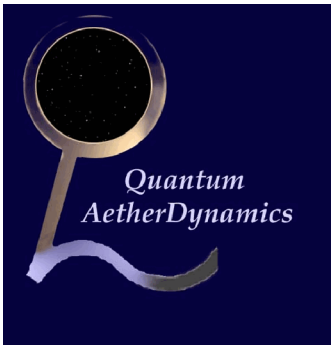

Quantum AetherDynamics Institute (QADI)

Magnetic Moment Revisited: A Quantum Measurement Unit Analysis of Particle Magnetic Moments and the Neutron Magnetic Charge Prediction

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It develops the Aether Physics Model (APM)

Abstract

This paper establishes the Quantum Measurement Unit (QMU) authority derivation for magnetic moment, denoted (magm), within the Aether Physics Model (APM). The magnetic moment unit is developed from first principles as a magnetic square-charge, area, and quantum-frequency construct,

$$\text{magm} = {e_{\text{emax}}}^2 {\lambda_C}^2 F_q,$$

and is related to the equivalent QMU identities

$$\text{magm} = \text{curr}\,\text{area}, \qquad \text{magm} = \text{qanr}\,\text{curl}, \qquad \text{enrg} = \text{magm}\,\text{mfxd}.$$

The analysis identifies magnetic moment as a special charge-conversion exception in which the measured magnetic resonance observables must be distinguished from the theoretical magnetic-charge normalization used to infer a particle magnetic moment. The electron, proton, and neutron magnetic moments are derived using their appropriate charge-conversion factors (ccf_x) [Thomson, 2025a], with special attention to the neutron. The central prediction is that existing neutron resonance experiments correctly measure neutron spin dynamics, but the conventional conversion of those observables into neutron magnetic moment uses proton-sector magnetic charge. In the QMU interpretation, the neutron possesses its own magnetic square-charge, requiring a revised magnetic-charge normalization and yielding a neutron (g)-factor near (-3.831359). The paper therefore separates experimental observables, conventional interpretation, QMU derivation, and falsifiable prediction.

Keywords: magnetic moment; magm; QMU; APM; charge conversion factor; magnetic charge; neutron magnetic moment; neutron magnetic charge; proton magnetic charge; gyromagnetic ratio; (g)-factor; magnetic resonance; NIST CODATA

1 Introduction

1.1 Purpose of the Paper

Magnetic moment is one of the fundamental quantities of modern physics. It connects magnetic fields, angular momentum, quantum spin, magnetic resonance, atomic structure, nuclear structure, and elementary particle physics. Measurements of magnetic moment provide some of the most precise determinations of fundamental constants [Tiesinga et al., 2023, Mohr et al., 2025] and form the experimental basis for electron spin resonance, nuclear magnetic resonance, and neutron magnetic resonance [Rabi et al., 1939, Ramsey, 1950, Greene et al., 1979].

Within the Quantum Measurement Unit (QMU) framework of the Aether Physics Model (APM), magnetic moment has not previously been developed as a complete authority unit. The primary purpose of this paper is therefore to establish the magnetic moment unit, denoted magm, directly from the QMU ledger [Thomson, 2025b] and derive its complete network of equivalent relationships.

A second objective is to examine how experimentally measured resonance observables are converted into particle magnetic moments. Particular attention is given to the neutron, where the QMU derivation predicts that the conventional interpretation employs proton-sector magnetic charge normalization instead of neutron-sector magnetic charge normalization.

This paper therefore serves both as the authority reference for the QMU magnetic moment unit and as a quantitative investigation into the metrological interpretation of neutron magnetic moment measurements.

1.2 Magnetic Moment as a Metrological Problem

The determination of a particle magnetic moment consists of two distinct stages.

First, experiments measure physical observables such as resonance frequencies, magnetic flux densities, spin-precession frequencies, and frequency ratios.

Second, those experimentally measured quantities are converted into magnetic moments, gyromagnetic ratios, and (g)-factors through theoretical relationships that incorporate assumptions regarding magnetic charge normalization.

The distinction between measured observables and inferred quantities is frequently implicit because conventional theory has successfully described a wide range of experimental results. Nevertheless, the conversion from measurement to inferred magnetic moment remains a theoretical step whose assumptions may be examined independently of the experimental observations.

The present work adopts this metrological viewpoint throughout. Experimental measurements are accepted as reported in the literature. The focus instead is upon the mathematical interpretation used to derive particle magnetic moments from those measurements.

1.3 The QMU Research Question

Within the QMU framework, magnetic moment is derived directly from the fundamental ledger definition

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q.$$

From this definition follows an interconnected network of equivalent identities,

$$\mathrm{magm} = \mathrm{curr}\,\mathrm{area},$$

$$\mathrm{magm} = \mathrm{qanr}\,\mathrm{curl},$$

and

$$\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd}.$$

These relationships establish magnetic moment simultaneously as a current-area quantity, a quantum angular relationship with curl, and the quantity that couples energy to magnetic flux density. The resulting dimensional closure integrates magnetic moment naturally with the previously established QMU authority papers concerning magnetic charge, charge conversion, curl, the Aether Unit, and Ledger One.

The principal question addressed by this paper is whether this QMU derivation leads to the same interpretation of experimentally determined particle magnetic moments as the conventional framework.

1.4 Statement of the Neutron Magnetic Charge Prediction

The central prediction developed in this paper concerns the interpretation of neutron magnetic moment measurements rather than the measurements themselves.

The QMU framework does not dispute experimentally measured resonance frequencies, magnetic flux densities, or neutron spin-precession behavior. Instead, it predicts that the theoretical conversion from those observables into neutron magnetic moment employs proton-sector magnetic charge normalization.

Within the QMU framework, the neutron possesses its own magnetic square-charge and therefore its own particle-sector charge conversion factor [Thomson, 2025a]. Replacing proton-sector normalization with neutron-sector normalization preserves the experimentally observed resonance behavior while yielding a revised neutron magnetic moment and a corresponding neutron (g)-factor near -3.831359.

