Notions of a Neutron

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Neutrons are vitally important for predicting the basic properties of atoms, and a realistic model (see Figure 1) has long been a major goal of physics. This "tiny, uncharged bit of matter" explains so much about atoms that neutrons were invented without the experimental evidence that proved their existence. Even an elementary knowledge of a neutron's most prominent properties—mass without charge—gave promise of solving many puzzles in the theory of atoms: [1]

- Why do some particles penetrate several inches in lead when most are quickly stopped?
- What makes some elements heavier than others with nearly identical chemical and physical properties?
- Why is helium *four* times as heavy as hydrogen when it has only *twice* the number of protons and electrons?
- What could cause the ejection of protons from a material containing hydrogen?
- What was causing "transmutation of atoms of one element to those of another…by bombardment with alpha particles (helium nuclei)"?

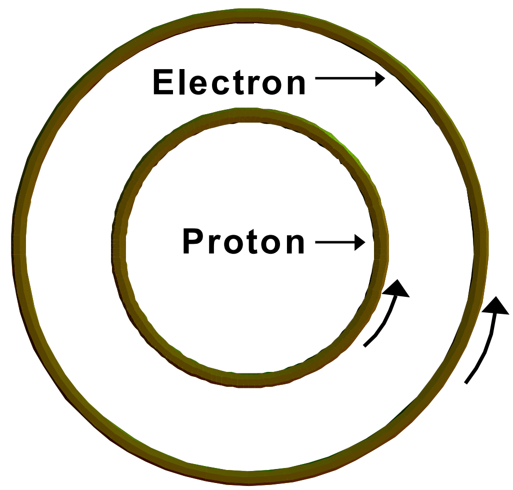

Figure 1.
CSS Concept of a Neutron
The neutron is not an elementary particle but a paired electron and proton. This coaxial and coplanar configuration, with the same direction of particle rotation, stores the maximum excess energy called *beta decay energy.* Arrows show direction of moving charge.

James Chadwick, a British physicist, solved these puzzles. "It was most logical, he pointed out, that…protons were set in motion by a particle of mass similar to their own…. [I]f the particle carried no electric charge, its great penetrating power would be explained: the electric fields of atoms would not affect its motion. By measuring the velocities with which protons were ejected from various materials and utilizing simple collision theory, it was possible for Chadwick to determine the mass of this new particle and show that it was close to the mass of the proton." [1]

The concept of *mass without charge* was innovative and explained many things. However, this simple concept was severely challenged by more research:

- Observations showed the neutron has a magnetic moment, and magnetic moments are caused by circulating charge.

- Several researchers found that neutrons outside an atom disintegrated into one proton and one electron.
- Electrons were, by all estimates, much too large to be contained in a neutron or in atomic nuclei.
- The mass of the neutron was more than the mass of its two components (prompting suggestions that another undetected particle made up the difference in mass).
- Even with a third elementary particle in atoms, it was impossible to add the masses of neutrons, protons and electrons to get the precise mass of atoms.

The Neutron becomes a Concept. No longer could the neutron be called an *elementary particle* (*elementary* means a particle that is not composed of other particles). Such a useful "particle" could not be abandoned, however, and the neutron came to be called a *fundamental particle*. In the following years, several new neutron models were proposed:

<u>Pauli Model of the Neutron</u>. To account for the extra neutron mass, Pauli added a neutrino to one proton and one electron. This also conserved spin, although the neutrino was later replaced by an antineutrino upon additional study of spin directions.

<u>Negative Meson Cloud Model</u>. In 1959, prominent physicists thought that "one aspect of neutron behavior" could be illustrated as shown in Figure 2. "For a small fraction of time, the neutron separates into a positively charged core (proton) surrounded by a circulating negative meson "cloud." [1]

"These mesons, of mass about one seventh that of the neutron (but about three hundred times the electron mass), have a very evanescent existence and are continually being created from the mass of the neutron and absorbed back into it, without escaping from the structure. A meson, if *separated* from nuclear particles, disintegrates almost immediately, and about a millionth of a second later it has become an electron and a neutrino." [1]

