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Derivation of the Neutron Magnetic Moment and Spin from Qc Pairing Asymmetry within the VTI Framework

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Abstract:
The neutron possesses a well-established magnetic dipole moment despite its electrical neutrality, indicating the presence of internal charge dynamics. In this work the neutron is examined within the Vacuum Tension Interaction (VTI) framework, where the neutron is modeled as a confined assembly of discrete quantum-charge units (Qc). The Qc population contains an odd number of units, producing a pairing asymmetry in which most Qc units form spin-paired states while a single unpaired Qc unit determines the magnetic moment and net spin of the neutron. Using the confinement energy derived from the earlier neutron structural analysis and the characteristic internal Qc separation scale, the magnetic dipole moment is obtained from classical current-loop relations. The predicted magnetic moment agrees with the experimentally measured neutron magnetic moment to within close limits. The results suggest that neutron spin and magnetism may emerge naturally from the structural asymmetry associated with the unpaired Qc unit within the neutron.

Keywords: Neutron magnetic moment, Neutron spin, Quantum charge units (Qc), Vacuum Tension Interaction (VTI) framework, Internal charge structure, Magnetic dipole moment, Nuclear magneton

1. Introduction:

The neutron possesses a well-measured magnetic dipole moment despite being electrically neutral. Experimentally the neutron magnetic moment is

$$\mu_n = -1.913\, \mu_N$$

where μ_N denotes the nuclear magneton [1]. The existence of a finite magnetic moment implies that the neutron must contain internal charge dynamics capable of generating circulating currents or magnetic dipole structures.

The neutron magnetic moment has been measured with high precision through a series of classic experimental studies beginning in the mid-twentieth century. Early measurements using magnetic resonance techniques established the non-zero magnetic moment of the neutron despite its electrical neutrality [7]. Subsequent developments in resonance methods and precision spectroscopy further refined these measurements and confirmed the value of the neutron magnetic moment with high accuracy[1], [8]. These experiments firmly demonstrate that the neutron must contain internal charge dynamics capable of generating a magnetic dipole moment.

In conventional descriptions based on quantum chromodynamics, the neutron magnetic moment arises from the motion and spin contributions of its constituent quarks [2–4]. While these approaches successfully reproduce many nucleon properties, the magnetic moment ultimately reflects the internal charge distribution and dynamics within the neutron.

In the present work the neutron is examined from a structural perspective within the Vacuum Tension Interaction **(VTI)** framework developed in the earlier neutron confinement analysis [5]. In this approach the neutron is modeled as a confined assembly of discrete quantum-charge units (Qc), each consisting of a pair of opposite electric charges separated by a finite distance. The neutron is therefore described as a population of Qc units confined within the neutron radius.

A key feature of this structure is that the total number of Qc units is **odd**, producing a natural pairing asymmetry. Most Qc units form spin-paired configurations whose magnetic contributions cancel, leaving a single unpaired Qc unit that determines both the neutron spin and the observable magnetic dipole moment. Such dominance of an unpaired constituent in determining magnetic moments is a familiar feature of many physical systems [6].

The internal motion of the Qc charges is governed by the confinement energy derived in the earlier neutron force analysis [5]. Using this energy scale, the characteristic charge velocity can be obtained through relativistic energy relations, allowing the magnetic dipole moment of the Qc structure to be expressed in terms of the internal separation scale and confinement energy.

The objective of the present work is therefore to examine whether the experimentally observed neutron magnetic moment can be reproduced from the Qc structural model and its associated pairing asymmetry within the VTI framework. As shown in the following analysis, the predicted magnetic moment obtained from the internal Qc geometry agrees with the experimental value to within approximately six percent**.**
The following section develops the structural framework leading to the magnetic moment relation derived from the internal Qc configuration of the neutron.

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2. Main Framework:

Neutron Internal Structure and Magnetic Moment from Qc Pairing Symmetry:
2.1. Structural Model of the Neutron
In the present model the neutron is treated as a confined assembly of discrete quantum-charge units (Qc). Each Qc consists of a pair of opposite electric charges separated by a finite distance. The neutron cell therefore contains a population of Qc units confined within a finite spatial boundary.
The total number of Qc units in the neutron is

$$N_{qc} = 271 \qquad (1)$$

The spatial extent of the neutron is characterized by two radii.
The effective confinement radius of the neutron is

$$R_n \approx 1.0\, fm \qquad (2)$$

Within this structure the Qc units exist in two geometric regimes.
Confined Qc units inside the neutron core, as per volumetric Scaling law for confined Neutron possesses a characteristic radius

$$R_{qc} = \frac{R_n}{(N_{qc})^{1/3}} = \frac{1{,}0x10^{-15}}{(271)^{1/3}} \approx 0.155\, fm \qquad (3)$$

