are two varieties of right circularly polarized photon (and also two types of left circularly polarized photon), depending on whether the positive or negative charge sheet is in front in the photon's direction of motion, and two varieties of negative electron (and two varieties of positron), depending on whether the electric charge sheet in the electron moves

forward clockwise or counterclockwise in its closed helical structure. These 2 predicted varieties of the present photon and electron should be distinguishable by the different magnetic fields that they would produce.

Recent 3-D electron models

Several recent 3-D electron models have some but not all of the electron's known physical parameters. One such model is the Spinning Charged Ring model [1]. This model, which is based completely on classical electrodynamics, is consistent with the electron's spin and its magnetic moment (to the second order approximation). This extremely thin charged ring (its main radius is the Compton wavelength divided by 2π and its ring radius is about 10^{-200} meters [2] spins at the speed of light. This model is missing a major characteristic of the electron–its experimentally observed deBroglie wavelength. Another recent electron model is the Compton Radius Vortex model [3], which describes the electron as a relativistic vortex rotating at the speed of light, whose radius is the Compton wavelength. In this model there is a physically inaccessible region at a radius less than the Compton wavelength within the electron vortex where there are virtual particles traveling at superluminal velocities, while on a sphere of radius equal to the Compton wavelength there are massless 'particlets' travelling at the speed of light. This model has the electron's spin and magnetic moment (to first order) but also does not account for the deBroglie wavelength. A third electron model, the Space Resonance model [4], is also related to the Compton wavelength by incoming and outgoing spherically symmetric scalar waves to and from the electron model's center. This model has the electron's spin, 720^{o} rotational symmetry and deBroglie wavelength but not its magnetic moment. There are apparently no successful quantitative 3-D geometrical models for the photon, although there is some theoretical and experimental evidence for a composite structure of the photon [5].

The superluminal flexible charged sheet -- a new concept interrelating the proposed photon and electron models

The present electron and photon models are an outgrowth of earlier work (6) on modeling the photon and electron as open and closed helices but did not include the charged sheet concept proposed here. The proposed charged sheets photon model has the following properties:

1.It is a quantum particle consisting of two equal and oppositely-charged transformable sheets of charge +e and –e. Each of the uniformly charged sheets if laid flat would be a 45-degree parallelogram one wavelength long at its base and one wavelength high and so has an area of one wavelength squared. The two charged sheets are attached along a common 45-degree side so that their top and bottom sides are in line (see Figure 1). Then the top edge of the first charge sheet is attached to the bottom edge of the second charged sheet to form a perfectly-fitting, continuous 45-degree helical tube of the two charged sheets, with no openings in the sides and no overlapping. If L is the length of the base and the length of the top of each parallelogram, then the radius R of the double-sheet cylinder-like tube that is formed is given from the geometry of the 45-degree helical structure by $L = 2\pi R$. So in this photon model, L is the wavelength of the photon and R is the radius of the photon's helical tube structure.

2.The photon model consisting of this tube of two circularly curved connected charged sheets moves forward at the speed of light c while the charged sheets themselves rotate and advance along the direction of the two charge sheets' common 45-degree boundary. So due to this geometry, all bits of electric charge on the charged sheets moves uniformly in a winding, helical motion at the superluminal speed of $c\sqrt{2}$ or 1.414..c . Since the whole photon model's structure rotates once at some rotational frequency f while it moves forward a distance L at the speed of light c, it's rotational frequency f is given by $f = c / L$, the frequency to wavelength relationship for a photon.

3.The two connected transformable, oppositely charged sheets that compose the photon model carry energy, linear momentum and angular momentum such that, like a real photon:

a. its total energy E given by $E = hf$

b. its linear momentum is given by $P = h / L$

c. its angular momentum or spin is given by $S = h / 2\pi$

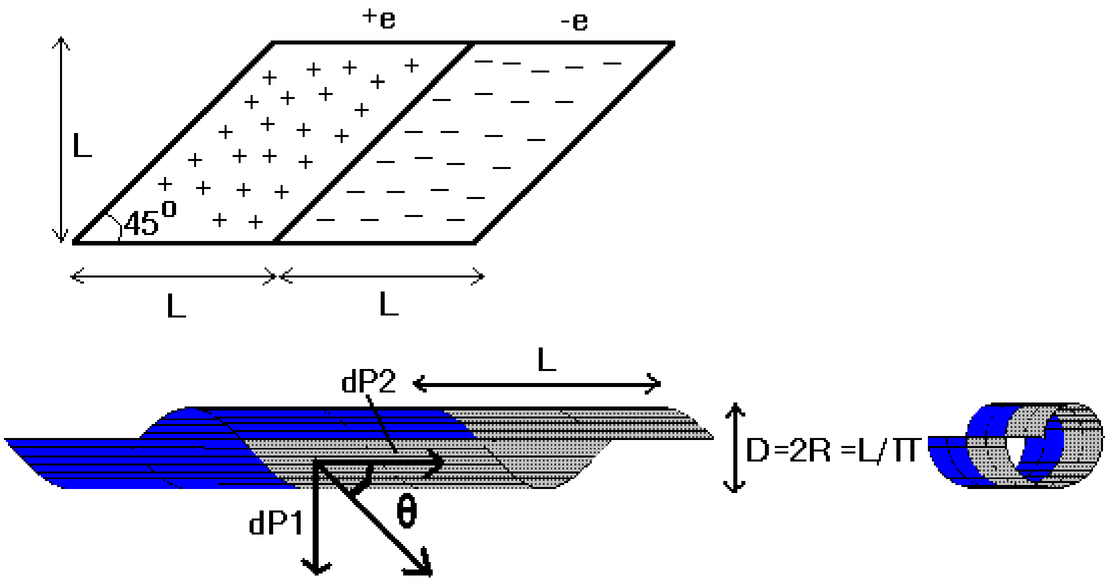

Figure 1. The charged sheets model of a photon (2-D lay-out, 3-D side view and 3-D angle view). The total charge on each sheet is +e and –e respectively. The two sheets of electric charge move to the right in a helical path with a turning distance L corresponding to the wavelength L of a photon. The angle θ (theta) that the helical path makes with the forward direction is found to be 45° for the photon model. dP1 and dP2 are the transverse and longitudinal components of the momentum of a small area dA of one of the charged sheets.

So if the photon model moves in the z direction, formulas for a helix, which include the radius, wavelength and 45° angle of the charge sheets photon model of wavelength L, shown in Figure 1, are given by:

$$x = (L/2\pi)\cos(2\pi z/L) \qquad (1)$$

$$y = (L/2\pi)\sin(2\pi z/L) \qquad (2)$$

The two charged sheets in the photon model move through space with their described helical structure. But the helical form defined by x and y above is not itself a wave and so does not itself move through space at the speed of light. Rather, the photon model flows through space along this helix, with a forward velocity of the speed of light. The movement of the two charged sheets along this helix gives the photon model its wave-like character, while the two connected charged sheets themselves give the photon model its particle-like character. This wave-particle character of the photon model, created by the charged sheets and their motion, will also apply to the electron model described below. So these two models express a novel and unifying concept of quantum wave-particle duality.

Why is the helical angle 45° in the photon model for any photon energy, and not some other angle? Here is the proof. Assume that you do not at first know that the correct value of the forward helical angle θ is 45° . The charge density σ (sigma) of each of the two charged sheets is given by $\sigma = \pm e / L^2$ since the area of each charged sheet carrying charge e and -e is L^2. Each small area dA (which carries charge $dQ = \sigma dA$) of either charged sheet has a momentum component dP_1 (whose value is also proportional to dA) perpendicular to the direction of motion of the photon model (which contributes an angular momentum of R dP_1 to the photon model), and a momentum component dP_2 (also proportional to dA) that is parallel to the direction of motion of the photon model (which contributes to the forward linear momentum of the photon model). For all dP_1 and dP_2 corresponding to small areas dA on both of the charged sheets, dP_1 and dP_2 are (as seen in Figure 1) in a geometrical relationship $\tan(\theta) = dP_1 / dP_2$ where θ is defined as the angle that the total instantaneous momentum of the small charge dQ in area dA (which moves along its own helical path) makes with the forward direction, i.e. with its forward component of momentum dP_2. The radius of the helix is R and its wavelength or pitch is L. The total forward momentum P_2 of either of the charged sheets is given by $P_2 = \sum dP_2$ over area L^2 for each charged sheet, or $P_2 = dP_2 (L^2 / dA)$ for each charged sheet since dP_2 is proportional to dA. Since it is experimentally known that the linear momentum of any photon is $P_{total} = h / L$, in the charged sheets model for the two charged sheets this gives $P_2 + P_2 = h / L$, or $P_2 = h / 2L$ as the forward momentum P_2 of each charged sheet . And so

$$dP_2 = P_2 (dA / L^2) = (h / 2L) (dA / L^2) \quad . \tag{3}$$

Similarly, the total angular momentum S of the charged sheets photon is given by $S = 2 \text{ sheets} \times R \sum dP_1$, summed over one of the charged sheets, or $S = 2 R P_1$, where $P_1 = \sum dP1$ over either charged sheet's area L^2. So $P_1 = dP1 (L^2 / dA)$. So from the photon model, $S = 2R\,P_1 = 2R\,dP1\,(L^2 / dA)$. Since the spin of any photon is experimentally known to be $S = h / 2\pi$, this gives the total photon model's spin or angular momentum to be the sum of the contributions of the charged sheets e and –e to the spin , or

$$S = 2\,R\,P_1 = h / 2\pi \text{ . So } P_1 = h / 4\pi R \text{ , and } dP_1 = (h / 4\pi R)(dA / L^2) \text{ .} \qquad (4)$$