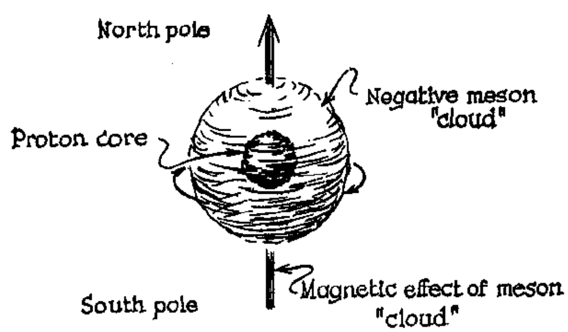

Figure 2.
Negative Meson Cloud Neutron
A negative meson "cloud" gives the neutron its negative magnetic moment in this model. The meson first "pops" into existence and then orbits about the proton core, and then goes back into the "mass of the neutron." But, if the neutron is separated from other nuclear particles, then the meson changes permanently into an electron and neutrino. [1, pp. 67, 75]

<u>Standard Model of the Neutron</u>. Physicists soon learned they could make many more short-lived "particles" in their atom-smashing machines, and when the number of short-lived "particles" grew to several hundred, there was certainly an

adequate number to select some with properties suitable for constructing protons and neutrons. Indeed, the elite of physics were so confident of atomistic particle theory that they established a radical new model for protons and neutrons based on *quarks* even though the existence of quarks was known only by *inference* rather than *direct observation* that is possible for other particles. As the Standard Model developed, physicists concluded that not just one quark was needed for their models but many different kinds of quarks were required to predict the properties of protons and neutrons.

The mass of a neutron is almost the same as the mass of a proton. Furthermore, both are most commonly found in atomic nuclei. Accordingly, these particles are called *nucleons.* Models of the nucleons change frequently: "A new generation of experiments promises to pin down more of the still uncertain internal structure of protons and neutrons." [2] "The full quantum description [includes] a complicated, flickering dance of virtual quarks and antiquarks, including strange quarks not usually considered a part of ordinary matter…. The details of how this dance produces the spin of the proton [and neutron] are still too difficult to be calculated reliably and are only gradually being revealed by experiment." [2]

Properties of Neutrons. Experiments on neutrons reveal the following properties.

Property #1—Negative Magnetic Moment. Researchers report that neutrons have a magnetic moment of –9.66237 % 10^{-27} JT^{-1}. [3] The negative sign indicates that the vector of magnetic moment is in a direction opposite to the vector of angular momentum, strongly hinting that a negatively charged circuit (perhaps an electron) predominates to produce a net magnetic moment that is negative.

Property #2—Zero Net Charge. The net electrostatic charge of a neutron is *zero* so that a moving neutron has very great penetrating power in materials consisting of charged particles; *e.g.,* penetration through several inches of lead. [1] Since property #1 depends upon moving charge, *a zero net charge implies that positive and negative charges are paired.* Empirical evidence shows that a neutron sometimes decays, producing an electron and proton simultaneously. [4] Since the electron and proton have equal but opposite charge, a neutron consisting of one electron and one proton would have zero net charge.

Property #3—Size. In order to be contained within an atomic nucleus, a neutron must have compatible dimensions. Experimentation reveals a small neutron radius on the order of 10^{-15} meters.

Property #4—Rest-Mass. The rest-mass of a neutron is 1.67493 % 10^{-27} kilograms, [3] slightly and significantly greater than the combined mass of one free electron and one free proton. By equivalence of mass and energy, the electromagnetic rest-mass energy of the neutron is related to its rest-mass by $E = mc^2$ and equals 1.50535 % 10^{-10} Joules.

Property #5—Stability. Neutrons confined to the atomic nucleus seem to be stable indefinitely. Free neutrons (outside the atom) are observed to decay into an electron and proton with a half-life of 886.7 seconds. [5]

Property #6—Nuclear Forces. Scattering experiments have shown that neutrons respond to nuclear forces: "One characteristic feature of nuclear forces is their short range. Although the exact dependence on distance is not well established, there is good evidence that the force vanishes for all practical purposes at distances greater than a few times 10^{-15} meters. There are many experiments which suggest that the force between two nucleons sets in quite abruptly at a separation of 1 or 2 % 10^{-15} meters." [6, p. 677]

Property #7—Spin. The angular momentum of a neutron—defined as the product of mass, velocity, and radius, or $p_s = M_n\, v\, R_n$—has been measured and is reported to equal $\hbar/2$ where h is Planck's constant.

Property #8—Resonance. Diffraction experiments reveal that the neutron has resonant frequencies.