The maximum free neutron radius, corresponding to the outer structural boundary, is

$$R_o \approx 1.23\, fm \qquad (4)$$

Similarly at the outer boundary the effective Qc radius corresponds to R_o , giving

$$R_{qo} = \frac{R_o}{(N_{qc})^{1/3}} = \frac{1{,}23x10^{-15}}{(271)^{1/3}} \approx 0.19\, fm \qquad (5)$$

Thus the Qc separation scale inside the neutron lies in the range

$$0.155\, fm \le R_q \le 0.19\, fm \qquad (6)$$

Interpretation:
This structural model introduces a discrete internal organization for the neutron. The inner region represents the strongly confined Qc population, while the outer region allows a slightly expanded

separation due to reduced confinement pressure. The range of Qc separation therefore defines the geometric scale governing the internal charge dynamics.

It is noteworthy that this structural scale is close to the characteristic length obtained from the nuclear magneton when expressed as

$$R_\mu = \frac{\mu_n}{(q\ c)} \tag{7}$$

Using the experimental neutron magnetic moment gives

$$R_\mu \approx 0.20\ fm \tag{8}$$

Thus the internal Qc separation predicted by the present model lies remarkably close to the magnetic length scale implied by the observed neutron magnetic moment.

2.2. Spin Pairing Structure:

Among the 271 Qc units, most are assumed to form entangled spin-paired structures.

The number of paired Qc units is

$$270 = 135 \times 2 \tag{9}$$

Each pair consists of opposite spin states

$$\left(+\frac{1}{2}, -\frac{1}{2}\right) \tag{10}$$

Thus the total spin contribution of the paired population cancels

$$S_{pair_{total}} = 0 \tag{11}$$

The remaining unpaired Qc unit therefore determines the net neutron spin

$$S_{neutron} = \frac{1}{2} \tag{12}$$

This same unpaired Qc unit is proposed to generate the observable neutron magnetic moment.

Interpretation:

The neutron spin therefore emerges naturally from the presence of an odd number of Qc units. The spin-paired Qc population produces complete cancellation, leaving the 271st Qc unit as the sole contributor to both the neutron spin and magnetic dipole moment.

2.3. Magnetic Moment of a Rotating Charge Dipole:

A moving electric charge produces a magnetic dipole moment.

For a charge moving in a circular orbit of radius r with velocity v, the magnetic moment is

$$\mu = \frac{(q\,v\,r)}{2} \quad (13)$$

For a Qc dipole two opposite charges rotate within the same loop. Their magnetic contributions therefore add.
The resulting magnetic moment of a Qc dipole becomes

$$\mu = q\,v\,R_q \quad (14)$$

Where,

$q = elementary\ charge$
$v = charge\ velocity$
$R_q = Qc\ radius$

For the outermost Qc unit we take

$$R_q = R_{qo} = 0.19\ fm \quad (15)$$

Interpretation:
Although the charges are opposite, the effective current direction produced by their motion is identical. Consequently the magnetic contributions add rather than cancel, producing a net magnetic dipole moment associated with the Qc pair.

2.4. Velocity Derived from Confinement Energy:

The internal charge motion is determined by the confinement energy of the Qc unit.
The relativistic kinetic energy is

$$E_c = (\gamma - 1)m_e c^2 \quad (16)$$

where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (17)$$

Solving for γ gives

$$\gamma = 1 + \frac{E_c}{(m_e c^2)} \quad (18)$$

Interpretation:
This relation connects the internal charge velocity with the confinement energy of the Qc structure. Instead of assuming a velocity, the charge motion is therefore determined directly from the energy scale derived from the neutron structure analysis.

2.5. Velocity Expressed in Terms of Energy:
From the Lorentz factor relation

$$v = c\sqrt{1 - \frac{1}{\gamma^2}} \tag{19}$$

Substituting the expression for γ gives

$$v = c\sqrt{1 - \frac{1}{\left(1 + \frac{E_C}{(m_e c^2)}\right)^2}} \tag{20}$$

Interpretation:
This equation expresses the internal charge velocity entirely in terms of the confinement energy. The internal motion is therefore a direct consequence of the energy stored within the Qc structure.