Substitute the results for solving for dP_1 and dP_2 above into the above relationship

$$\tan(\theta) = dP_1 / dP_2 \qquad (5)$$

$$= (h/4\pi\,R)\,(dA/L^2)\ /\ (\ h/2L)(dA/L^2) \qquad (6)$$

$$= (1/4\pi\,)\,(h/R)\,/(\,h/2L) \qquad (7)$$

$$= L/2\pi\,R \qquad (8)$$

This equation for $\tan(\theta)$ is based on comparing the photon model's angular momentum with its linear momentum. A second equation for $\tan(\theta)$ is found based on the photon model's geometry. In one complete rotation of the charged sheets along their helical paths, each small charge amounts dQ on a sheet moves forward a distance L while moving at an angle θ in a helical path along the surface of a cylinder-like tube whose radius is R. So the transverse distance the charge dQ moves around the cylindrical tube is $2\,\pi R$ each time the charge dQ advances a longitudinal distance L. So purely by the geometry of the cylinder-like tube and the way θ has been defined (see Figure 1) ,

$$\tan(\theta) = \text{circumference of cylinder / length of cylinder segment or helical pitch}$$

$$= 2\pi\ R/L\ . \qquad (9)$$

So we have found two different expressions for tan (θ): $\tan(\theta) = L/2\pi\,R$ and $\tan(\theta) = 2\pi\,R / L$. So they must equal each other: $\tan(\theta) = 2\pi\,R/L = L/2\pi\,R$. This can only be true if $\tan(\theta) = 1$. So since $\tan(45^o) = 1$, then

$$\theta = 45^o,\ L = 2\pi\,R\ ,\ dP_1 = dP_2\ ,\ \text{and}\ P_1 = P_2 = P \qquad (10)$$

for each charged sheet. And so, from above, $P = h / 2L$, the longitudinal momentum of each charged sheet. This proves why the forward angle of the helix can only be 45^o in the charged sheets photon model. It also gives a simple geometric relationship between the photon model's wavelength L and its radius R: $L = 2\pi\,R$.

The charge densities in the photon model

For the negative charge sheet on the charged sheets photon model with wavelength L, the charge –e is spread uniformly over the area L^2, so the negative charge density $\sigma_{\text{photon neg}}$ is given by $\sigma_{\text{photon neg}} = -e/L^2$ .The positively charged sheet will have a positive charge density $\sigma_{\text{photon pos}} = +e/L^2$. In the case of the lowest energy photon that can create an electron/positron pair (obtained from $E = 2m_e c^2 = hf = hc/L$) such a photon's wavelength is $L = h/2m_e c = L_c/2$ (where $L_c = h/m_e c$, the Compton wavelength) and so the negative charge sheet's density for such a photon is

$$\sigma_{\text{photon neg}} = -e/L^2 = -4e/L_c^{\ 2} \tag{11}$$

and its positive charge sheet's density is

$$\sigma_{\text{photon pos}} = +e/L^2 = +4e/L_c^{\ 2} \ . \tag{12}$$

The momentum density in the photon model

In the same way, the two charged sheets in the photon model can be considered to each carry a momentum density, uniform over the two sheets, which give the photon model its total longitudinal momentum h/L. The total longitudinal momentum of the negatively charged sheet, for example, is $p = h/2L$. Since the area of this sheet of negative charge is L^2, its momentum density is

$$\sigma_{\text{photon longitudinal momentum neg}} = (h/2L)/L^2 = h/2L^3 \ . \tag{13}$$

As above for electron/positron pair production, the lowest energy photon for this has $L = L_c/2$, and so in this photon,

$$\sigma_{\text{photon longitudinal momentum neg}} = h/2(L_c/2)^3 = 4h/L_c^{\ 3}. \tag{14}$$

Since the forward helical angle is 45^{o} , the transverse photon momentum density equals the longitudinal momentum density, so also

$$\sigma_{\text{photon transverse momentum neg}} = h/2(L_c/2)^3 = 4h/L_c^{\ 3}. \tag{15}$$

If we check this transverse momentum density by calculating the spin S of the whole photon model (with both charge sheets) for any photon, we have

$$S_{photon} = 2 \text{ sheets} \times \text{radius of photon model} \times \sigma_{\text{photon transverse momentum neg}} \times \text{area of negative sheet}$$
$$= 2 \times L / 2\pi \times h / 2L^3 \times L^2$$
$$= h / 2\pi \quad \text{which is the correct spin of any photon.} \qquad (16)$$

Electron-positron pair production from the charged sheets photon model

When a photon whose energy equals or exceeds the rest mass energy of two electrons (or rather the total rest mass energy of an electron and a positron) comes near a heavy particle like a proton or an atomic nucleus, there is a probability that the photon will be transformed into an electron-positron pair in this interaction

$$\text{photon} + \text{heavy particle} \rightarrow \text{electron} + \text{positron} + \text{heavy particle} \qquad (17)$$

The heavy particle is not transformed during the interaction. The heavy particle absorbs almost all of the forward momentum of the photon but very little of its energy. (It is similar to when a rubber ball bounces off a wall. The interaction transfers ball's forward momentum to the wall, but most of the ball's original energy remains with the reflected ball). The electron-positron pair that is produced still contains together the total angular momentum or spin that the photon originally carried—h/2π, i.e. each has a spin h/4π, the experimentally measured z-component of electron spin.

Electron/positron pair production from a photon interacting with a heavy nucleus should require a close geometrical and dynamical relationship between 3-D photon and electron models. In the photon model, when the electron and positron are formed from a photon in pair production, the negatively charged sheet in the photon model becomes a circulating negatively charged sheet that composes the produced electron, while the positively charged sheet of the photon model will become the positively charged sheet that composes the positron. The newly formed electron and positron keep the angular momentum associated with their corresponding charged sheets in the photon model, while the charged sheets are transformed and reconfigured, while conserving energy, momentum and angular momentum.

Consider the case where the energy E_1 of the photon model in electron-positron pair production exactly equals the rest energy of the electron-positron pair produced, that is, $E_1 = 2m_e c^2 = h f_1 = hc / L_1$ (where $2m_e$ is the sum of the rest masses of the electron and the positron that will be created from the photon model, f_1 is the photon model's frequency, and L_1 is its wavelength). So according to our previous result, $L = 2\pi R$ for the photon model, so the charged sheet -e in the photon model is moving in a helical path whose radius is $R_1 = L_1 / 2\pi$. Since $2 m_e c^2 = hc / L_1$, this gives $L_1 = h / (2 m_e c)$, and $R_1 = h / (4\pi m_e c)$ for the wavelength and the radius respectively of this photon model.

Now consider the electron model that can be produced in this pair production reaction (the results will be the same for the produced positron). This electron model will be composed of a new configuration of the photon model's negatively charged sheet carrying charge -e, which in the electron model now travels with a new wavelength L_2 in a circular orbit of radius R_2 (both to be determined), where the plane of this circular orbit is perpendicular to the original direction of movement of the photon model. This new electron model, a circulating sheet of charge -e, has the same total spin $h/4\pi$ (in the original forward direction) as the negatively charged sheet had in the photon model. (If the direction of the photon model's spin had been opposite to the photon's longitudinal motion, then the spins of the created electron and positron pair would also both be in that opposite direction.)

Now let us look at the energy E_2 and wavelength L_2 of the electron model produced (as yet we don't know it's structure). If the electron model is a circulating photon-like entity composed of only a negative charged sheet, then its energy E_2, frequency f_2 and wavelength L_2 are proposed to be given by $E_2 = m_e c^2 = h f_2 = hc / L_2$. This gives $L_2 = hc / (m_e c^2) = h / m_e c$ (the Compton wavelength). Note that E_2 of the electron is half of E_1, the original energy of the photon model for pair production, which had wavelength $L_1 = hc / (2 m_e c^2)$. And $L_2 = 2 L_1$, i.e. the wavelength of the photon-like entity composing the new electron (and positron) model is twice the wavelength of the original photon model for pair production.