Components of the Neutron. An acceptable model of the neutron must adequately account for these major properties. Once considered an elementary particle, today the neutron is supposed to be composed of quarks, gluons, and other particles that give it angular momentum. [2]

Problem of Electron Magnetic Moment. Early investigators believed that an electron's magnetic moment and size ruled out the presence of an electron in neutrons and atomic nuclei. Concerning the magnetic moment, Richtmyer, *et al.* stated that "the hypothesis that electrons exist in the nucleus encounters a number of difficulties, however, some of which were already apparent long before the neutron was discovered. For one thing, there was the problem of the magnetic moment: a single odd electron in the nucleus would be expected to contribute, from its spin alone, a moment of 1 Bohr magneton; nuclear moments are very much smaller than this." [6, p. 671]

Problem of Electron Size. Concerning the size of the neutron, Evans stated: "In order to be confined within a nucleus, a particle must have a rationalized de Broglie wavelength of $\bar{\lambda} = \hbar/p$ which is not greater than the nuclear dimensions. A 1-Mev electron has $\bar{\lambda}$ { 140 % 10^{-13} cm. This could not possibly be retained within nuclei whose radii are all smaller than 10 % 10^{-13} cm.…" [7, p. 277]

Invariance Assumption. Thus, according to an assumption generally made, the magnetic moment and size of a neutron are both too small to allow an electron in a nucleus. Evans was aware of the assumption, for he stated: "We assume throughout that if a neutron, proton, electron, neutrino, or meson enters a nucleus, the particle retains its identity and extra nuclear characteristics of spin, statistics, magnetic moment, and rest mass." [7, p. 276]

CSS claims that this assumption is incorrect. As a result of magnetic flux coupling and electric forces that control the size and shape of particles, the combination of an electron and proton produces a two-body system that is much smaller than the free electron.

CSS Model of the Neutron. Common Sense Science describes the neutron as a paired electron and proton (see Figure 1). In this model, the neutron is composed of two elementary particles and is therefore a *useful conceptual model but not an elementary particle*.

Configuration. Each of the component particles is a rapidly spinning ring of charge. In this introduction of the CSS neutron, we consider only ring particles in their lowest energy state, $k = 1$, that was illustrated in the previous issue of FOUNDATIONS OF SCIENCE. The notional neutron shown in Figure 1 has one electron and one proton bound together in a coaxial, coplanar arrangement that maximizes the coupling of electric and magnetic energy fields. Inside the atomic nucleus, the notional neutron will take up a variety of planar and axial relationships with corresponding energies of mutual coupling between the two particles which respond by adjusting their dimensions.

The smaller inner ring of the CSS neutron is a proton, which has one unit of positive electrostatic charge distributed over its surface. Most of the charge lies at the surface (the interior is hollow), because like-charge generates a repelling force.

The outer ring is an is an electron, much smaller than a free electron, with one unit of negative charge distributed over its surface.

Interactions. The physical and electrical dimensions of the two rings are adjusted by the forces of all other rings within the atom, by the forces between the two rings, and also by the self-imposed force of each ring acting upon itself; *i.e.,* all charge and current elements act upon all other charge and current elements. This includes self-imposed forces of a ring acting upon itself to adjust the ring's own radius and thickness. (Self-interactions within a particle are only possible for finite-sized particles.)

The electron and proton are rotating in the same direction. Since they are oppositely charged, their currents are in opposite directions. When bound into a two-body system (the neutron), the rings' dimensions are different than their respective dimensions as free particles due to magnetic coupling and electrostatic forces.

Self-fields. The electric and magnetic fields produced by the two-body neutron system are stable and static. They are symmetrically located about a common axis and are time-invariant. In accordance with Faraday's Law of Magnetic Induction, there is no loss of field energy through radiation.

Beta Decay. Beta decay means *ejection of a beta-particle (electron).* A neutron ejected from the nucleus of an atom (by natural or artificial bombardment) maintains its existence as an electron/proton pair for approximately 887 seconds. During this period of existence outside the nucleus, a neutron's structural configuration changes slowly and continuously as a result of mutually interacting forces and negative feedback between the two rings. The process of disintegration is governed by electromagnetic fields and forces, not by chance events or an imagined "Weak Force."