This prediction is quantitative, reproducible, and falsifiable through reanalysis of existing neutron magnetic resonance measurements.

1.5 Separation of Measurement and Interpretation

Throughout this paper, four categories of scientific information are distinguished.

The first consists of experimentally measured observables, including resonance frequencies, magnetic flux densities, spin-precession frequencies, and frequency ratios.

The second consists of theoretical quantities inferred from those measurements, including gyromagnetic ratios, magnetic moments, and (g)-factors.

The third consists of independent derivations obtained directly from the Quantum Measurement Unit framework.

The fourth consists of falsifiable predictions arising from comparison of the conventional and QMU interpretations.

Maintaining these distinctions allows alternative theoretical interpretations to be evaluated without questioning the validity of the experimental measurements themselves.

1.6 Structure of the Paper

Section 2 reviews the historical development of magnetic moment measurements from early current-loop concepts through modern neutron magnetic resonance experiments.

Section 3 summarizes the conventional theory of magnetic moment and identifies where charge normalization enters the interpretation of experimental observables.

Section 4 establishes the QMU magnetic moment unit magm and derives its complete dimensional network.

Section 5 develops the general charge conversion factor $\mathrm{ccf_x}$, together with the particle-specific quantities $\mathrm{ccf_e}$, $\mathrm{ccf_p}$, and $\mathrm{ccf_n}$, demonstrating why magnetic moment is a unique charge-conversion exception within the QMU framework.

Section 6 derives the electron, proton, and neutron magnetic moments directly from their respective particle-sector magnetic square-charges.

Section 7 reviews the principal experimental determinations of particle magnetic moments and distinguishes measured observables from inferred quantities.

Section 8 presents the QMU reinterpretation of neutron magnetic moment measurements by replacing proton-sector magnetic charge normalization with neutron-sector normalization.

Section 9 derives the predicted neutron (g)-factor.

Section 10 discusses experimental consequences and proposes methods for distinguishing between the conventional and QMU interpretations.

The paper concludes by summarizing the metrological significance of the QMU magnetic moment unit and its role within the expanding QMU authority framework.

2 Historical Development of Magnetic Moment

2.1 Classical Magnetic Moment and Current Loops

The concept of magnetic moment originated in classical electromagnetism as a convenient description of the torque experienced by an electric current circulating within a closed conducting loop. Ampère's investigations of electrical currents and their magnetic interactions established that a current-carrying loop behaves as a magnetic dipole whose strength is proportional to the current and the enclosed area.

The classical magnetic moment is therefore defined as

$$\boldsymbol{\mu} = I\mathbf{A},$$

where I is the electric current and $\mathbf{A}$ is the vector area enclosed by the current loop [Jackson, 1999, Griffiths, 2017]. The direction of the magnetic moment follows the right-hand rule relative to the direction of current flow.

When placed within a magnetic flux density $\mathbf{B}$, the current loop experiences a torque

$$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B},$$

and possesses the magnetic potential energy

$$U = -\boldsymbol{\mu} \cdot \mathbf{B}.$$

These equations remain fundamental throughout modern electromagnetism and continue to define the operational meaning of magnetic moment in laboratory measurements.

Within the Quantum Measurement Unit framework, the current-area relationship is preserved exactly,

$$\text{magm} = \text{curr}\,\text{area},$$

but is interpreted as one member of a larger dimensional network rather than the primary definition of magnetic moment.

2.2 Electron Magnetic Moment and the Bohr Magneton

The discovery of the electron introduced a profound challenge to the classical current-loop picture. Atomic spectroscopy revealed that electrons possess intrinsic magnetic moments even in the absence of any physically observable circulating charge.

Early quantum theory addressed this problem through orbital angular momentum, leading to the definition of the Bohr magneton,

$$\mu_B = \frac{e\hbar}{2m_e},$$

which established the characteristic magnetic moment scale for atomic physics.

Subsequent development of quantum mechanics and the introduction of intrinsic electron spin [Uhlenbeck and Goudsmit, 1925, Dirac, 1928] demonstrated that the electron magnetic moment is proportional to its angular momentum through the dimensionless electron (g)-factor. Precision measurements together with quantum electrodynamics have since determined the electron magnetic moment with extraordinary accuracy, making it one of the most precisely measured quantities in physics.

Although the Bohr magneton provides an exceptionally useful SI reference quantity, it is not treated as fundamental within the QMU framework. Instead, it becomes a bridge quantity derived from the underlying QMU definition of magnetic moment.

2.3 Nuclear Magnetic Moment and the Nuclear Magneton

The discovery of the atomic nucleus required an analogous magnetic moment scale appropriate for nuclear masses. This led to the introduction of the nuclear magneton [Fermi, 1930, Rabi et al., 1939],

$$\mu_N = \frac{e\hbar}{2m_p},$$

where the electron mass appearing in the Bohr magneton is replaced by the proton mass.

The nuclear magneton provides a convenient unit for expressing the magnetic moments of protons, neutrons, and atomic nuclei. Unlike the electron, however, nucleons exhibit magnetic moments that differ substantially from the simple Dirac prediction, requiring experimentally determined (g)-factors.

These deviations have traditionally been interpreted as evidence of internal nucleon structure and are now understood within the framework of quantum chromodynamics through the composite

quark nature of nucleons.

From the perspective of QMU metrology, however, the nuclear magneton is again regarded as a bridge quantity rather than a fundamental definition. The present work instead derives nucleon magnetic moments directly from particle-sector magnetic square-charge.

2.4 Neutron Magnetic Moment: Historical Context

The neutron presented an immediate conceptual difficulty following its discovery in 1932 [Workman et al., 2022, Navas et al., 2024]. Despite possessing no net electrostatic charge, numerous theoretical considerations suggested that it should nevertheless exhibit intrinsic angular momentum and therefore potentially possess a magnetic moment.

Confirmation of a non-zero neutron magnetic moment represented one of the earliest demonstrations that magnetic properties cannot be inferred solely from electrostatic charge.

