Mass-Energy States of the Pion Particle

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The laws of conventional physics, Coulomb's Law, Quantum Mechanics, Special Relativity Theory (SRT) are combined to formulate the mass-energy states of the pion, an elementary particle. The structure of the pion is revealed from the electron-positron relationships orbiting each other near speed c, the speed of light. This structure is based on only two forces, the force of attraction between particles and the inertial centrifugal force. The resulting formulae suggest that two orbiting particles create one particle. Based on the formulae developments for the pion, a possible structure for the electron structure is also presented.

Introduction

This development of the formulae in this article suggests that matter particles at the sub-atomic level can be composed of two orbiting particles of opposite charges. Some mass-energy states relating to known elementary particles correlate with the mass-energy states of the pion and are presented.

The following major concepts form the basis for the formula derivations: **1)** Bohr's Atom concepts of force balance and total angular momentum, with Planck's constant, **2)** Special Relativity Theory (SRT), and **3)** the fine structure constant. The attractive force is the standard Coulomb force between opposite electrical charges. The Coulomb force appears to create the strong nuclear force when the 'charged' particles are moving at or near the speed of light. The relativistic mass increase of the orbiting electron and positron create the mass of the pion. The fine structure constant α relates the strong relativistic force to the Coulomb force.

Force Balance Between the Electron and Positron Orbiting Each Other

Using SRT, the force balance between the orbiting pair is represented by the Coulomb force and the centrifugal force acting through the center of mass, CM. See Fig. 1

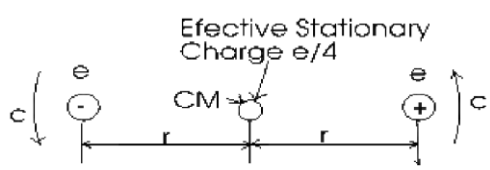

Figure 1. Orbiting electron-positron pair.

As seen at the CM, these forces are:

$$\gamma k e^2 \big/ 4r^2 = \gamma m_e c^2 \big/ r \quad , \tag{1}$$

where $\gamma = 1\big/\sqrt{1 - v^2/c^2}$; v is the speed of the orbiting positron and electron, and whose value is near c, the speed of light; m_e the rest mass of either the electron or positron; e is the magnitude of the electrical charge of either the electron or positron; $k = 1/4\pi\varepsilon_0$; ε_0 is the permittivity of free space; and r is the distance between one orbiting particle and the CM. Ordinarily, in SRT one would not represent the force between two moving particles with just a γ in the numerator on the left side of the above equation [1]. But because the force is acting through a stationary CM it can be represented this way. (This is the concept whose difficulty to see and accept is the greatest in this whole analysis.) The reference for the application of SRT is the CM. An effective stationary charge of $e/4$ is placed at the CM for SRT considerations. The centrifugal force on the right side of the above equation is represented by speed c because the velocity is assumed to be very near c. Also, the γ on the right side of the above equation represents the mass increase of the electron or positron due to its velocity relative to CM. Note that the γ's on each side of the equation cancel in math manipulations, but must remain in some situations. The radius of the orbit is r. The radius r is assumed to remain nearly constant for the various energy levels and values of γ's. According to SRT, when particle speed is near c, particle mass can vary radically with just a small change in speed. For examples of this effect, see Table 1.

Table 1. Mass $\gamma m_e = m_e \big/ \sqrt{1 - v^2/c^2}$

v/c ratio	γ factor
0.999999990	7071.1
0.999999950	3162.3
0.999999900	2236.1
0.999999500	1000.0
0.999999000	707.1

v/c ratio	γ factor
0.999995000	316.2
0.999990000	223.6
0.999950000	100.0
0.999900000	70.7
0.999500000	31.6

The Fine Structure Constant α and the Pion Particle

Re-arranging Eq. (1):

$$\gamma k e^2 = 4 \times r \times \gamma m_e \times c^2 \quad . \tag{2}$$

There are several important things to note about Eq. (2):

1) If we set $\gamma = 1/\alpha$, which is not unreasonable since the particles are orbiting each other near the speed of light c, then Eq. (2) becomes:

$$ke^2 \big/ \alpha = 4 \times r \times (m_e/\alpha) \times c^2 = \hbar c \quad , \tag{3}$$

where $\hbar$ is Planck's constant h divided by 2π. And $\hbar c$ is the numerator of the Planck force. It is a strong force that matches the color force of quarks in the proton [2]. The fact that it matches gives strong support to this description of the fine structure constant α. So we may define the inverse of the fine structure constant ($1/\alpha$) as the relativistic gamma factor that modifies the coulomb force and the balanced orbiting masses when the forces are in a state of balance and the masses orbiting at or near the speed of light. This is supported by the fact that $ke^2 = \hbar c\alpha$.

2) We also note that α is associated with the mass m_e, and not the radius of rotation r. The γm_e in (2) refers to the mass of one of the orbiting particles. The total mass of the rotating pair is $2m_e / \alpha = 274.07 m_e$ which is very close to the mass of the charged pion, which is reported to be $273.14 m_e$. In this author's opinion, this is too close to be coincidental.