The structure of the electron model

We have seen above that for the new electron model (as a circulating negatively charged sheet photon-like entity), the z-component of the electron model's spin is $h/4\pi$ by conservation of angular momentum in photon pair production from the photon model (which originally traveled in the z direction) , and the electron model's (and also the positron model's) wavelength L_2 is given by $L_2 = 2 L_1$ by conservation of energy from the photon model. But we know that in the photon model, $L_1 = 2\pi R_1$ where R_1 is the radius of the photon model's charged sheets' helical path. Combining these two equations we get the electron model's wavelength $L_2 = 4\pi R_1 = h / (m_e c)$. We still do not know R_2 , a radius associated with the electron model. Could R_2 be related to the wavelength L_2 as a radius to a circumference, like in the photon model? Then R_2 would be $L_2 / 2\pi$. A photon-like object of momentum $p = h / L_2 = m_e c$, circulating at a distance $R_2 = L_2 /2\pi = h/(2\pi m_e c)$ would have an angular momentum or spin S given by $S = p R_2 = m_e c \times h/(2\pi m_e c) = h/2\pi$. This is not correct for an electron because it is twice the electron's known spin of $h/4\pi$. If however the charged photon-like charged sheet of wavelength L_2 circulates TWICE around a circle of radius R_2 before joining itself, then the radius R_2 would be found from $2 \times 2\pi R_2 = L_2$, or $R_2 = L_2 / 4\pi$. Now the charged photon-like object (our electron model) of momentum $p = h / L_2 = m_e c$, circulating at a distance $R_2 = L_2/4\pi = h/(4\pi m_e c)$ would have angular momentum or spin $S = p R_2 = m_e c \times h/(4\pi m_e c) = h/4\pi$, which is the correct electron spin. Note that this R_2 for the electron model has the same value as R_1 , the radius of the photon model having the minimum energy that can create the electron-positron pair in this example: $R_2 = R_1 = h/(4\pi m_e c)$. This equality of radii of the photon model and the electron (and also the positron) model in pair production, consistent with conservation of energy, momentum and angular momentum during the interaction, should make it easy for a photon's two charged sheets to reconfigure themselves during the interaction to form an electron model and a positron model.

But if the electron model is to be composed of a circulating negatively charged sheet, it cannot just circulate with a constant radius R_2 like a spinning ring or a spinning sphere. Rather, R_2 will be one parameter of it's the electron model's 3-D structure. The sheet of negative charge that forms the electron model must move with a wavelength $L_2 = h/(m_e c)$ as found above. What will be the 3-D structure of the electron model? First we can, as a mathematical construction, model the circulating charged photon-like entity in our electron model as a closed charged helical loop containing total charge –e , which moves along a helical path whose axis is a closed circular path rather than a straight line. Then according to our above geometrical results for the electron, that $R_2 = L_2/4\pi = h/(4\pi\ m_e c)$, the form of this path of electric charge in the electron model is a closed helix. This helix closes on itself after traveling along its circular axis one helical wavelength L_2 that equals 2 times the circumference, that is $L_2 = 2 \times 2 R_2$, of its circular axis which has radius $R_2 = h/(4\pi\ m_e c)$. Second, when we have the 3-D shape and equations for the charged closed helical path with the proper wavelength L_2 , that charged closed helix can be uniformly spread out in space to form a closed sheet of negative charge by rotating it 360^o about its z-axis to generate the 3-D form of the electron model, as will be shown below.

We might think that the radius of the closed helix photon-like negatively charged sheet in the electron model should keep the same $1/2\pi$ ratio to the wavelength of the closed helical path, as in the charged sheets photon model. That latter ratio was caused by the photon model's dynamical properties and geometry, while the electron has a different geometry and different dynamical properties, such a its spin and magnetic moment. And the analysis of the electron-positron pair production above only included the wavelength L_2 of the circulating photon-like object composing the electron model, and not the electron model's second helix-generating radius (not the same as R_2 which is the first helix-generating radius that defines the circular axis of the closed helix of the electron model) of that circulating photon-like object. So it may be that the second generating radius of the closed helical photon-like charged sheet, composing the electron model, is different from that of the photon model, composed of two oppositely charged sheets that travel in an open helix. And in fact the second generating radius of the helical path of the electrically charged sheet in the electron model will be found to depend on, in fact to determine, the magnetic moment of the electron model, which a photon does not have.

The calculated spin of the electron model must take into account the actual positions of the circulating negatively charged sheet and not only its average position, because it is the circulating charged sheet that carries the momentum which is used to calculate the electron model's spin. Also the magnetic moment of the electron model will depend on the velocities and positions of the electric charge in the charged sheet. For the electron model to be viable, these more detailed calculations must yield the correct spin of the electron and, at least to a first order approximation the correct magnetic moment of the electron (i.e. it should yield at least the so-called anomalous or $g = 2$ gyromagnetic ratio of the electron). Higher order quantum electrodynamic corrections to the $g = 2$ gyromagnetic moment of the electron model are beyond the scope of this article, though the present electron model includes the possibility of incorporating such later higher order corrections in the magnetic moment through further adjustments in the electron model's helical parameters.

The equations for the form of the electron model

In this electron model, what is the form and formula of a closed helix which closes after a single wave length L_2 which equals twice the circumference of $2\pi R_2$ of its circular axis? This 3-D closed helix can be generated in the following way. Take a first generating circle in the x-y plane of radius one whose center is at the z-axis $(x = 0,\ y = 0,\ z = 0)$. Choose a first generating point P_1 on this circle $(x = 1,\ y = 0,\ z = 0)$ as the center of a second generating circle of radius b that is perpendicular to the x-y plane in the direction of the z-axis, with a second generating point P_2 ($x = 1 + b,\ y = 0,\ z = 0$, where b is a real number) on this second circle, that is initially also in the x-y plane (so that the initial distance of point P_2 from the z-axis is $1 + b$.) As the first generating point P_1 on the first generating circle moves counterclockwise in the x-y plane with increasing angle θ in the x-y plane as measured from the x-axis, and carries the second generating circle of radius b with it, the generating point P_2 on the second generating circle moves through an angle $\theta/2$ first upwards and around this circle's horizontal axis (which is in the x-y plane, at $z = 0$). At $\theta = 720^o$ (the first generating point P_1 having moved twice around the first circle), the helical figure that is generated by the movement of the rotating second generating point P_2 on the second generating circle closes on itself (at $\theta/2 = 360^o$). The resulting geometrical figure (a closed helix) swept out by point P_2 is given in cylindrical coordinates by:

$$r = 1 + b\cos(\theta/2) \tag{18}$$

$$z = b\sin(\theta/2) \tag{19}$$

where r is the distance of the moving second point P_2 from the z-axis, z is the distance of point P_2 above (or below) the x-y plane, and θ is the angle in the x-y plane that r makes with the x-axis. θ goes from 0 to 720^{o} to create the generated closed helix.

This same closed helix is described in rectilinear coordinates by:

$$x = (1 + b\cos(\theta/2))\cos(\theta) \tag{20}$$

$$y = (1 + b\cos(\theta/2))\sin(\theta) \tag{21}$$

$$z = b\sin(\theta/2) \tag{22}$$

where (x,y,z) is the position of the moving second point P_2, and θ is the angle that a horizontal line from the z axis to the point $(x, y, z = 0)$ makes with the x-axis. θ goes from 0 to 720^{o} as before.

If R_o is now defined as the previous $R_2 = (1/4\pi)\, h/m_e c$, the first generating radius obtained for the helical axis used to generate the closed helix for our electron model, and the generating radius of the second circle is R_o b, then in cylindrical coordinates:

$$r = Ro(1 + b\cos(\theta/2)) \tag{23}$$

$$z = R_o\, b\sin(\theta/2) \tag{24}$$

where r is the distance from the moving second point P_2 to the z-axis, where z is the distance above (or below) the x-y plane, and θ is the angle in the x-y plane that r makes with the x-axis. θ goes from 0 to 720^{o} to close the curve.

And in rectilinear coordinates:

$$x = R_o (1 + b \cos(\theta/2)) \cos(\theta) \quad (25)$$

$$y = R_o (1 + b \cos(\theta/2)) \sin(\theta) \quad (26)$$

$$z = R_o b \sin(\theta/2) \quad (27)$$

where θ goes from 0 to 720° as before.