2.4.1 Alvarez and Bloch

The first successful determination of the neutron magnetic moment was reported by Alvarez and Bloch in 1940 using magnetic resonance techniques applied to neutron beams [Alvarez and Bloch, 1940]. Their experiment demonstrated conclusively that free neutrons undergo magnetic resonance in externally applied magnetic fields and therefore possess an intrinsic magnetic moment.

Equally important, the experiment established that neutron spin dynamics could be measured directly through resonance phenomena rather than inferred indirectly from nuclear structure.

This work laid the experimental foundation upon which essentially all subsequent neutron magnetic moment measurements have been built.

2.4.2 Arnold, Roberts, and Ramsey

The introduction of Ramsey's separated oscillatory field method [Ramsey, 1950, Ramsey and Silsbee, 1951, Ramsey, 1956] dramatically improved the precision of magnetic resonance experiments by increasing frequency resolution while reducing systematic uncertainties.

Experiments employing separated oscillatory fields produced increasingly accurate determinations of neutron spin-precession frequencies and gyromagnetic ratios [Arnold and Roberts, 1947], establishing magnetic resonance as one of the most precise tools available for particle metrology.

These methods continue to influence modern neutron resonance experiments.

2.4.3 Greene et al.

Further advances in neutron beam technology, magnetic field control, and frequency metrology culminated in increasingly precise determinations of neutron magnetic properties during the latter half of the twentieth century [Greene et al., 1979].

Among these investigations, the work of Greene and collaborators represented a significant improvement in experimental precision and helped establish values that later contributed to international

recommended constants.

By this stage, experimental uncertainties had become sufficiently small that theoretical interpretation rather than measurement precision increasingly dominated the overall uncertainty budget.

2.5 Modern Magnetic Resonance and Precision Metrology

Modern determinations [Afach et al., 2014, 2015, Schulthess et al., 2023] of particle magnetic moments employ a wide variety of experimental techniques, including magnetic resonance, polarized neutron beams, ultracold neutrons, magnetic trapping, precision frequency metrology, and increasingly sophisticated magnetic field calibration procedures.

These experiments routinely determine resonance frequencies with extraordinary precision while carefully controlling systematic effects arising from magnetic field gradients, geometric phase shifts, environmental fields, and instrumental calibration.

The resulting experimental observables are among the most accurately measured quantities in all of experimental physics.

An important distinction, however, motivates the present investigation. Experiments directly determine resonance frequencies and related spin dynamics. Magnetic moments, gyromagnetic ratios, and particle (g)-factors are subsequently inferred through theoretical relationships that connect those observables with an assumed particle magnetic charge.

The following sections therefore review the conventional theoretical framework before developing the QMU derivation of magnetic moment and its associated charge-conversion relationships.

3 Magnetic Moment in Conventional Electromagnetism

3.1 Current-Loop Definition

The classical definition of magnetic moment originates from the magnetic field produced by an electric current circulating around a closed loop. The magnetic moment is proportional to the electric current and the enclosed area,

$$\boldsymbol{\mu} = I\mathbf{A},$$

where $\mathbf{A}$ denotes the vector area perpendicular to the plane of the current loop [Jackson, 1999, Griffiths, 2017]. The direction of the magnetic moment follows the right-hand rule and establishes the orientation of the magnetic dipole.

This definition forms the basis of nearly every practical application of magnetic moment, from electromagnets and electric motors to magnetic resonance and particle physics.

Within the QMU framework, the same physical relationship appears naturally as

$$\text{magm} = \text{curr}\,\text{area},$$

demonstrating that the classical current-loop definition is preserved while becoming one member of a more comprehensive dimensional network.

3.2 Torque and Potential Energy in a Magnetic Flux Density

A magnetic dipole placed within a magnetic flux density experiences both torque and potential energy. The torque aligns the magnetic moment with the applied field,

$$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B},$$

while the corresponding potential energy is

$$U = -\boldsymbol{\mu} \cdot \mathbf{B}.$$

These equations define the operational meaning of magnetic moment throughout experimental physics. Every magnetic resonance experiment ultimately measures the response of a magnetic moment to an externally applied magnetic flux density.

The energy relationship is especially important because it directly parallels the QMU definition

$$\text{enrg} = \text{magm}\,\text{mfxd},$$

which identifies magnetic moment as the quantity coupling energy to magnetic flux density.

This correspondence provides one of the principal bridges between conventional electromagnetism and the Quantum Measurement Unit framework.

3.3 Spin Magnetic Moment

Classical current loops successfully describe many macroscopic magnetic systems but cannot account for the intrinsic magnetic properties of elementary particles.

Quantum mechanics introduced intrinsic angular momentum, or spin, as a fundamental property independent of spatial rotation. Every charged elementary particle possessing spin also exhibits an intrinsic magnetic moment proportional to its angular momentum.

For a particle of charge q, mass m, and spin angular momentum $\mathbf{S}$, the magnetic moment is conventionally written

$$\boldsymbol{\mu} = g\left(\frac{q}{2m}\right)\mathbf{S},$$

where g is the dimensionless gyromagnetic factor [Dirac, 1928, Sakurai and Napolitano, 2017].

This equation is one of the defining relations of quantum electrodynamics and forms the basis for interpreting virtually all particle magnetic moment measurements.

Within the QMU framework, however, the proportionality between angular momentum and magnetic moment is rederived from particle-sector magnetic square-charge rather than assumed through linear electric charge.

3.4 Gyromagnetic Ratio

The proportionality between magnetic moment and angular momentum is commonly expressed through the gyromagnetic ratio,

$$\gamma = \frac{\mu}{S}.$$

Equivalently,

$$\gamma = g\frac{q}{2m}.$$

The gyromagnetic ratio plays a central role in magnetic resonance because it determines the Larmor precession frequency [Rabi et al., 1939, Ramsey, 1950],

$$\omega = \gamma B,$$

or, in terms of ordinary frequency,

$$f = \frac{\gamma B}{2\pi}.$$

Modern magnetic resonance experiments measure these frequencies with extraordinary precision, allowing the gyromagnetic ratio to be determined directly from experimental observables.