Any neutron that gets outside the nucleus of its parent atom immediately begins to separate its constituent particles. The products of the neutron disintegration process are one electron and one proton [4] as expected from the CSS model. The final products are *not* quarks, gluons, neutrinos, or other short-lived debris of violent collisions that occur in particle accelerators. The natural disintegration of a neutron necessarily produces a relative velocity between the two component particles. Experiments such as Robson's [4] indicate that the process that separates the two particles will impart a separation velocity and corresponding energy whose maximum value is equal to $1.294 \% 10^{-13}$ Joules—called "beta decay energy."

<u>Magnetic Moment</u>. The neutron's magnetic moment is the sum of two components, one provided by the electron moment and the other by the proton moment. As a result of its larger radius, the electron has the larger moment of the two particles;[8] therefore the magnetic moment of the electron predominates, giving the neutron its characteristic negative magnetic moment. Just as the neutron takes up a variety of physical dimensions depending upon its environment, so also the magnetic moment of a neutron has a variety of values depending upon its immediate electromagnetic environment.

<u>Spin</u>. Rigid particles have angular momentum in proportion to their product of mass, radius, and velocity. The total spin of a two-body object, such as the neutron, depends upon the spin of each component and the degree these components are coupled.

<u>Neutron Rest-Mass</u>. The published value of the neutron mass corresponds to a neutron rest-mass energy ($E_n = M_n c^2$) that equals the sum of three component energies: $E_n = E_e + E_p + E_\beta$ where E_n is the energy of the two-body neutron, E_e is the self-energy of the electron, E_p is the self-energy of the proton, and E_β is the energy of beta decay or *the mutual energy between the two particles*.

Here is strong evidence for the *electromagnetic character* of the neutron. It's mass-equivalent energy is the sum of all electromagnetic energy components, including mutual energy shared by the particles. The potential energy from mutually shared electromagnetic fields is converted to the kinetic energy of beta decay as the neutron disintegrates. The inertial mass of atoms can be derived from the electromagnetic field energy of component particles, provided the mutual electromagnetic energy is included. This is true not only for two-body systems of charged particles, but also for larger assemblies of electrons and protons, *i.e.,* atoms and molecules.

If mutual coupling is ignored, a simple count of elementary particles times their respective weights does *not* give the atomic mass of any element. But, if mutual energy is included, the atomic mass can be correctly predicted.

Isolated Neutron. The concept of an isolated neutron, as given above, portrays a two-ring system with ever-changing dimensions. Can a set of dimensions and currents be found that corresponds to the published values of mass and magnetic moment ascribed to the nuclear neutron? Yes. This is done by keeping track of all electromagnetic energies as a neutron is "formed."