So $R_o = (1/4\pi)\, h/m_e c$. The angle θ is a linear function of time t and will be seen later to be $\theta = (4\pi\ m_e c/h)\, t = (c/R_o)\, t$ for the electron model. The value b in the closed helix formulas will be seen below to depend on and determine the magnetic moment of the electron model, and is found later to be $b = \sqrt{2}$

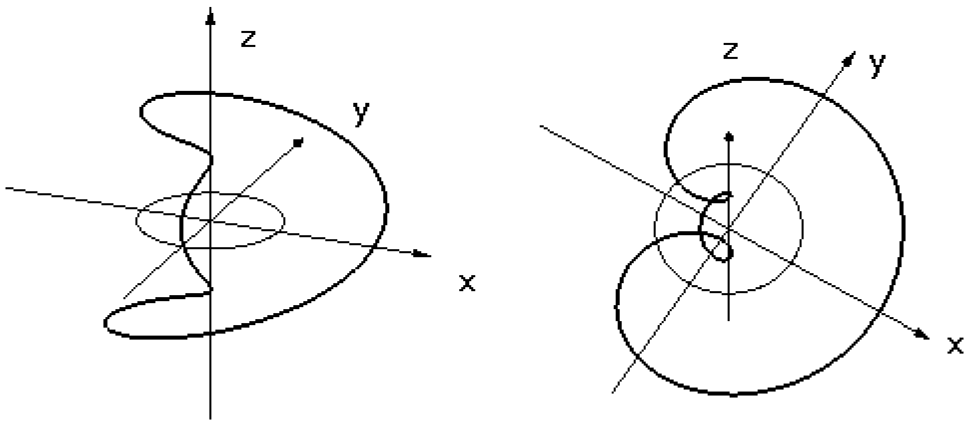

Figure 2 Two views of the closed 3-D helix which is rotated around the z-axis to generate the electron model's form, using $b = \sqrt{2}$. The circle in the x-y plane of radius $R_o = (1/4\pi)\, h/m_o c = 1.9 \times 10^{-13}$ meters, is used to generate the closed helix.

To obtain the electron model, first the electric charge –e is mathematically distributed continuously along the closed helical loop in Figure 2 such that equal intervals of θ around the z-axis contain equal amounts of electric charge. (θ goes from 0° to 720° i.e. twice around the z-axis while $\theta/2$ goes from 0° to 360° around the generating axis of the closed helix.) Then this whole charged closed helical loop is mathematically rotated 360° around the z-axis, evenly spreading out its charge along the 360° rotational direction to form a closed toroidal surface which is the form of the electron model (once b has been determined) as shown in Figure 3. At each point on the surface of the electron model, charge flows superluminally along a closed helical path of the same shape as the original closed helical path which was mathematically rotated to obtain the electron model's form. Due to the way the electron model's closed charged sheet form was generated, the charge density on the surface of the electron model is constant around the z-axis of the electron model for a particular angle θ of the closed helical path. But the charge density on the surface of the electron model, like the mathematical distribution of charge on the closed helix used to generate the electron model, varies with the angle θ in such a way that for equal angular intervals of θ between 0^o and 720^o, circular horizontal surface rings on the electron model, centered on the z-axis of the electron model, contain equal amounts of electric charge.

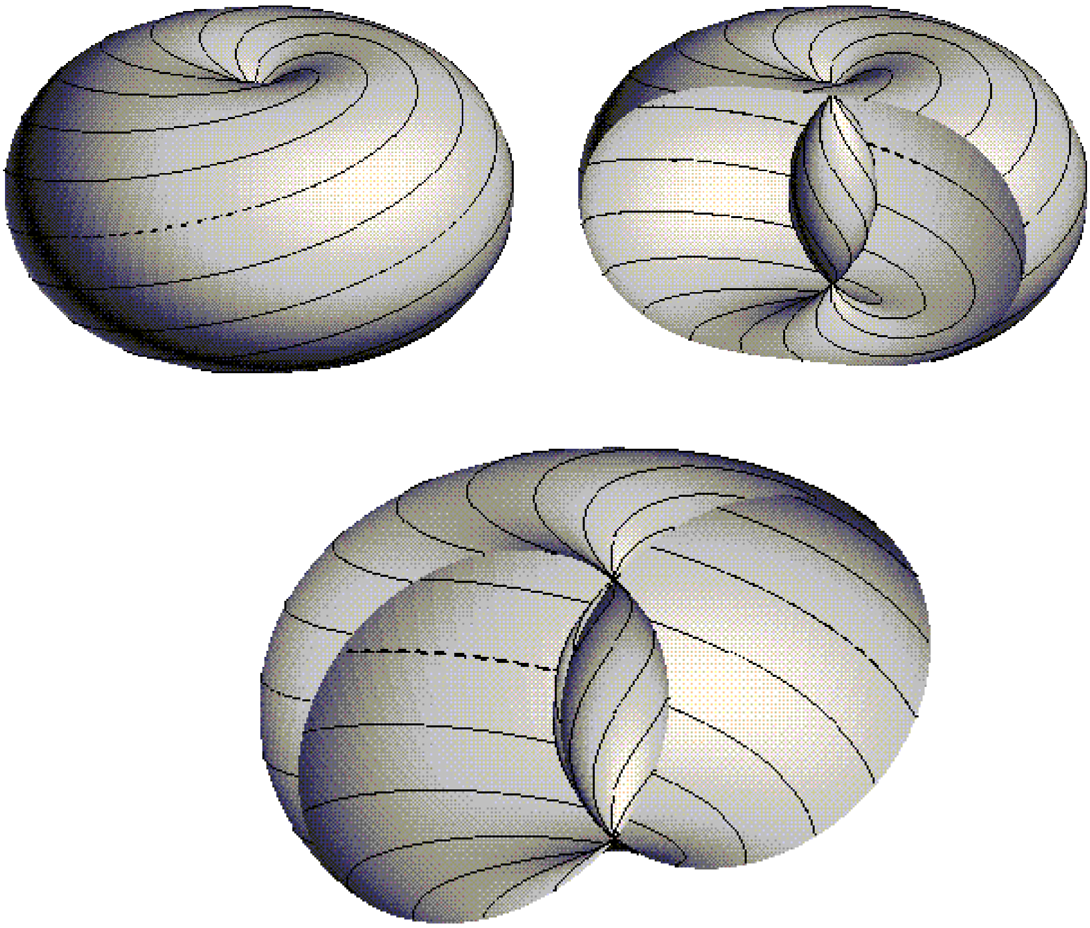

Figure 3. Side views of the 3-D charged sheet electron model made by rotating the closed helix in Figure 2 360^o around the z-axis. Three views are shown: from the outside, in a partial cross section, and in a central cross section. Electric charge totaling -e is flowing on the surface of the whole negatively charged sheet in the directions indicated by the lines, at variable speeds all greater than the speed of light.

The charge density of the electron model

What is the charge density of the electron model? Based on the way the electron was generated by rotating the charged closed helix above around the z-axis, the surface charge density $\sigma_{electron}$ of the electron model is found to be:

$$\sigma_{electron} = -e/(2\pi)^2 R_o^{\,2}(1+b\cos(\theta/2)) \qquad (28)$$

And since $R_o = (1/4\pi)\, h / m_e c$ this gives

$$\sigma_{electron} = -4\, e\, m_e^{\,2} c^2 / h^2\, b(1+b\cos(\theta/2))$$

$$= -4\, e / (L_c^{\,2}\, b(1+b\cos(\theta/2)) \qquad (29)$$

Comparing $\sigma_{photon\ neg} = -4e / L_c^{\,2}$ obtained earlier for the photon model, with $\sigma_{electron}$, it can be see that these charge densities are similar and are quite compatible with the proposal that the open helical form of the negatively charged sheet in the photon for pair production can be straightforwardly transformed into the closed helical, self-intersecting, helically circulating charged sheet of the electron model. The charge density of the electron model depends on the values of θ and its closed helix's radius radio b (found below to be $b = \sqrt{2}$ for the electron model). The negatively charged sheet of the photon model would have to stretch in some parts and compress in other parts in order to be transformed into the negatively charged sheet of the electron model while the charged sheet continues to move at superluminal velocities.

The spin and momentum density of the electron model

Each bit of charge in the electron model contributes to the angular momentum or spin S of the electron model as that bit of charge travels in a closed helical path which closes on itself after traveling a distance $L_c = h / m_e c$ and through 720^o , twice along the helix's circular axis of radius $R_o = (1/4\pi)\, h/m_e c$. Collectively, the electron model's spread-out charge, moving helically with this wavelength L_C , can be described as a photon-like object of wavelength L_C and energy given by

$E = hf = m_e c^2$ moving in a closed, double-looped path, where f is its cycling frequency of any bit of electric charge along its helical path in the electron model. If a photon of Compton wavelength $L_c = h / m_e c$ and momentum $p = m_e c$ could actually travel in a circular path in the x-y plane of radius R_O, with its momentum concentrated at the distance R_O from the z-axis, its angular momentum or spin S would be $S = R_o\, p = (1/4\pi)\,(h/m_e c) \times m_e c = h/4\pi$, the experimentally measured z-component of the spin of an electron.

But in the electron model, the momentum and angular momentum contributions of the charge -e are spread out over the whole circulating charged sheet, and not only located at the radius R_O from the z axis (except at moments when any bit of the charge crosses this distance R_O while circulating in its closed helical path described by the above formulas.