The magnetic moment itself, however, is obtained only after assigning the appropriate theoretical relationship between gyromagnetic ratio, angular momentum, and particle charge.

This distinction becomes important later in the paper when the neutron magnetic moment is reconsidered within the QMU framework.

3.5 (g)-Factor Definition

The dimensionless (g)-factor quantifies the proportionality between a particle's angular momentum and its magnetic moment.

For an ideal Dirac particle,

$$g = 2,$$

while radiative corrections produce the well-known anomalous magnetic moment of the electron.

Composite particles such as the proton and neutron exhibit much larger departures from the Dirac value because their magnetic moments arise from internal structure.

Experimentally determined (g)-factors therefore provide important information concerning particle dynamics while simultaneously serving as convenient normalization factors for magnetic moments expressed in Bohr or nuclear magnetons.

Within the QMU framework, the (g)-factor remains an experimentally useful quantity but does not replace the underlying particle-sector magnetic square-charge from which magnetic moment is derived.

3.6 Bohr Magneton and Nuclear Magneton

Conventional magnetic moments are almost universally expressed relative to either the Bohr magneton or the nuclear magneton.

The Bohr magneton is defined as

$$\mu_B = \frac{e\hbar}{2m_e},$$

while the nuclear magneton is

$$\mu_N = \frac{e\hbar}{2m_p}.$$

These quantities provide convenient units for comparing magnetic moments across atomic and nuclear systems [Tiesinga et al., 2023, National Institute of Standards and Technology, 2025b].

The QMU framework does not dispute their usefulness. Instead, they are interpreted as bridge quantities derived from more fundamental QMU relationships involving magnetic square-charge, quantum length, and quantum frequency.

Consequently, the present paper derives particle magnetic moments directly from the QMU ledger before translating those results into conventional units where comparison with experiment is required.

3.7 Where Charge Normalization Enters Conventional Theory

An important feature of conventional magnetic moment theory is that experimentally measured quantities are not themselves magnetic moments.

Magnetic resonance experiments measure frequencies, frequency ratios, spin precession, and magnetic flux densities. From these observables, gyromagnetic ratios are determined.

The conversion from gyromagnetic ratio to magnetic moment then requires the assumed relationship among particle charge, particle mass, angular momentum, and the adopted magneton.

This conversion implicitly specifies the particle charge normalization used in the interpretation.

For electrons and protons, this normalization has become so familiar that it is seldom discussed explicitly. For the neutron, however, the situation is more subtle because the neutron possesses no net electrostatic charge while exhibiting a substantial intrinsic magnetic moment.

The Quantum Measurement Unit framework therefore revisits this conversion step directly. Rather than treating particle magnetic moments as primary quantities, the following sections derive them from particle-sector magnetic square-charge and the corresponding charge conversion factors,

$$\mathrm{ccf_x}, \qquad \mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n},$$

thereby providing an independent metrological interpretation of magnetic moment that can be compared directly with the conventional framework.

4 Definition of the QMU Magnetic Moment Unit

4.1 Fundamental QMU Definition of magm

Within the Quantum Measurement Unit (QMU) framework, magnetic moment is treated as a fundamental derived quantity rather than as a secondary quantity obtained from the Bohr or nuclear magnetons. The unit of magnetic moment is denoted magm and is defined directly from the QMU ledger [Thomson, 2025b] as

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q.$$

This definition expresses magnetic moment as the product of three fundamental physical quantities:

- magnetic square-charge, ${e_{\mathrm{emax}}}^2$,
- quantum area, ${\lambda_C}^2$,
- quantum frequency, F_q.

Unlike conventional formulations that begin with electric current or intrinsic spin, the QMU definition begins with dimensional closure. Magnetic moment therefore becomes a natural consequence of the fundamental QMU constants rather than an independently introduced physical quantity.

This definition also reveals that magnetic moment is fundamentally associated with magnetic square-charge rather than linear electrostatic charge, a distinction that becomes essential when particle-sector charge conversion is introduced in Section 5.

4.2 Magnetic Square-Charge, Area, and Quantum Frequency

The QMU definition immediately identifies magnetic moment as a transport quantity relating magnetic square-charge to the fundamental geometry and temporal evolution of the Aether.

The magnetic square-charge determines the magnitude of the interaction.

The quantum area determines the spatial extent over which the interaction is distributed.

The quantum frequency determines the rate at which that interaction propagates.

Consequently,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q$$

represents the natural magnetic analogue of angular momentum transport through quantized space.

Unlike the SI definition, no arbitrary reference quantity such as the Bohr magneton is required. The dimensional structure follows directly from the QMU ledger.

4.3 Current-Area Identity

One of the oldest relationships in electromagnetism appears naturally within the QMU framework.

Using the QMU definitions of current and area,

$$\mathrm{curr} = {e_{\mathrm{emax}}}^2 F_q,$$

and

$$\mathrm{area} = {\lambda_C}^2,$$

their product becomes

$$\mathrm{curr\,area} = \left({e_{\mathrm{emax}}}^2 F_q\right) {\lambda_C}^2 = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q = \mathrm{magm}.$$

Therefore,

$$\boxed{\mathrm{magm} = \mathrm{curr\,area}}$$

is not merely a classical approximation but an exact dimensional identity within the QMU framework.

The familiar current-loop interpretation of magnetic moment therefore emerges naturally from the underlying QMU ledger.

4.4 Quantum Angular Relationship and Curl Identity

Magnetic moment also possesses a direct relationship with quantum angular geometry through the QMU quantity qanr.

Using the Ledger-One identities previously established for angular relationships and curl,

$$\mathrm{qanr} = {e_{\mathrm{emax}}}^2 \lambda_C,$$

and

$$\mathrm{curl} = \lambda_C F_q,$$

their product gives

$$\text{qanr curl} = \left({e_{\text{emax}}}^2 \lambda_C\right)(\lambda_C F_q) = {e_{\text{emax}}}^2 {\lambda_C}^2 F_q = \text{magm}.$$

Thus,

$$\boxed{\text{magm} = \text{qanr curl}}$$

demonstrates that magnetic moment is equally an angular-geometric quantity and not merely the consequence of electrical current.