3) The radius of the orbiting pair is calculated from Eq. (3);

$$r = ke^2 / 4m_e c^2 = r_e / 4 = 7.044850719 \times 10^{-16} \text{m} \quad , \tag{4}$$

where $r_e = 2.890285814 \times 10^{-15}$ m is the conventional electron radius. This result is in the same range as the proton radius, 8.4×10^{-16} m.

4) Using Bohr's Atom assumption that the *total* angular momentum is $m \times r \times c = n\hbar$ we get:

$$2m_e / \alpha \times r_e / 4 \times c = n\hbar \quad . \tag{5}$$

Eq. (5) will agree with Eq. (3) if $n = 1/2$.

5) Thus we have presented a structure of the pion that agrees with what is written in the physics books about the pion: It has a charge of e from (2); it has a mass of $274\, m_e$ (calculated); and a spin of $\hbar / 2$.

Important and Interesting Formulae Resulting from Eq. (3)

Eq. (3) depicts the relationships of several physical constants that have an important place in basic physics. This section will describe some of them. First is one showing the relationship of Plank's reduced constant $\hbar$ with r_e, m_e, α, c. Substituting (4) into (3) and solving for $\hbar$:

$$\hbar = r_e m_e c / \alpha \quad . \tag{6}$$

Also, in terms of the coulomb force:

$$\hbar = ke^2 / c\alpha \quad \text{and} \quad ke^2 = \hbar c\alpha \quad . \tag{7}$$

Another interesting formula is the expression of the charge squared e^2 in terms of r_e and m_e. By noting that $k = c^2 \times 10^{-7}$ and solving for the charge squared e^2 in (3):

$$e^2 = r_e m_e \times 10^7 \quad . \tag{8}$$

Note that r_e is not the radius of rotation in (3) and m_e is *not* the magnitude of the mass rotating in (3), but that they are characteristics of the basis electron or positron.

Another 'fallout' from (3) in generalized terms is the Bohr Atom assumption:

$$m_{\text{total}} \times r_{\text{rotation}} \times c = n\hbar \quad . \tag{9}$$

as shown in (5). Also, this is related to the de Broglie relation for light photons.

The Mass-Energy States of the Pion

Bohr stated the assumption that the total orbital angular momentum of orbiting particles is $m \times r \times c = n\hbar$, $n = 1/2, 1, 3/2, 2$, *etc*. Writing out this equation for the pion situation:

$$\gamma 2m_e \times r_e / 4 \times c = n\hbar \tag{10}$$

We see in (10) that as the energy of the system increases, γ increases along with the energy state defined by n. The total mass m of the orbiting pair is represented as:

$$m = \gamma 2m_e = m_n m_e \tag{11}$$

where m_n is the total mass at energy state n expressed in units of m_e. Substituting (11) into (10), using (6), and solving for m_n:

$$m_n = \gamma 2 = 4n / \alpha \quad . \tag{12}$$

The mass-energy states of Eq. (12) are easily computed and compared with known energy states of baryons and mesons [3]. See Table 2.

Eq. (12) is a simple linear discreet equation with a slope of $4/\alpha$. The first value of m_n for $n = 1/2$ is 274.07. At $n = 8$ the value of m_n is 4385.15. The value of the radius of the orbiting pair is constant for all n and is $r_e / 4$. The speed of each particle is at or near c. Observe from Table 1 how the speed of the particle can be near c, yet the mass can vary considerably due to relativity.

It is to be noted from (11) that:

$$\gamma_n = m_n m_e / 2m_e = m_n / 2 \tag{13}$$

Table 2. Comparison between Computed Output Masses and Known Particle Masses

(Masses in m_e Units) Matches are within 1/2 percent; Known Elementary Masses: p-Baryons, b-Mesons

	n	computed	known
1	0.5	274.07	p[2]273.15
2	2.5	1370.36	p[6]1369.85
3	4.5	2466.65	p[18]2465.72
4	4.5	2466.65	p[19]2473.55
5	5.5	3014.79	p[29]3013.66
6	8.5	4659.22	p[52]4639.87
7	8.5	4659.22	p[53]4647.69
8	8.5	4659.22	p[54]4657.48
9	10.0	5481.44	p[57]5479.39
10	4.0	2192.58	b[3]2183.14
11	5.0	2740.72	b[12]2749.48
12	5.5	3014.79	b[18]3001.53
13	5.5	3014.79	b[19]3003.88
14	6.0	3288.86	b[24]3272.76
15	6.0	3288.86	b[25]3287.63
16	6.0	3288.86	b[26]3303.29
17	6.5	3562.94	b[34]3551.60
18	6.5	3562.94	b[35]3561.60
19	7.5	4111.08	b[47]4109.54
20	8.0	4385.15	b[49]4403.08
21	9.5	5207.37	b[55]5185.85
22	11.5	6303.66	b[58]6320.87

Discussion of Results in Table 2

The large number of matches within ½ percent supports the analysis and the idea that (2) and (3), while being equations that depicts two orbiting particles (electron and positron), provide a description of one particle (pion). The results do point to a way in which basic matter may be regarded. Stability is achieved by balance of two forces: attraction force and centrifugal force. Quantum theory and SRT are also incorporated. The mass-energy states are achieved by SRT with velocity near the speed of light. The radii of the particles remain constant for different n's and is in the nuclear size range. The particle acts like an energy container. The comparisons ignore angular momentum and charges of the known particles. Only the masses of the known particles were taken in consideration. Thus, more work is required for further analysis. The results suggest that basic charged particles are just composed of two orbiting particles and that charge and electric fields are representations of particle size r_e and basic rest mass m_e as in (8). With charge represented in this manner, it becomes possible that matter is fractal in structure.