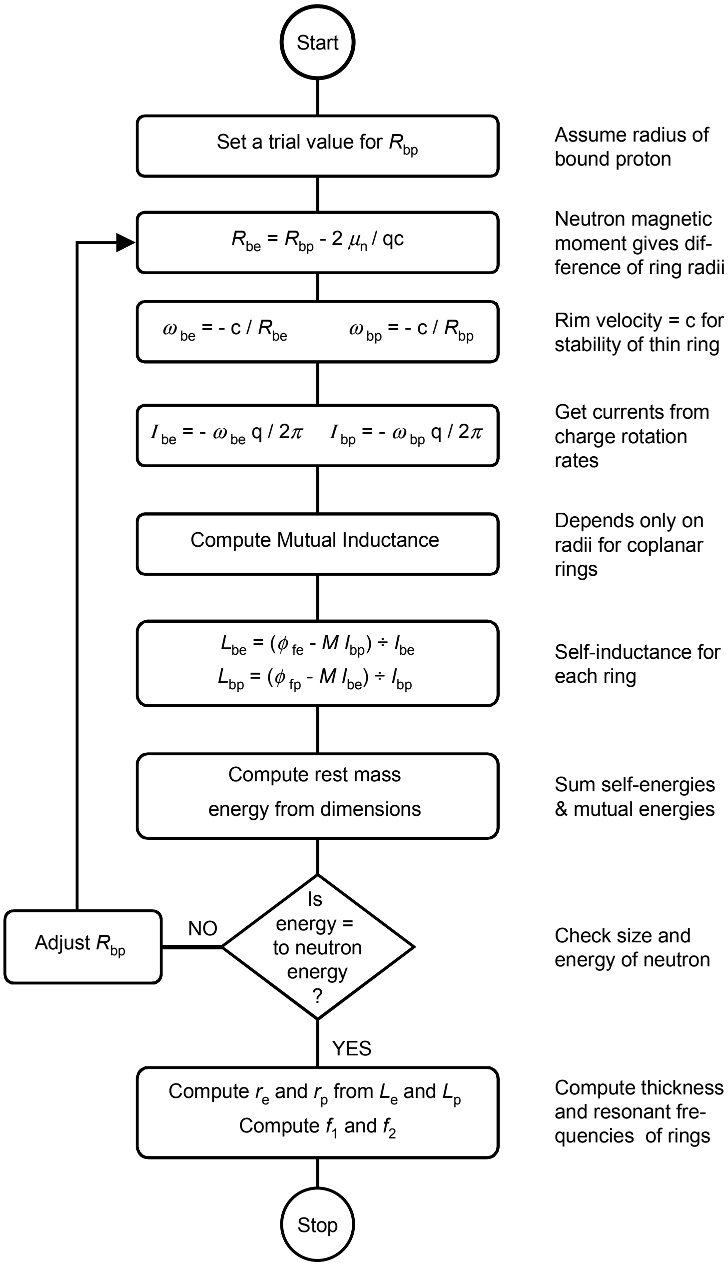

Figure 3.
Algorithm for Neutron Properties
Algorithm for Computing the Dimensions and Properties of the CSS Concept of Neutron shown in Figure 1.

Forming a Neutron. Forming a neutron is the reverse process of beta decay. Neutron decay produces an electron and a proton. The two particles separate with a peak relative velocity that generates a peak kinetic energy known as the *beta decay energy.*

The structural and electrical characteristics of an isolated neutron were analytically estimated by bringing together an electron and proton to form a neutron. Although the natural process occurs in reverse, the analytical procedure is valid because the process is conservative; *i.e.,* energy is conserved and completely allocated. In the case of ring particles, magnetic flux also remains constant in the presence of strong electromagnetic fields from another nearby ring particle.

In "forming" the neutron, a force is applied to bring the two particles together and achieve the dimensions that are consistent with the neutron's rest-mass and magnetic moment. The neutron formed in this way is called the CSS isolated neutron (see Figure 1).

This concept of a neutron describes a particular neutron configuration characterized in the literature rather than the total range of dimensions that actually exist for the neutron as it resides in various host atoms. However, the dimensions of the CSS isolated neutron are typical of the dimensions that exist in certain atomic nuclei.

Conservation of Flux. Even though magnetic flux is induced in a ring (in accordance with Faraday's Law) whenever another ring is brought into close proximity, nevertheless the total flux enclosed by each ring remains constant. Each ring keeps the total flux constant by changing size and self-generating additional flux that counteracts induced flux. The author has shown [9] that these adjustments of particle size are linked to the following relationships: $L_{\text{be}} = (\phi_{\text{fe}} - M\, I_{\text{bp}}) / I_{\text{be}}$ and $L_{\text{bp}} = (\phi_{\text{fp}} - M\, I_{\text{be}}) / I_{\text{bp}}$ where the symbols and subscripts have the following meanings: L is self-inductance of a ring, M is mutual inductance of two rings, ϕ is magnetic flux, I is ring current, b indicates a bound particle, f indicates a free particle, e indicates an electron, and p indicates a proton.

Measured and Derived Properties. The rest-mass energy of the CSS isolated neutron was computed for all six of the electromagnetic energy fields described above (consisting of self-generated fields and the mutual energy of coupling). Figure 3 shows the algorithm used to determine the dimensions of the Isolated Neutron. Table 1 lists dimensions for the two particles that are paired in the Isolated Neutron.