This identity establishes an important bridge between magnetic moment and the QMU description of rotational geometry developed in previous authority papers.

4.5 Energy Coupling to Magnetic Flux Density

One of the defining physical properties of magnetic moment is its coupling to magnetic flux density.

Within the SI framework this relationship appears as magnetic potential energy,

$$U = \mu B.$$

Within the QMU framework the corresponding dimensional identity is

$$\boxed{\text{enrg} = \text{magm}\,\text{mfxd}}$$

which follows directly from the fundamental QMU definitions.

Unlike the SI expression, which is introduced through electromagnetic potential energy, the QMU identity represents an exact dimensional equality.

This equation establishes magnetic flux density as the field quantity conjugate to magnetic moment, just as force is conjugate to length and pressure is conjugate to volume.

The identity also provides one of the principal dimensional bridges between magnetic phenomena and energy throughout the QMU system.

4.6 Ledger-One Closure

Because every quantity appearing in the definition of magm is itself a Ledger-One quantity, magnetic moment participates naturally in the dimensional closure of the QMU system.

Beginning with

$$\text{magm} = {e_{\text{emax}}}^2 {\lambda_C}^2 F_q,$$

all subsequent identities are obtained through substitution of previously established QMU definitions.

Consequently, magnetic moment is not introduced independently but occupies a unique location within the dimensional network connecting magnetic charge, current, angular geometry, curl, magnetic flux density, and energy.

This dimensional closure distinguishes the QMU formulation from conventional definitions that begin with experimentally convenient reference quantities such as the Bohr or nuclear magnetons.

4.7 Complete Dimensional Network of magm

The magnetic moment unit is therefore characterized by the equivalent identities

$$\text{magm} = {e_{\text{emax}}}^2 {\lambda_C}^2 F_q,$$

$$\text{magm} = \text{curr}\,\text{area},$$

$$\text{magm} = \text{qanr}\,\text{curl},$$

and

$$\text{enrg} = \text{magm}\,\text{mfxd}.$$

These identities reveal that magnetic moment occupies a central position within the QMU framework.

It is simultaneously a magnetic square-charge quantity, a current-area quantity, an angular-geometric quantity, and the quantity that couples energy to magnetic flux density.

The following section extends this dimensional foundation by introducing the particle-sector charge conversion factors. Those conversion factors explain why magnetic moment constitutes one of the few QMU quantities whose numerical value depends upon the magnetic square-charge associated with a particular particle species, thereby leading naturally to distinct electron, proton, and neutron magnetic moments.

5 Charge Conversion and the Exceptional Nature of Magnetic Moment

5.1 Magnetic Square-Charge from Particle Mass

The particle-sector magnetic square-charge used throughout this paper is not introduced as an adjustable parameter. Instead, it follows from a more fundamental principle of the Aether Physics Model (APM): magnetic square-charge is directly proportional to the total mass of the particle.

Within the QMU framework, mass and magnetic square-charge are therefore not independent physical properties. Rather, they are complementary manifestations of the same underlying Aether structure. Once the total mass of a particle is established, its corresponding magnetic square-charge

is determined uniquely through the fundamental mass–magnetic charge relationship [Thomson, 2025a].

Consequently, the particle-sector magnetic square-charge is obtained independently of any magnetic resonance measurement. The electron, proton, and neutron each possess distinct total masses and therefore possess distinct magnetic square-charges,

$$e_{\mathrm{emax}}{}^2, \qquad e_{\mathrm{pmax}}{}^2, \qquad e_{\mathrm{nmax}}{}^2.$$

These magnetic square-charges are fundamental particle properties within the APM and are not inferred from magnetic moment measurements.

The charge conversion factors introduced in the following subsection therefore do not introduce additional degrees of freedom into the theory. They simply express the ratio between the independently determined particle magnetic square-charge and the universal electrostatic charge,

$$\mathrm{ccf_x} = \frac{e_{\mathrm{xmax}}{}^2}{e}.$$

Accordingly, the particle-sector charge conversion factors

$$\mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n},$$

are fixed before the magnetic moment derivation begins.

This logical ordering is essential to the present work. The neutron magnetic square-charge is determined from the neutron's total mass rather than from its measured magnetic moment. The magnetic moment is subsequently derived from the particle's magnetic square-charge through the QMU definition of magnetic moment. The resulting neutron (g)-factor therefore constitutes a prediction of the APM rather than a parameter chosen to reproduce an existing experimental value.

Within the broader APM ontology, the fine-structure constants do not determine magnetic square-charge. Instead, they quantify the bifurcation between electrostatic charge and magnetic square-charge originating from the Singularity. The fine-structure hierarchy [Thomson, 2025a] therefore provides the conversion between the two charge sectors, while the particle's total mass determines the magnitude of its magnetic square-charge.

5.2 Independence of the Neutron Sector Parameter

The neutron-sector charge conversion factor used in this paper is not obtained from neutron magnetic moment data. It is fixed independently by the neutron total mass through the APM mass–magnetic-charge law.

In the APM, magnetic square-charge is directly proportional to total particle mass. Therefore, once the neutron total mass is specified, the neutron magnetic square-charge $e_{\mathrm{nmax}}{}^2$ is determined before any magnetic resonance measurement or magnetic moment interpretation is considered.

The logical sequence is

$$m_n \longrightarrow {e_{\mathrm{nmax}}}^2 \longrightarrow \mathrm{ccf_n} \longrightarrow \mu_n^{\mathrm{QMU}} \longrightarrow g_n^{\mathrm{QMU}}.$$

The neutron magnetic moment does not enter this chain until after ${e_{\mathrm{nmax}}}^2$ and $\mathrm{ccf_n}$ have already been fixed. Consequently, the predicted neutron (g)-factor is not obtained by fitting $\mathrm{ccf_n}$ to the known neutron magnetic moment.