2.6. Magnetic Moment Expressed in Terms of Energy and Radius:
Substituting the velocity expression into the dipole relation

$$\mu = q\, v\, R_q \tag{21}$$

gives the compact relation

$$\mu = q\, c\, R_q\sqrt{1 - \frac{1}{\left(1 + \frac{E_C}{(m_e c^2)}\right)^2}} \tag{22}$$

Interpretation:
This equation links three fundamental parameters of the neutron model:
• confinement energy
• internal charge separation
• magnetic moment
Thus the magnetic moment becomes a direct function of the structural properties of the neutron

$$\mu = f(E_c, R_q) \tag{23}$$

2.7. Dimensional Consistency:
The compact expression derived for the magnetic moment is

$$\mu = q\, c\, R_q \sqrt{1 - \frac{1}{\left(1 + \frac{E_c}{m_e c^2}\right)^2}} \tag{24}$$

The square-root term is dimensionless because it depends only on the ratio

$$\frac{E_c}{(m_e c^2)} \tag{25}$$

which is an energy ratio. Therefore the dimensional structure of the magnetic moment is determined entirely by the product

$$\mu \approx q\, c\, R_q \tag{26}$$

Examining the physical dimensions,

$$q \rightarrow coulomb\ (C)$$
$$c \rightarrow meter\ per\ second\ m/s$$
$$R_q \rightarrow meter\ (m)$$

Thus

$$q\, c\, R_q \rightarrow C \times \left(\frac{m}{s}\right) \times m \tag{27}$$

which gives

$$\mu \rightarrow C\frac{m^2}{s} \tag{28}$$

Since electric current is defined as

$$1\,A = 1\frac{C}{s} \tag{29}$$

the expression becomes

$$\mu \rightarrow A\, m^2 \tag{30}$$

which is exactly the SI unit of magnetic dipole moment.

Interpretation:

This dimensional consistency confirms that the magnetic moment scale in the present model is fundamentally controlled by the product of three physical quantities: the elementary charge, the characteristic velocity scale (c), and the internal charge separation radius of the Qc structure. The relativistic correction factor modifies the magnitude but does not alter the dimensional structure of the magnetic moment.

2.8. Numerical Evaluation for the Neutron Model:
Using the confinement energy obtained in the neutron structure analysis

$$E_c = 3.46\ MeV \tag{31}$$

and the outer Qc radius

$$R_q = 0.19\ fm \tag{32}$$

the predicted magnetic moment becomes

$$\mu \approx 9.05 \times 10^{-27} A \cdot m^2 \tag{33}$$

Interpretation:
The predicted magnetic moment emerges directly from the internal charge geometry and confinement energy without introducing adjustable parameters.

2.9. Comparison with Experiment:
The experimentally measured neutron magnetic moment is

$$\mu_n = -1.913\ \mu_N \tag{34}$$

where the nuclear magneton is

$$\mu_N = \frac{(e\,\hbar)}{(2\,m_p)} \tag{35}$$

Numerically this corresponds to

$$\mu_n \approx 9.65 \times 10^{-27} A \cdot m^2 \tag{36}$$

Thus the predicted value lies within approximately

$$\approx 6\ \% \tag{37}$$

of the experimentally observed neutron magnetic moment.

Interpretation:
The close agreement between the predicted and measured magnetic moments suggests that the characteristic internal separation scale

$$R_q \approx 0.15 - 0.19\ fm \tag{38}$$

naturally reproduces the magnitude of the neutron magnetic moment within the proposed Qc structural framework.

Conclusion:

The neutron magnetic moment can be interpreted within the Qc structural framework developed in the preceding analysis. In this model the neutron contains an odd population of quantum-charge units (Qc), defined in Eq. (1). The majority of these units form spin-paired states whose magnetic contributions cancel according to Eqs. (9)–(11), leaving a single unpaired Qc unit that determines the net neutron spin given in Eq. (12).

The magnetic moment arises from the rotating Qc dipole described by the current-loop relation of Eq. (13). Because the Qc dipole contains two oppositely charged particles moving in the same current path, their magnetic contributions combine, yielding the effective dipole expression given in Eq. (14). The internal charge velocity derived from the confinement-energy relation of Eqs. (16)–(20) leads to the compact magnetic-moment expression presented in Eq. (22).

The predicted magnetic moment obtained from this relation agrees with the experimentally measured neutron magnetic moment within approximately **6 %**, as shown by the comparison in Eqs. (33)–(37). This level of agreement indicates that the essential magnitude of the neutron magnetic dipole moment can be reproduced from the internal Qc geometry and confinement energy.

An additional feature of the model is that the outer Qc separation scale implied by the neutron structure is close to the characteristic magnetic length scale obtained from the experimental neutron moment when expressed as

$$R_\mu = \frac{\mu_n}{(q\ c)}$$

as defined in Eq. (7). This correspondence suggests that the magnitude of the neutron magnetic moment may be governed primarily by the internal charge separation scale within the neutron.

In this interpretation, neutron spin and magnetism emerge naturally from the presence of a single unpaired Qc unit within an otherwise spin-paired Qc structure.

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