The Electron

Since we have used Eq. (1) and Bohr's assumption to create the pion from two orbiting masses, the electron and positron, maybe we can use the same equations to find the mass value m_p of one of two orbiting oppositely charged particles to create a particle having the characteristics of an electron. Charges are conserved. The electron has a negative charge of magnitude e, a mass value of m_e, and a spin of $\hbar / 2$. Start with an equation like Eq. (3):

$$ke^2 / \alpha = 4 \times r \times (m_p / \alpha) \times c^2 = \hbar c \quad . \qquad (14)$$

We desire that twice the mass in (14) to be equal to m_e:

$$2m_p / \alpha = m_e \quad \text{or} \quad m_p = \alpha m_e / 2 = m_e / 274 \quad . \qquad (15)$$

Substituting m_p of (15) into (14) and solving for r:

$$r = \frac{ke^2}{\alpha \times 4 \times m_e c^2 / 2} = \frac{r_e}{2\alpha} = 1.9307963218 \times 10^{-13}\text{m} \quad . \qquad (16)$$

Applying Bohr's assumption, $m \times r \times c = n\hbar$:

$$m_e \times r_e / 2\alpha \times c = n\hbar \quad . \qquad (17)$$

Eq. (17) matches Eq. (14) if $n = 1/2$.

Thus, it is demonstrated a particle can be represented with (14) that has characteristics of the electron or positron: It has a mass of m_e, a spin of $\hbar / 2$, and a charge of e that follows from Eq. (14). Perhaps there is a photon of mass $m_e / 274$, with a spin of $\hbar / 2$, and a charge of e that has two smaller charge particles orbiting in it and that particle is one of the orbiting particles in the electron or positron.

A Fractal Theory of Matter

The formulae deriving the characteristics of the pion and possibly an electron suggest that matter is fractal in nature.

Here are some characteristics that these particles might have:

1) Two orbiting charged particles make one orbiting particle in a bigger particle. See Fig. 2.

2) Each such particle has a charge of e.

3) Each such particle has a spin of $\hbar / 2$.

4) Each such particle has a relativistic mass increase moving at near light speed c, making it smaller to fit into the larger particle.

5) The charge is created by its size, rest mass, and angular momentum.

6) The fractal formula is (14) with r and m_p generalized appropriately to be variables that keeps the forces balanced. This establishes 'scales' of the fractal.

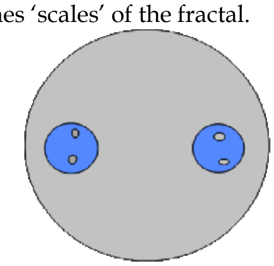

Figure 2. Possible fractal nature of particles of matter .

What would create the first pair in the fractal remains an open question. The proton particle may be somewhat more complex than a fractal particle, since it is composed of three quarks. However, there may be a way to fit it into the fractal theory.

Matter is mostly relativistic energy moving at light speed. Another problem with this fractal idea is how to get bigger, lightweight masses into smaller, heavier masses. However, light does not seem to have this problem. Photons of large wavelength can condense their energy and size into a much smaller atom.

Conclusion

The formulae representing the orbiting electron-positron relationship at the subatomic level is shown to have the characteristics of a charged pion particle. In a similar manner a particle having the characteristics of an electron is developed. The probable cause of the inverse of the fine structure constant α is identified as a relativistic gamma factor increase. Some mass-energy states of a pion have been shown to match masses of known elementary particles. All the results, taken together, suggest a simple fractal theory of matter that could be used in describing particles of matter.

Acknowledgments

The author wants to acknowledge Dr. Cynthia Whitney for helping edit this article. Also the author wants to acknowledge Francis V. Fenandes who has presented ideas similar to the ones in this paper.

References

[1] James Keele "SR Theory of Electrodynamics for Relatively moving Charges", Proceedings of the Natural Philosophy Alliance, 16th Annual Conference of the NPA, 25-29 May, 2009, at the University of Connecticut, Storrs, 6 (1) pp. 118-122

[2] R.J. Heaston, "A New Look at the Concept of Force", Speculations in Science and Technology, Vol 6, No. 5 (1983) – pp. 485-497.

[3.] CRC Handbook of Chemistry and Physics, 52nd edition, The Chemical Rubber Co., 18901 Cranwood Parkway, Cleveland, Ohio 44128, 1971, p. F-211 to F217.