This distinction is essential. If $\mathrm{ccf_n}$ were selected to reproduce the accepted neutron magnetic moment, the result would be a retrodiction. In the present framework, however, $\mathrm{ccf_n}$ is a prior input derived from the neutron mass and the APM charge ontology. The magnetic moment calculation then becomes a test of whether the independently determined neutron magnetic charge produces the observed neutron spin dynamics.

The same standard applies to the electron and proton sectors. The sector-specific factors $\mathrm{ccf_e}$, $\mathrm{ccf_p}$, and $\mathrm{ccf_n}$ must be fixed from particle mass and charge structure before being applied to magnetic moment. The magnetic moment calculation is therefore not permitted to adjust these factors particle by particle.

This requirement provides a clear falsification criterion. If the independently determined neutron magnetic square-charge does not reproduce a coherent neutron magnetic moment interpretation, the QMU magnetic moment framework fails for the neutron. If it does, then the neutron magnetic moment becomes evidence that particle-sector magnetic square-charge is a physically meaningful metrological quantity rather than an adjustable normalization convention.

5.3 Definition of the Charge Conversion Factor

One of the central developments of the Quantum Measurement Unit (QMU) framework is the recognition that magnetic square-charge is particle dependent. While electrostatic charge is represented by the universal quantity e, the corresponding magnetic square-charge depends upon the particle under consideration.

To relate conventional electrostatic charge to particle-sector magnetic square-charge, the QMU framework defines the general charge conversion factor [Thomson, 2025a]

$$\mathrm{ccf_x} = \frac{{e_{\mathrm{xmax}}}^2}{e},$$

where ${e_{\mathrm{xmax}}}^2$ represents the magnetic square-charge associated with particle species x.

Unlike most QMU quantities, magnetic moment depends explicitly upon the magnetic square-charge of the particle. Consequently, the charge conversion factor becomes an essential component in the derivation of particle magnetic moments.

The particle-specific charge conversion factors used throughout this paper are

$$\mathrm{ccf_e} = \frac{{e_{\mathrm{emax}}}^2}{e},$$

$$\mathrm{ccf_p} = \frac{{e_{\mathrm{pmax}}}^2}{e},$$

and

$$\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e}.$$

These quantities convert the universal electrostatic charge into the corresponding particle-sector magnetic square-charge [Thomson, 2025a,b] required by the QMU framework.

5.4 Why Magnetic Moment Is a Charge-Conversion Exception

Most quantities within the QMU ledger are universal.

Once expressed in terms of the fundamental quantities, their dimensional definitions remain independent of particle species. Length, frequency, area, volume, energy, curl, and magnetic flux density all possess unique dimensional definitions that do not depend upon whether an electron, proton, or neutron is being considered.

Magnetic moment is fundamentally different.

The dimensional structure

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q$$

contains magnetic square-charge explicitly. Replacing the electron magnetic square-charge with the magnetic square-charge of another particle immediately produces a different magnetic moment.

Consequently, magnetic moment belongs to a small class of QMU quantities whose numerical value depends upon particle-sector magnetic charge.

This exceptional behavior was first recognized in *Secrets of the Aether* and forms one of the principal motivations for introducing the charge conversion factors.

Rather than representing an inconsistency, the particle dependence of magnetic moment follows directly from its dimensional definition.

5.5 Square-Charge Normalization versus Linear Charge Notation

Conventional electromagnetism expresses magnetic moments in terms of the linear electrostatic charge e.

Within the QMU framework, however, the fundamental magnetic interaction is represented by magnetic square-charge.

This distinction is subtle but important.

Electrostatic charge remains universal,

$$e = \mathrm{constant},$$

whereas magnetic square-charge depends upon particle structure.

Accordingly,

$$e_{\mathrm{emax}}{}^2 \neq e_{\mathrm{pmax}}{}^2 \neq e_{\mathrm{nmax}}{}^2.$$

The charge conversion factors bridge these two descriptions by relating universal electrostatic charge to particle-specific magnetic square-charge.

The resulting formulation preserves compatibility with conventional measurements while making explicit a normalization step that is usually hidden within conventional magnetic moment equations.

5.6 Magnetic Moment and the Inference of Particle-Sector Charge

Magnetic resonance experiments do not measure magnetic square-charge directly.

Instead, experiments determine resonance frequencies, magnetic flux densities, spin-precession rates, and frequency ratios.

From these observables, the magnetic moment is inferred through theoretical equations that contain an implicit assumption regarding the magnetic charge associated with the particle.

Within conventional theory, this assumption is absorbed into definitions involving the Bohr magneton, the nuclear magneton, and the particle (g)-factor.

The QMU framework separates these steps.

First, the experimentally measured observables are accepted without modification.

Second, the magnetic square-charge associated with the particle is identified.

Finally, the appropriate charge conversion factor is applied to obtain the corresponding particle magnetic moment.

This explicit separation provides a transparent metrological pathway from experimental observation to inferred magnetic moment.

5.7 The Role of $\mathrm{ccf_x}$ in Particle Magnetic Moments

The charge conversion factor is not an empirical correction.

Instead, it specifies which particle-sector magnetic square-charge participates in the dimensional definition of magnetic moment.

For electrons,

$$\mathrm{magm}_e \propto \mathrm{ccf_e}.$$

For protons,

$$\mathrm{magm}_p \propto \mathrm{ccf_p}.$$

For neutrons,

$$\mathrm{magm}_n \propto \mathrm{ccf_n}.$$

The proportionality constants include the appropriate angular momentum and particle-specific (g)-factor corrections discussed in the following section.

The important point is that each particle derives its magnetic moment from its own magnetic square-charge rather than from a universal magnetic charge.

Consequently, the charge conversion factor is not an adjustable parameter but an intrinsic property of the particle sector.

5.8 Consequences for Electron, Proton, and Neutron Moments

The introduction of particle-sector charge conversion produces three immediate consequences.

First, the dimensional definition of magnetic moment remains universal,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

while particle-specific magnetic moments differ through their associated magnetic square-charge.

Second, electron, proton, and neutron magnetic moments arise from the same underlying QMU definition without requiring separate fundamental equations.