We want to calculate the spin S of the electron model to confirm that it is $h/4\pi$ as it should be. Since the electron model is rotationally symmetric around the z-axis, it can only have a non-zero component of spin along it's z-axis, which is what we will calculate. Due to this rotational symmetry, all the charge in a surface ring around the electron model at a particular angle θ (and since the charge -e is spread continuously over the surface, this means all the charge within a differential angular range of θ and $\theta + d\theta$ around the electron model) , contributes equally to the spin of the electron model. So for this spin calculation, as well as the later magnetic moment calculation, the charge and momentum can be mathematically considered to be concentrated along the original closed helical loop given by the formulas above, with equal amounts of the total charge –e spread between equal angular intervals of θ. So S can be calculated based on what the momentum density of this charge is at all angles θ along its 720^{o} path, in the same way that the magnetic moment of the electron model is to be calculated based on the position and velocity of the spread-out electric charge as it moves with variable velocity v at different angles θ along it's closed helical paths.

How is the axial momentum density (that which contributes to the electron model's spin) of the circulating charge at angle θ in the charge sheet electron model to be calculated? This momentum density will not necessarily be independent of θ, since the curvature of the path of the circulating charge, and so presumably its momentum also, depends on θ. The way this momentum is calculated should be consistent with the way it is calculated in the photon model. So consider first the path of a small amount of negative charge in the photon model. This bit of charge travels in a helical path whose curvature is constant and related to the wavelength of the photon model. If the curvature of the path of the bit of negative charge in the photon model would be decreased (this would only happen if the radius of the photon model were proportionally increased), then the corresponding wavelength L would also increase, and the forward momentum of this bit of charge along its open helical path would decrease according to the photon's momentum relationship $p = h/L$. So the less is the instantaneous curvature of the helical path of a small amount of charge in the photon model, the larger it's instantaneous wavelength will be and the smaller will be its instantaneous forward momentum, and vice versa. In a photon model of a particular wavelength, a bit of charge follows a path of constant curvature.

But in the electron model, the curvature of the path of a bit of charge varies continuously as the charge follows its closed helical path as θ changes from 0^o to 720^o. How will the axial momentum density of a helically cycling bit of charge vary with θ? Comparing with the photon model, it is reasonable to propose that for the electron model the instantaneous momentum of a bit of charge moving in its closed helical path is also inversely proportional to the instantaneous wavelength that, in the electron model, changes with its path's curvature at angle θ along its closed helical path, so that a lower path curvature at some angle θ corresponds to a higher instantaneous wavelength and therefore a lower momentum density at that θ. Assume for example, in the electron closed helix formulas above, that the second generating radius of the electron model's closed helical path is $R_o/2$ (that is, set $b = 1/2$ in the closed helix formulas above) while the first generating radius remains R_o. As a bit of charge cycles helically at a distance $R_o/2$ around its circular axis of radius R_o, it will come closest to the z-axis at a distance $R_o/2$ (at $\theta = 360^o$ where $\cos\theta/2 = -1$) while the circulating bit charge will be furthest from the z-axis at a distance of 1.5 R_o (at $\theta = 0^o$ and again at $\theta = 720^o$ where $\cos\theta/2 = 1$). The bit of charge that is at its maximum distance from the z-axis (where the axial velocity component for the charge is proportional to the distance from the z-axis and in this example is 1.5 c), also has its minimum path curvature here. So by geometry, the corresponding instantaneous wavelength for the bit of charge at the distance 1.5 R_o from the z-axis is 1.5 L_c where L_c is the Compton wavelength. The instantaneous momentum of a bit of charge here would then be inversely proportional to 1.5 L_c (just as in the photon model the momentum of a bit of charge is inversely proportional to the wavelength L, except that in the electron model, L varies with θ). When this cycling bit of charge reaches its minimum distance from the z-axis, it's path has its maximum curvature, since at this minimum distance from the z-axis its axial velocity component – in the x-y plane—is now only half of what it is at the distance R_o from the z-axis. So the instantaneous wavelength for a bit of charge moving in its closed helix at the distance $R_o/2$ is $L_o/2$. The instantaneous momentum of a bit of charge here would be inversely proportional to $L_o/2$. And when the circulating bit of charge passes the distance R_o from the z-axis, either at a distance $R_o/2$ directly above or directly below the helix's circular axis in the x-y plane, the bit of charge's axial velocity component is c and its instantaneous path curvature corresponds to the wavelength L_c , the same wavelength of a free photon of energy m_ec^2 and momentum m_ec. So the instantaneous momentum contribution of the bit of charge at this position in the cycle (corresponding to $\theta/2 = 90^o$) is inversely proportional to L_c.

Since the instantaneous wavelength L of a bit of charge along its closed helical path is geometrically found to be proportional to the distance r from the z-axis in the electron model, and since $r(\theta) = R_o\,(1 + b\cos(\theta/2))$ we can summarise our above results for the instantaneous wavelength of a circulating bit of charge in our electron model, with the formula $L(\theta) = L_c\,(1 + b\cos\,(\theta/2))$, where $L(\theta)$ is the instantaneous wavelength of a bit of charge at angle θ in its closed helical path from 0^o to 720^o, and L_c , the Compton wavelength h/m_oc , is the instantaneous wavelength of the photon-like closed helical path when $r(\theta) = R_o$ So for example, if $b = 0$, then $L(\theta) = L_c$ always and there is no change in the instantaneous wavelength of the charge -e as it circles around the z axis always at distance R_o. If for example b = 1, then the instantaneous wavelength L goes to zero when the spread-out charge passes through $r = 0$ (where $\cos(\theta/2) = -1$), and $L = 2\,L_c$ at the maximum distance of the charge from the z-axis (where $\cos(\theta/2) = 1$ and $r(\theta) = Ro(1+1\cos(\theta/2)) = 2\,R_o$). By comparing the formulas for the position r(θ) of a bit of charge and L(θ) for that charge path's instantaneous wavelength, since r(θ) and L(θ) exactly proportional we get

$r(\theta)/L(\theta) = R_o\,(1+b\cos(\theta/2))/\;L_c\,(1+b\cos(\theta/2)) = Ro/\,L_c$. Since $L_c = h/m_o c$ from above and $R_o = (1/4\pi)h/m_o c$, we see that $r(\theta)/L(\theta) = 1/4\pi$ for any bit of circulating charge in the electron model, independent of the value of b.

What then is the momentum density of the electron model? For a photon with the minimum energy for producing an electron/positron pair it was found above that the charge density is $\sigma_{\text{photon neg}} = -4e/L_c^2$

and the longitudinal momentum density is $\sigma_{\text{photon longitudinal momentum neg}} = 4h/\;L_c^3$

For the electron model, the charge density is

$\sigma_{\text{electron}} = -4\,e/(L_c^2\,b(1+b\cos(\theta/2)\;)$

Similarly, since in the electron model the instantaneous wavelength of a bit of charge at position θ along its helical path was found above by geometrical considerations to be $L(\theta) = L_c\,(1+b\cos(\theta/2))$, the electron model's axial momentum density $\sigma_{\text{electron axial momentum}}$ is, by comparison with the above charge and momentum density formulas, proposed to be

$$\sigma_{\text{electron axial momentum}} = 4h/L_c^3 b(1+b\cos(\theta\;/2)^2 \tag{30}$$

If b is much less than 1, then the electron model would look like a thin charged ring (spinning at the speed of light) of main radius R_O and second radius (half thickness) bR_O , its axial momentum density from above formula would be

$$\sigma_{\text{electron axial momentum}} \cong 4h/L_c^3 b \tag{31}$$

and its spin S would be

$$S \cong \text{Radius of ring} \times \text{surface area of ring} \times \sigma_{\text{electron axial momentum}} \tag{32}$$

$$\cong \; R_o \times (2\pi \, R_o \times 2\pi \, bR_o) \times 4h / L_c^3 \, b \tag{33}$$

$$\cong 16\pi^2 \, h \, R_o^3 / L_c^3$$

since $R_o = L_c / 4\pi$ and so $R_o^3 = L_c^3 / 64\pi^3$

this gives

$$S \cong 16\pi^2 h / 64\pi^3$$

$$S \cong h / 4\pi \tag{34}$$

which is the electron's spin.