Property (SI MKS units)	**Free Electron**	**Free Proton**	**Bound Electron in Neutron**	**Bound Proton in Neutron**	**Isolated Neutron**
Electrostatic Energy	4.10305×10^{-14}	7.53382×10^{-11}	2.79012×10^{-11}	9.51138×10^{-11}	Sum of 2 left cells
Magnetostatic Energy	4.08406×10^{-14}	7.49894×10^{-11}	2.77722×10^{-11}	9.46736×10^{-11}	Sum of 2 left cells
Mutual E-Static Energy	N/A	N/A	N/A	N/A	-3.13472×10^{-13}
Mutual M-Static Energy	N/A	N/A	N/A	N/A	1.22507×10^{-13}
Total Energy	8.18711×10^{-14}	1.50328×10^{-10}	N/A	N/A	1.50535×10^{-10}
Magnetic Moment	-9.28483×10^{-24}	5.05669×10^{-27}	-1.36690×10^{-26}	4.00662×10^{-27}	-9.66237×10^{-27}
Radius (meter)	3.86607×10^{-13}	2.10553×10^{-16}	5.69157×10^{-16}	1.66830×10^{-16}	N/A
Spin Rate (rad/sec)	$-7.75445 \times 10^{+20}$	$1.42383 \times 10^{+24}$	$-5.26731 \times 10^{+23}$	$1.79700 \times 10^{+24}$	N/A
Current (Ampère)	-19.7736	36307.2	-13431.4	45822.8	N/A
Capacitance	3.12817×10^{-25}	1.70366×10^{-28}	4.60017×10^{-28}	1.34944×10^{-28}	N/A
Inductance	2.08906×10^{-16}	1.13774×10^{-19}	3.07889×10^{-19}	9.01771×10^{-20}	N/A
Magnetic Flux	-4.13082×10^{-15}	-4.13082×10^{-15}	-4.13082×10^{-15}	-4.13082×10^{-15}	N/A
Mutual Inductance	N/A	N/A	9.98143×10^{-23}	9.98143×10^{-23}	9.98143×10^{-23}
Coefficient of Coupling	N/A	N/A	5.99028×10^{-4}	5.99028×10^{-4}	5.99028×10^{-4}
Resonant Frequency 1	$1.23703 \times 10^{+20}$	$2.27136 \times 10^{+23}$	N/A	N/A	$2.86665 \times 10^{+23}$
Resonant Frequency 2	N/A	N/A	N/A	N/A	$8.40264 \times 10^{+22}$
Beta Decay Energy	N/A	N/A	N/A	N/A	1.25743×10^{-13}

Table 1.

Dimensions and characteristics of an Isolated Neutron composed of a paired electron and proton. Similar characteristics of free particles are shown for comparison. N/A means *Not Applicable*.

Validating the CSS Concept of a Neutron. CSS concludes that an arrangement of a paired electron and proton in the configuration of Figure 1 predicts the natural phenomena associated with "neutron" observations.

Prediction #1—Negative Magnetic Moment. The magnetic moment of any circuit is defined as the product of current and the area enclosed by the circuit. The magnetic moment of the two-ring neutron is the sum of the moments of the bound proton and bound electron. The moment calculated and listed in Table 1 is the same as the experimental value.

Prediction #2—Zero Net Charge. The CSS neutron is composed of one electron and one proton. The sum of their equal but opposite charges produces a composite net charge of zero.

Prediction #3—Size. The predictions of size for the ring particles (see Table 1) are consistent with the peaks of charge density measured by Hofstadter and shown in Figure 4. This remarkable result verifies the physical arrangement of the proton and electron rings that form a neutron. *The CSS Ring Model is the only model that predicts the measured distributions of charge in protons and neutrons.* Furthermore, the CSS Model of Particles reveals that the charge is concentrated at a single location—in a torus of radius R—rather than spread more evenly over the general volume of the particle. Evidently, the resolving power of equipment used by Hofstadter to measure charge density was not sufficiently precise to detect the concentration of charge in two thin rings.

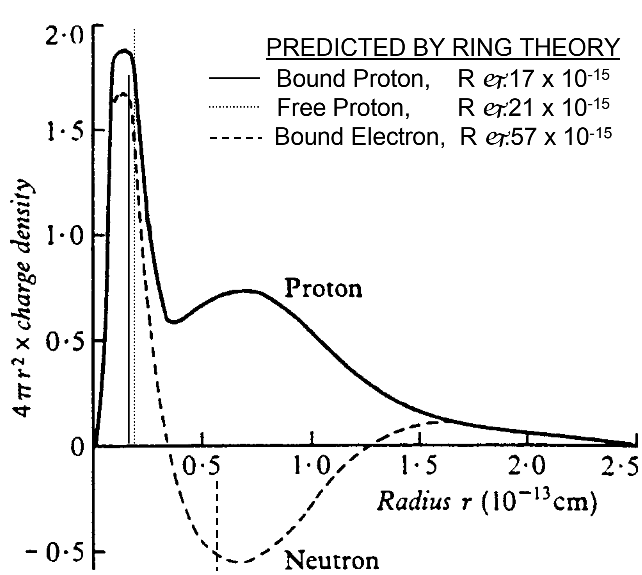

Figure 4.