Third, because the neutron possesses its own magnetic square-charge, its magnetic moment should be interpreted using $\mathrm{ccf_n}$ rather than $\mathrm{ccf_p}$.

This final consequence forms the central prediction developed throughout the remainder of the paper.

The following section derives the magnetic moments of the electron, proton, and neutron directly from their respective particle-sector magnetic square-charges and corresponding charge conversion factors before comparing those derivations with experimental measurements.

6 Derivation of Particle Magnetic Moments

6.1 General QMU Particle Magnetic Moment Form

The preceding section established that magnetic moment is one of the few Quantum Measurement Unit (QMU) quantities whose numerical value depends upon the magnetic square-charge associated with a particular particle species. The dimensional definition of magnetic moment remains universal,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

while the appropriate particle-sector magnetic square-charge is introduced through the corresponding charge conversion factor.

Accordingly, the magnetic moment of particle species x may be written in the general form

$$\mathrm{magm}_x = \mathrm{ccf_x}\left({e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q\right) f(g_x),$$

where $f(g_x)$ represents the particle-specific correction associated with the experimentally determined (g)-factor.

The dimensional structure is therefore identical for every particle. Only the particle-sector magnetic square-charge and the corresponding experimental (g)-factor distinguish one particle from another.

This separation between universal dimensional structure and particle-specific normalization provides one of the principal advantages of the QMU formulation.

6.2 Electron Magnetic Moment

The electron provides the natural starting point because the QMU system is normalized to the electron sector.

The electron magnetic moment follows directly from

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

together with the electron charge conversion factor,

$$\mathrm{ccf_e} = \frac{{e_{\mathrm{emax}}}^2}{e}.$$

Because the electron defines the fundamental magnetic square-charge used throughout the QMU ledger, no additional particle-sector substitution is required.

The experimentally observed electron magnetic moment is then obtained through the corresponding electron (g)-factor.

6.2.1 Electron-Sector Magnetic Charge

The electron magnetic square-charge serves as the reference magnetic charge throughout the QMU framework.

Consequently,

$${e_{\mathrm{emax}}}^2$$

is the canonical magnetic square-charge from which the remaining particle sectors are defined.

The electron magnetic moment therefore establishes the normalization of the QMU magnetic moment unit itself.

6.2.2 Electron Charge Conversion

The electron charge conversion factor,

$$\mathrm{ccf_e} = \frac{{e_{\mathrm{emax}}}^2}{e},$$

provides the bridge between conventional electrostatic charge and the QMU magnetic square-charge.

This conversion is already incorporated into the fundamental definition of magm and therefore requires no additional particle-sector adjustment.

6.2.3 Electron (g)-Factor Correction

Once the dimensional structure has been established, the experimentally measured electron (g)-factor accounts for the well-known quantum electrodynamic corrections to the Dirac value.

Within the QMU framework, these corrections modify the measured magnetic moment without altering its underlying dimensional origin.

6.3 Proton Magnetic Moment

Unlike the electron, the proton possesses its own magnetic square-charge and therefore requires a separate particle-sector normalization.

The dimensional definition remains unchanged.

Only the particle-sector charge conversion differs.

6.3.1 Proton-Sector Magnetic Charge

The proton magnetic square-charge is represented by

$${e_{\mathrm{pmax}}}^2,$$

which differs from the corresponding electron magnetic square-charge through the proton-sector charge conversion.

The magnetic moment therefore remains a magnetic square-charge quantity while reflecting the proton's distinct internal magnetic structure.

6.3.2 Proton Charge Conversion

The proton charge conversion factor is

$$\mathrm{ccf_p} = \frac{{e_{\mathrm{pmax}}}^2}{e}.$$

This conversion introduces the proton magnetic square-charge into the otherwise universal dimensional definition of magnetic moment.

The dimensional identity itself is unchanged.

Only the particle-sector normalization differs.

6.3.3 Proton (g)-Factor Correction

The experimentally measured proton (g)-factor accounts for the proton's composite internal structure.

Within the QMU framework, the (g)-factor modifies the particle magnetic moment after the appropriate proton-sector magnetic square-charge has been introduced through $\mathrm{ccf_p}$.

6.4 Neutron Magnetic Moment

The neutron represents the primary focus of the present investigation.

Although electrically neutral, the neutron possesses a substantial intrinsic magnetic moment that has been measured through magnetic resonance experiments for many decades.

Within conventional theory, the conversion from measured observables to neutron magnetic moment is generally presented without explicitly separating the particle-sector magnetic charge normalization from the experimental measurements themselves.

The QMU framework treats these two steps independently.

6.4.1 Neutron-Sector Magnetic Charge

The neutron possesses its own particle-sector magnetic square-charge,

$$e_{\mathrm{nmax}}{}^2,$$

which is neither equal to the electron magnetic square-charge nor the proton magnetic square-charge.

Accordingly, the neutron constitutes a distinct magnetic sector within the QMU framework.

6.4.2 Neutron Charge Conversion

The neutron charge conversion factor is

$$\mathrm{ccf_n} = \frac{e_{\mathrm{nmax}}{}^2}{e}.$$

This conversion introduces the neutron magnetic square-charge into the universal dimensional definition of magnetic moment.

It therefore represents the appropriate particle-sector normalization for neutron magnetic moment.

The significance of this distinction becomes evident when historical neutron magnetic moment determinations are examined in Section 8.

6.4.3 Neutron (g)-Factor Correction

Following particle-sector normalization through $\mathrm{ccf_n}$, the experimentally measured neutron (g)-factor provides the remaining correction required to determine the neutron magnetic moment.

The present paper argues that this particle-sector normalization has not previously been treated independently of the conventional magnetic moment formalism.

Separating these two steps permits a direct comparison between the conventional interpretation and the QMU interpretation without modifying the experimentally observed resonance behavior.

6.5 Comparison of Particle-Sector Magnetic Moments

The QMU derivation places the electron, proton, and neutron magnetic moments within a single unified framework.

Each particle shares the same dimensional definition,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

while differing only through

1. the particle-sector magnetic square-charge,
2. the corresponding charge conversion factor,
3. the experimentally determined (g)-factor.