But when b is larger, the electron form is that of a torus (a thin ring is also a torus) which will intersect itself if $b > 1$, as will be found in the present electron model. The electron model's spin S can be found exactly using the above formula

$$\sigma_{\text{electron axial momentum}} = 4h / L_c^3 b(1 + b\cos(\theta/2)^2 \tag{35}$$

Then

$$S = \oiint r(\theta)\sigma_{\text{electron axial momentum}}(\theta) dA =$$

$$\int_0^{4\pi}\int_0^{2\pi} R_o(1 + b\cos(\theta/2) \times 4h / (L_c^3 \, b(1 + b\cos(\theta/2)^2) \times$$

$$R_o(1 + b\cos(\theta/2)) \, d\theta \times R_o b \, d(\theta/2) \tag{36}$$

The $(1 + b\cos(\theta/2))$ expressions cancel above, giving

$$S = \int_0^{4\pi}\int_0^{2\pi} 4h \; R_o^3 / L_c^3 \, d\,\theta \, d\,(\theta/2) \tag{37}$$

$$= 4h \times 2\pi \times 2\pi \times R_o^3 / L_c^3$$

$$= 16\pi^2 \, h / 64\pi^3$$

$$= h / 4\pi \tag{38}$$

So the spin of the electron model is found to be the correct experimental value $S = h / 4\pi$ independent of the value of b. So the helical parameter b can be selected to obtain the experimental value of the electron's magnetic moment, without altering the spin of the electron model. Now this value b will be calculated.

The magnetic moment of the electron model

When an electron is in a magnetic field, the electron apparently precesses like a gyroscope, with an experimentally measurable precessional frequency proportional to the strength of the magnetic field. Because of this, the electron is said to have a magnetic moment M. For any spinning object, the larger the value of M relative to the object's angular momentum or spin S, the faster the object will precess in a particular strength magnetic field. The value of M for an electron is known to a very high accuracy. The relation of the magnetic moment M to the spin S of an electron is traditionally given as

$$M = (-e / 2m)\ g\,S \quad \text{where } g = 2 \text{ approximately for an electron.} \tag{39}$$

The dimensionless number g is called the gyromagnetic ratio. The value of g for an electron is slightly more than 2, ($g = 2.0023193044..$) so to a first order approximation (setting $g = 2$):

$$M = (-e / m)\,S \tag{40}$$

The experimentally measured magnetic moment of an electron is slightly more than one Bohr Magneton, which has the value $M_{Bohr} = e / m\ S$, where $S = h / 4\pi$.

The calculated value of g would be only 1 for a classical (non-quantum) particle having the charge and mass of an electron, with its charge moving circularly at the speed of light at a radius of $R_o = (1/4\pi)\,h/m_o c$, which is the radius corresponding to an angular momentum or spin $S = h / 4\pi$ (the spin of an electron). It is not understood in classical (pre-quantum) terms how the electron can have an actual g value of more than twice this classical value of 1 (although the charged spinning ring model in (1) is claimed to have solved this problem by having only 50% of the electro-magnetic energy of that model contribute to the electron's spin.). This is why the experimentally observed g value of slightly more than two has been called "anomalous" in classical terms.

Calculation of the magnetic moment M in the electron model

Since the value of the position as well velocity of the spread-out electric charge -e in the electron model can be precisely specified mathematically, the value of its magnetic moment can also be calculated exactly according to a formula for M. Since the electron model is rotationally symmetric around the z-axis, the x and y components of M are zero, so the z-component of the magnetic moment M_Z is equal to the total magnetic moment M of the electron model.

In the electron model, all equal bits of charge at the angle θ along their individual helical paths have the same velocity and direction relative to the x-axis, and so contribute equally to the value of M. So the calculation of M can be mathematically simplified by first assuming that the electric charge –e is distributed smoothly(with equal amounts of charge between equal angular θ intervals) around the helical path described by the closed helix formulas derived above (It was this one-dimensional distribution of charge that was mathematically rotated to obtain the form and surface charge density of the electron model). For a numerical calculation of M that obtains the required value of b, this continuous charge distribution along the closed helix defined in the helical formulas, can be further approximated by 720 mathematical point charges, each of value $q = -e / 720$, spaced at 1-degree angular intervals of θ along the closed helix (the distances between the point charges themselves along the helical path varies with θ.)

In this numerical calculation for the magnetic moment M of the electron model, for the i'th charge $q(\theta_i)$ moving at a distance $R_x(\theta_i)$ from the z-axis, with an axial velocity $V_y(\theta_i)$ counterclockwise in the x-y plane, the value of the magnetic moment M created by all the 720 charges, each of charge $q = -e / 720$, is given by the formula for a magnetic moment M_Z.

$$M = M_z = \sum_{i=1}^{720} q(\theta_i)\ V_y(\theta_i)\ R_x(\theta_i) \tag{41}$$

In the closed helix formulas for the electron model, we have

$$R_x(\theta) = R_o(1 + b\cos(\theta/2))\cos(\theta) \quad \text{and} \tag{42}$$

$$R_y(\theta) = R_o(1 + b\cos(\theta/2))\sin(\theta)\ . \tag{43}$$

For bits of charge cycling in a closed helical path, we can specify θ precisely as linearly increasing with time t: $\theta = Kt$, by solving for this constant K. In the electron model, the helically moving charge sheet has total energy E, frequency f and cycling period T given by $E = m_o c^2 = hf = h/T$. Therefore $T = h/m_o c^2$. The angle

θ goes from 0 ^{o} to 720^o or 4 π (since $\theta/2$ goes through 1 cycle of 0^o to 360^o before the helix closes). So $\theta = 4\pi$ when $t = T = h / m_o c^2$.

Solving for K: $\theta(720^o) = 4\pi = K\ T$

$4\pi = K\ h / m_o c^2$

and therefore $K = 4\pi m_o c^2 / h$

so $\theta = (4\pi m_o c^2 / h)\ t$ (44)

or $\theta = (c / R_o)\ t$ where $R_o = (1/4\pi)\, h / m_o c$. (45)

Also, $d\theta / dt = c / R_o$ (46)

Now get $V_y(\theta)$ from the closed helix formula:

$R_y(\theta) = R_o (1 + b\cos(\theta/2)) \sin(\theta)$ which gives: (47)

$V_y(\theta) = d R_y/dt = d(\theta)/dt \times d R_y/d(\theta)$ (48)

$= (c / R_o) \times R_o ((1 + b\cos(\theta/2)) \cos(\theta) + \sin(\theta)\ (-1/2\ b\sin(\theta/2)))$

$= c\ ((1 + b\cos(\theta/2)) \cos(\theta) + \sin(\theta)\ (-1/2\ b\sin(\theta/2)))$ (49)

Substituting into the above formula for M:

$$M = \sum_{i=1}^{720} e/720\ V_y(\theta_i)\ R_o (1 + b\cos(\theta_i/2)) \cos(\theta_i) \quad (50)$$

$$= 1/720 \sum_{i=1}^{720} e R_o c\, ((1 + b\cos(\theta_i/2)) \cos(\theta_i) - 1/2\ b\sin(\theta_i/2)\sin(\theta_i)) \times ((1 + b\cos(\theta_i/2)) \cos(\theta_i)) \quad (51)$$

$$= e R_o c\ \ 1/720 \sum_{i=1}^{720} (1 + b\cos(\theta_i/2))^2 \cos^2(\theta_i)$$

$$+\ e R_o c\ \ 1/720 \sum_{i=1}^{720} ((1 + b\cos(\theta_i/2))\ (-1/2\ b\sin(\theta_i/2)) \sin(\theta_i) \cos(\theta_i) \quad (52)$$

The sum of the second line term over 720^o is vanishingly small by computer calculation, for all values of b.

$$\text{So } M = e R_o c\ \ 1/720 \sum_{i=1}^{720} (1 + b\cos(\theta_i/2))^2 \cos^2(\theta_i) \quad (53)$$

We need to find the value of b that will give the known value of the magnetic moment M of an electron. We know that (to a first order approximation)

$M = M_{bohr} = (e / m_o) \; Spin_{electron}$, where M_{Bohr} is the Bohr Magneton, and $Spin_{electron} = h / 4\pi$. So experimentally,

$$M = (e / m_o) \; (h / 4\pi) = (1 / 4\pi) \, (h / m_o c) \; ec = e R_o \, c \qquad (54)$$

Equating the known first order value for M with the electron model's calculation formula for M above, we see that:

$$e R_o \, c = e R_o \, c \times 1/720 \sum_{i=1}^{720} (1 + b \cos(\theta_i / 2))^2 \cos^2(\theta_i) \qquad (55)$$

or

$$1 = 1/720 \sum_{i=1}^{720} (1 + b \cos(\theta_i / 2))^2 \cos^2(\theta_i) \qquad (56)$$

What is the value of b for which the above expression is true? Knowing this value of b will yield the formula for the closed helix that will generate the electron model having the correct first order magnetic moment M. We can solve for b exactly in the following way:

The above sum is found by a computer calculation to give exactly the same result for 8 equally spaced angles as for 720 equally spaced angles. So when $n = 8$,
$\theta = 90, 180, 270, 360, 450, 540, 630, 720$ and
$\theta / 2 = 45, 90, 135, 180, 225, 270, 315, 360$ respectively.