Charge Distribution in a Neutron

Locations of the proton and electron in the CSS Neutron model agree with the scattering measurements of Hofstadter [10] as reported by Burcham. [11]

Prediction #4—Rest-Mass. The energy of the CSS neutron model is equal to the electrostatic and magnetic field energies of its two rings, including the mutual electrostatic and mutual magnetostatic energies. The equivalent rest-mass is obtained by dividing the energy by c^2. The dimensions and spin properties of the CSS neutron model, given in Table 1, provide the neutron with the measured rest-mass of 1.67493 % 10^{-27} kg. This mass comes from mass of the proton plus the mass of the electron plus the equivalent mass of the beta decay energy. *The CSS model predicts the measured mass.*

Prediction #5—Stability. An electron-proton pair contained within the nucleus is stable indefinitely because (1) the forces on the electron and proton from *all* rings in the atom combine to balance each other in their radii (R) and thickness radii (r), and (2) unlike accelerated point charges, rings of circulating charge do not radiate energy or suffer "radiation death." When the two-ring neutron is outside the atomic nucleus, the forces between only two rings cannot be in balance, and the forces between the *two* rings cause them to separate into two free particles. *Thus, the CSS model explains the stability properties for both environments (within and outside the atomic nucleus).*

Prediction #6—Nuclear Forces. The forces that hold the two-ring neutron together within an atom are the electrostatic and magnetostatic forces between spinning rings of charge. These forces are adequately strong to be the "nuclear glue" that holds particles together within the nucleus. While the forces are strong for short "nuclear distances," they decrease rapidly for distances greater than the ring diameters. Gray gives the magnetic force between two coaxial, spinning charged rings (two magnetic dipoles) as $F = a_1/s^4 + a_2/s^6 + a_3/s^8 + \ldots$ where s is the distance between the center of one ring and the rim of the other. [12] This equation shows that as s increases and becomes large, the magnetic force between two dipoles decreases rapidly. Evidently, electromagnetic forces on magnetic dipoles provide the same force and distance relationship that the Strong Force is supposed to explain. *If elementary particles are ring-shaped, then the hypothesis of a Nuclear Strong Force can be discarded and replaced by the electromagnetic force with the scientific advantage of being applicable over all scales (long and short range) and domains (environments inside or outside atomic nuclei).*

The Nuclear Weak Force, invented primarily to explain beta decay of the neutron, is also unnecessary since any two-ring system is unstable under electromagnetic forces.

Prediction #7—Spin. The CSS neutron model predicts that one-half unit of angular momentum will be measured, using standard methods, in agreement with the Standard Model and experimental evidence. A spinning ring of charge has one-half unit of spin because *only one-half of the ring's energy is associated with the motion and velocity term* that enter into a particle's spin. [13]

The two ring-particles that make up a neutron are *loosely* coupled as shown by Table 1 where the coefficient of coupling is much less than one. Therefore, each particle of the neutron has an *independent spin*. The total energy for the bound electron (and the bound proton) is partitioned almost equally between electrostatic energy and magnetostatic energy as listed in the first two data lines of Table 1. Ring theory thus predicts a half unit of spin for the bound electron and a half unit of spin for the bound proton.

Resonance methods of measuring magnetic moments, such as Nuclear Magnetic Resonance, are used to measure spin in terms of a frequency. Frequencies associated with the proton are higher than frequencies associated with the larger electron (see Table 1). Without the knowledge that *two* particles in a neutron could be excited to resonate by different frequencies, researchers have unwittingly measured the spin of only one particle, the proton, and correctly measured this particle's spin.

Prediction #8—Resonance. Table 1 shows the two resonant frequencies found naturally for a loosely coupled two-ring system. These frequencies are computed by the use of an equation derived by the application of circuit and transmission line theory: [9, equation corrected in 2001]

$$f_{1,2} = \left[\frac{L_p C_p + L_e C_e \pm \left(L_p C_p + L_e C_e \right)^2 + 4\left(M^2 C_e C_p - L_p C_p L_e C_e \right)}{2\left(L_p C_p L_e C_e \right) - M^2 C_e C_p} \right]^{1/2}$$

Conclusion. The neutron is a composite but simple object consisting only of one electron and one proton. Application of classical electromagnetic theory to the CSS neutron composed of one electron and one proton yields predictions consistent with empirical data. The neutron is not a "tiny, uncharged bit of matter" as first thought; rather, it is two bits of equal but opposite charge in the shape of rings.

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