Use the following table:

θ_i	$\theta_i / 2$	$\cos(\theta_i / 2)$	$\cos(\theta_i)$
90	45	$\sqrt{2}/2$	0
180	90	0	-1
270	135	$-\sqrt{2}/2$	0
360	180	-1	1
450	225	$-\sqrt{2}/2$	0
540	270	0	-1
630	315	$\sqrt{2}/2$	0
720	360	1	1

and substitute from the table into the above formula to solve for b:

$$1 = (1/8) \sum_{i=1}^{8} (1 + b\cos(\theta_i/2))^2 \cos^2(\theta_i)$$

$$8 = 0 + (1+0)^2 (1) + 0 + (1-b)^2 + 0 + (1)^2 (1) + 0 + (1+b)^2$$

$$8 = +1 + 1 - 2b + b^2 + 1 + 1 + 2b + b^2$$

$$8 = 2b^2 + 4$$

$$2b^2 = 4$$

$$b^2 = 2$$

$$b = \sqrt{2} = 1.414... \quad (57)$$

As a check, when this value of $b = \sqrt{2}$ is substituted into the 720 degrees sum above

$$1 = 1/720 \sum_{i=1}^{720} (1 + \sqrt{2}\cos(\theta_i/2))^2 \cos^2(\theta_i) \quad (58)$$

it gives the same correct result in a computer calculation as for the 8-angle sum.

Similarly, and as check on our result for $b = \sqrt{2}$, if we calculate the magnetic moment M in the electron model from a 90-degree rotated direction using the closed helix formulas, as

$$M = \sum_{i=1}^{720} q(\theta_i) (-V_x(\theta_i)) R_y(\theta_i) \quad (59)$$

($-V_X$ is used instead of V_X because the contribution to M is positive in our x,y,z coordinate system when V_X is negative and R_y is positive) instead of

$$M = \sum_{i=1}^{720} q(\theta_i) V_y(\theta_i) R_x(\theta_i) \quad (60)$$

as we did above, and using our same formulas for $R_x(\theta)$ and $R_y(\theta)$ and deriving $V_x(\theta)$ from $R_x(\theta)$ instead of deriving $V_y(\theta)$ from $R_y(\theta)$ as we did above, the equation to solve for obtaining b comes out:

$$1 = 1/720 \sum_{i=1}^{720} (1 + b\cos(\theta_i/2))^2 \sin^2(\theta_i) \quad (61)$$

with $\sin^2(\theta)$ instead of $\cos^2(\theta)$ as previously. (The contribution to M of the SUM over the products of non-squared sine and cosine terms gives zero as before.) This equation with $\sin^2(\theta)$ above also has the solution $b = \sqrt{2} = 1.414...$ So we get the same value of b from whichever side of our electron model b is calculated.

Inserting this value of b into the formulas for the electron model's closed generating helix, we get:

$$x = R_o (1 + \sqrt{2} \cos(\theta / 2))\cos(\theta) \qquad (62)$$

$$y = R_o (1 + \sqrt{2} \cos(\theta / 2))\sin(\theta) \qquad (63)$$

$$z = R_o \sqrt{2} \sin(\theta / 2)) \qquad (64)$$

If $b \cong 0$ (corresponding to the negatively charged sheet moving exactly in a ring of radius $R_o = (1/4\pi)\, h / m_o c$ at the speed of light with no helical motion), the calculation for the magnetic moment M in our electron model gives

$$M = e R_o c \times 1/720 \sum_{i=1}^{720} (1 + 0 \cos(\theta_i / 2))^2 \cos^2(\theta_i) \qquad (65)$$

$$= e R_o c \times 1/720 \sum_{i=1}^{720} \cos^2(\theta_i) \qquad (66)$$

$= 1/2 \quad e R_o c$ since the average value of $\cos^2(\theta)$ over 720^{o} is ½ . (67)

This value of $M = 1/2 \quad e R_o c = 1/2 \quad M_{Bohr}$ is the value found when a classical spinning ring model of the electron is used to calculate M at radius R_O (the radius that gives the correct electron spin $S = h / 4\pi$ for a circulating charge –e of momentum $p = m_o c$). Because the experimental value of M is slightly more than twice this value, it has been traditionally concluded that the electron cannot be visualized as a 3-d object. But in the present electron model, the correct magnetic moment (to first order) is attained by allowing the electric charge to circulate helically as a closed sheet of charge moving faster than the speed of light, even though the electron model as a whole moves at less than the speed of light. For example in the equation for $V_y(\theta)$ above with $b = \sqrt{2}$, at $\theta = 0$ the axial component of the velocity of the negative charge sheet, since $V_x = 0$ here, is $V_y = c(1 + 1.414..) = 2.414..\, c$, while the z-component of the velocity at $\theta = 0$ is $V_z = 1.414..\, c$, giving the maximum velocity of the electron model's charge sheet of

$$V_{max} = \sqrt{V_x^2 + V_y^2 + V_z^2} = 2.797..c \, . \qquad (68)$$

It could be argued that the formula for magnetic moment M used above is not correct if the charge is moving faster than the speed of light. The magnetic force on a charge e moving at velocity v is $F = e v B$ when v is perpendicular to B. Since no mass is going faster than light in the electron model, only electric charge, relativistic limitations do not necessarily apply to the charge -e (as they also do not apply to a charge moving close to but less than the speed of light where the force is also $F = e v B$), and so the force formula $F = e v B$ (and therefore also the magnetic moment formula M) may be perfectly correct for electric charge moving at a velocity v greater than c. Also, a alternative formula for M, which is $M = I A$, for a current I passing around an area A, does not even use the velocity of the charge that composes the current I.

The deBroglie wavelength in the electron model

An electron moving with velocity v has an experimentally measurable wavelength $\lambda_{deBroglie}$ called the deBroglie wavelength, given by $\lambda_{deBroglie} = h / mv$ where h is Planck's constant and m is the electron's relativistic mass $m = m_o / \sqrt{1 - v^2 / c^2}$. So $\lambda_{deBroglie}$ is inversely proportional to the momentum $p = mv$ of an electron. The wave nature an electron can be observed, and its wavelength calculated when electrons of a particular velocity and momentum are diffracted, similarly to x-rays, by thin crystals. In present quantum theory the deBroglie relation above is accepted as an intrinsic property of a moving electron (and other moving objects with rest mass), like its spin and its magnetic moment.

The present electron model is a circulating photon-like entity composed of a continuous toroidal sheet of negative charge moving superluminally in a closed helical form. Since $b = \sqrt{2}$ (and therefore exceeds 1) in the formulas describing the closed helix that mathematically generates the electron model's toroidal form, this toroidal form intersects itself as the charged sheet circulates in a closed helical fashion. So there is photon-like wave interference at least in the central region of the electron model's structure (see Figure 2). If the electron model moves with velocity v, there will be relativistic Doppler shifting of the frequencies and the wavelengths within this circulating photon-like charged sheet. This will produce a relativistic increase in the frequency f and wave number k of the part of the circulating photon-like entity moving in the direction of the velocity v, and a corresponding decrease in f and k in the part of the photon-like entity moving in the opposite direction, given by

$k_f = \gamma\ k_o\ (1 + v/c)$ the increased wave number of the forward moving part of the electron with velocity v, and $k_r = \gamma\ k_o\ (1 - v/c)$ the decreased wave number of the rearward moving part of the electron with velocity v, where

$k_o = 2\pi / L_c = 2\pi\ m_o\ c/h$ is the wave number of the circulating charge sheet electron model with zero external velocity, and $\gamma = 1/\sqrt{1 - v^2/c^2}$.

So the electron model moving with velocity v in the x-direction has a wave-like internal structure composed of a superposition of two spatial waves whose Doppler-shifted wave numbers give an internal structure to the electron model of the form W where

$$W = \cos(k_f\ x) + \cos(k_r\ x) \quad (69)$$

$$= \mathrm{Re}\,[\,e^{i\,kf\,x} + e^{i\,kr\,x}\,] \quad (70)$$

$$= \mathrm{Re}\,[\,e^{i\,\gamma ko\,(1\,+\,v/c)\,x} + e^{i\,\gamma ko\,(1\,-\,v/c)\,x}\,]$$

$$= \mathrm{Re}\,[\,e^{i\,\gamma ko\ x}\,(e^{i\,\gamma ko\,(\,v/c)\,x} + e^{-i\,\gamma ko\,(\,v/c)\,x}\,)\,]$$

$$= \mathrm{Re}\,[\,e^{i\,\gamma ko\ x}\,(2\cos(\gamma\,k_o\ v/c\ \ x))\,]$$

$$= \cos(\gamma k_o\,x) \times 2\cos(\gamma k_o v/c\ \ x)$$

$$= 2\cos(\gamma k_o\,x)\ \cos(\gamma k_o v/c\ \ x)$$

$$= 2\cos(2\pi\gamma\ x/L_c)\ \cos(\gamma k_o v/c\ \ x) \quad (71)$$

W is seen to be a spatial wave of wave number $\gamma\ k_o = 2\pi\gamma / L_c$ that is modulated by a wave with wave number $k' = \gamma\ \ k_o\ v/c$, where $k_o = 2\pi / L_c$ and $L_c = h / m_o c$ is the Compton wavelength.

k' corresponds to a wavelength λ' found from $k' = 2\pi / \lambda' = \gamma\ k_o v/c$

or $$\lambda' = 2\pi / k' = 2\pi\ c/\gamma\ k_o\ v \quad (72)$$

$$= 2\pi\ c/\gamma(2\pi\ m_o\ c/h)v$$

$$= h/\gamma\ m_o v$$

$= h / mv$ where m is the relativistic mass γm_O of the electron with velocity v

$= \lambda_{deBroglie}$ (73)

This is the formula for the deBroglie wavelength $\lambda_{deBroglie}$ = h / mv of an electron moving with momentum mv . So in the present electron model, the deBroglie wavelength seems to arises from Doppler-shifted self-interference caused by a self-interacting photon-like helically circulating closed charged sheet, whose inner region is of the form

$$W = A \cos(2\pi\ \gamma\ x/L_C)\ \ \cos(2\pi\ x/\lambda_{deBroglie}) \quad (74)$$

The relativistic increase of mass with velocity in the electron model

It is known experimentally that an electron with relative velocity v has a relativistic mass given by $m = \gamma m_o = m_o/\sqrt{1 - v^2/c^2}$ where m_O is the rest mass of the electron.

Or in energy terms, the electron's total energy E is given by

$$E = mc^2 = m_o c^2 / \sqrt{1 - v^2 / c^2} \quad (75)$$

For an electron model moving with velocity v in the x direction, the Doppler-shifted frequency $f(\phi)$ of a part of the electron which makes an angle ϕ (from 0 to 2π around the electron model) with the forward direction of motion is given by

$$f(\varphi) = \gamma\ f_o\ (1 + v_x/c) = \gamma\ f_o\ (1 + v \cos\phi /c)) \quad (76)$$

So the energy dE of a part of the circulating electron model's wave within an angle $d\phi$ around the moving electron model) is given by

$$dE = h\, f(\phi) \times d\phi / 2\pi = \gamma\ hf_o\ (1 + v\cos\phi /c)\ (d\phi / 2\pi) \quad (77)$$

the total energy E of the circulating photon-like object moving with velocity v would then be

$$E = \int_{\phi=0}^{2\pi} \gamma\, hf_o\ (1 + v\cos\phi /c)\, (d\phi / 2\pi) \quad (78)$$

$$= (\gamma\, hf_o / 2\pi) \times \int_{\phi=0}^{2\pi} (1 + v\cos\phi / c)\, d\phi$$

$= \gamma\, hf_o = \gamma\ m_o c^2$ since in the electron model $hf_o = m_o c^2$

$= mc^2$ where $m = \gamma\ m_o$, the relativistic mass of an electron (79)

720^{o} quantum mechanical rotational symmetry of the electron model

In Dirac's quantum theory of the electron, it is found that the electron's wave function displays a 720^o or 4π rotational symmetry. This was necessary to give the proper spin and magnetic moment of the electron. The present electron model also has a 720^{o} or 4π rotational symmetry since the closed helix that generates and forms the electron model, closes when the axial angle $\theta = 720^o$. This 720^o periodicity for the electron model arises from the requirement to conserve energy and angular momentum, as well as linear momentum, when an electron/positron pair is formed from a single photon that interacts with a heavy nuclear particle, where there is principally an exchange of linear momentum with the nuclear particle.

Predictions from the photon and electron charged sheets models

There are two main experimental predictions based these models:

1. In the photon model, since either the positively or negatively charged sheet can be in front, in the direction of the photon's motion, this gives the prediction that there are two varieties of right circularly polarized photons, and two varieties of left circularly polarized photons. Although the photon model has no net charge, the electric and magnetic fields close to a specific photon model would depend on which type of electric charge is in front, and so experimental detection of two distinct electromagnetic field patterns from different right (and also for left) circularly polarized photons would provide strong support for this prediction.
2. The electron model gives the experimental prediction that there are two varieties of electron and two varieties of positron. This is because for a fixed direction of electron spin and magnetic moment in the electron model, the direction of the helical flow of electric charge on the outer surface of the electron model, as viewed from above, can either be upward or downward (and vice versa for charge in the interior of the electron model), depending on the turning direction or handed-ness of the closed helix that generates the electron model. This is true for the positron model also. (The spinning charged ring model of the electron, lacking any helical charge flow, does not give this

prediction). So the present electron model predicts that electrons (and also positrons) can be right- or left-handed. This would be a new parameter for describing electrons and positrons. Since the two predicted varieties of the electron (and the same for the positron) have two different charge flow patterns when their spin and magnetic moment directions are kept constant, the experimental detection, or inference from other experimental data, of two distinct electromagnetic field patterns near different electrons, produced by these two different charge flow patterns, from otherwise identical electrons, would provide strong support for this prediction of the electron model. Since the Dirac equation accounted for the electron's spin, its 720 degree quantum mechanical symmetry, it's first order magnetic moment, and the existence of the positron (but not the deBroglie wavelength of a moving electron), it would be interesting to see if it should have also predicted, from symmetry considerations, the two varieties of the electron (and also of the positron) that are predicted above.

Comparison of the electron model's size with experimental measurements of electron size from electron scattering experiments

Recent experimental results from very high energy (about 200 GeV) electron scattering experiments set an upper bound on the size of an electron at less than 10^{-18} meters. (7) What is the radius of the moving electron model when it has a total energy of 200 GeV?

In order to obtain the radius of a moving electron model, we use the fact that the spin of an electron is measured to be $h/4\pi$, independent of its velocity. So the calculation of the spin of the moving electron model must also always give $h/4\pi$.

In the present electron model, the spin was found to depend on the radius R_o of the circular axis of the closed helix, and to be independent of the radius of the closed helix itself. What will be the radius R' of the circular axis of the photon model at high velocities? To calculate R', assume that the momentum and wave number k of the stationary electron is concentrated at the stationary circular axis radius $R_o = 1.9 \times 10^{-13}$ meters. A moving electron model will have a relativistically Doppler-shifted wave number k' at R', given by $k' = \gamma k_o (1 + v/c \cos\theta)$ where θ is the angle that the moving electron model's varying internal wave number vector k'

makes with the velocity vector of the electron model. The average value of k' around the axis of radius R' is $k'(av) = \gamma k_o$ since the cosine term above averages to zero around the 360-degree circular axis. The spin S' of the moving electron model would then be given by

$$S'(\text{moving electron model}) = S(\text{resting electron model})$$

$$R' p'(av) = R_o\, p(\text{resting electron model})$$

$$R' (h/2\pi)\, k'(av) = R_o\, (h/2\pi)\, k_o$$

$$R' (h/2\pi)\, \gamma k_o = R_o\, (h/2\pi)\, k_o$$

So $R' = R_o / \gamma$

The radius of the circular axis of the moving electron model is contracted by a factor of γ compared to that of the stationary electron model. The faster the electron moves, the more the electron model's circular axis, and thus the size of the moving electron model, is reduced.

When the total energy of an electron is $E = 200$ Gev , then

$$\gamma(\text{at } 200\,\text{Gev}) = E/m_o c^2 = 2\times10^{11}\ \text{ev} / .511\times10^{6}\ \text{ev} = 3.91\times10^{5}$$

So $R'(\text{at } 200\,\text{GeV}) = R_o / \gamma(\text{at } 200\,\text{GeV})$

$$= (1.9\text{x}10^{-13}\ \text{meters}) / (3.91 \text{ x } 10^{5})$$

$$= (1.9\times10^{-13}\ \text{meters}) / (3.91\times10^{5})$$

$$= .49\times10^{-18}\ \text{meters}$$

So the electron model's circular axis radius at 200 GeV is consistent with the experimental upper bound for the electron's size of approximately 10^{-18} meters at $E = 200$ GeV .

This result implies that the experimentally measured maximum size of an electron will be found to decrease continually with higher and higher experimental electron energies, even though the size of the electron model at rest or at non-relativistic velocities (such as within an atom) remains on the order of the Compton wavelength h/mc . So such very low experimental limits on the maximum size of the electron obtained at high energies, do not prove that the electron is a structureless, point-like particle. Rather, such experimental results would be consistent with the proposed finite-sized superluminal electron model.

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The figures in this article were made with the shareware program 3D Grapher, which can be downloaded from www.romanlab.com , and Microsoft Paint..

I would like to thank Horace Drew, George Galeczki, Milo Wolff , Robert Neil Boyd and John Sefton for helpful comments and suggestions, and Marc Krocks for his computer graphics programming assistance. And finally Prabhat Rainjan Sarkar, whose concept of microvita provided much of the initial and continuing inspiration for this work.

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