This organization eliminates the need for separate fundamental equations for electrons, protons, and neutrons.

Instead, each magnetic moment is obtained from the same QMU dimensional structure combined with the appropriate particle-sector normalization.

The following section compares these derivations with the historical experimental literature, distinguishing carefully between quantities that are directly measured and quantities that are inferred through theoretical interpretation.

7 Review of Experimental Magnetic Moment Measurements

7.1 Experimental Categories

The measurement of particle magnetic moments has progressed through several generations of increasingly precise experimental techniques. Although the experimental apparatus has evolved considerably since the first neutron magnetic resonance experiments, the underlying objective has

remained unchanged: to determine the interaction between a particle's intrinsic magnetic moment and an externally applied magnetic flux density.

The principal experimental categories include:

- molecular beam magnetic resonance,
- separated oscillatory field resonance,
- polarized neutron beam measurements,
- ultracold neutron magnetic resonance,
- precision frequency-ratio measurements,
- magnetic trapping and spin-precession experiments.

Each of these techniques measures physical observables associated with spin dynamics rather than magnetic moment itself [Rabi et al., 1938, 1939, Ramsey, 1950, Greene et al., 1979, Afach et al., 2014].

Recognizing this distinction is essential for the QMU reinterpretation developed later in this paper.

7.2 Measured Observables

Modern magnetic resonance experiments directly determine several physical observables with exceptionally high precision.

7.2.1 Resonance Frequency

The primary observable is the resonance frequency at which transitions occur between magnetic spin states.

For a particle placed within a uniform magnetic flux density,

$$f = \frac{\gamma B}{2\pi},$$

where γ denotes the gyromagnetic ratio.

Frequency measurements represent some of the most precise quantities obtainable in experimental physics.

7.2.2 Magnetic Flux Density

The applied magnetic flux density constitutes a second directly measured quantity.

Considerable experimental effort is devoted to stabilizing and calibrating magnetic fields because uncertainties in magnetic flux density propagate directly into the inferred gyromagnetic ratio.

Within the QMU framework, magnetic flux density remains an experimentally measured field quantity and is represented by mfxd.

7.2.3 Spin Precession

Spin precession provides the physical mechanism through which resonance frequencies are determined.

The experimentally observed Larmor precession frequency is a direct manifestation of the interaction between intrinsic magnetic moment and the applied magnetic flux density.

Importantly, experiments observe the precession itself.

They do not directly observe magnetic square-charge or particle magnetic moment.

7.2.4 Frequency Ratios

Many modern experiments determine ratios of resonance frequencies rather than absolute frequencies.

Frequency-ratio measurements reduce systematic uncertainties associated with magnetic field calibration and permit extremely precise comparisons among different particle species.

These ratios frequently provide the most accurate experimental inputs for recommended values [Tiesinga et al., 2023, National Institute of Standards and Technology, 2025a,b] of gyromagnetic ratios and magnetic moments.

7.3 Inferred Quantities

Although resonance experiments directly determine frequencies and magnetic fields, several quantities commonly reported in the literature are obtained only after theoretical interpretation.

7.3.1 Gyromagnetic Ratio

The gyromagnetic ratio is inferred from measured resonance frequency and magnetic flux density through

$$\gamma = \frac{2\pi f}{B}.$$

Because both f and B are directly measured, the gyromagnetic ratio is itself strongly constrained by experiment.

7.3.2 Magnetic Moment

The magnetic moment is not measured directly.

Instead, it is obtained by combining the experimentally determined gyromagnetic ratio with assumptions concerning particle angular momentum and charge normalization.

This conversion constitutes the central metrological step examined throughout the present paper.

7.3.3 (g)-Factor

The dimensionless (g)-factor is likewise inferred rather than directly observed.

Its numerical value depends upon the theoretical relationship adopted between magnetic moment, angular momentum, particle mass, and particle charge.

Consequently, both magnetic moment and (g)-factor represent interpreted quantities rather than primary experimental observables.

7.4 Alvarez and Bloch

The landmark experiment of Alvarez and Bloch demonstrated that free neutrons undergo magnetic resonance in externally applied magnetic fields [Alvarez and Bloch, 1940].

Their work established the existence of an intrinsic neutron magnetic moment through direct observation of neutron spin dynamics.

From the perspective of the present paper, the significance of this experiment extends beyond the reported magnetic moment.

The experiment directly measured resonance behavior.

The magnetic moment was subsequently inferred through the theoretical framework available at the time.

This distinction between measurement and interpretation is fundamental to the QMU analysis.

7.5 Arnold, Roberts, and Ramsey

The introduction of Ramsey's separated oscillatory field method transformed magnetic resonance metrology [Arnold and Roberts, 1947, Ramsey, 1950, 1956].

By increasing frequency resolution while reducing systematic uncertainty, this technique enabled substantially more precise determinations of neutron spin-precession frequencies and gyromagnetic ratios.

Again, the primary experimental observables consisted of resonance frequencies and magnetic field conditions.

The reported magnetic moments were obtained through theoretical conversion.

7.6 Greene et al.

Subsequent work by Greene and collaborators further improved neutron magnetic moment precision through advances in neutron beam technology, magnetic field control, and frequency metrology [Greene et al., 1979].

By this stage, experimental uncertainties had become sufficiently small that theoretical assumptions contributed significantly to the interpretation of the measured observables.

The experiments therefore provide an excellent foundation for examining alternative metrological interpretations.

7.7 Ultracold Neutron Magnetic Resonance Measurements

Modern ultracold neutron facilities [Afach et al., 2014, 2015, Schulthess et al., 2023] have significantly extended the precision with which neutron spin-precession frequencies can be measured.

Long observation times, improved magnetic shielding, precision magnetometry, and sophisticated field-control techniques have reduced many traditional sources of systematic error.

These experiments now determine resonance frequencies with extraordinary precision.

From the QMU perspective, this increased precision strengthens rather than weakens the present analysis because the experimentally measured observables become increasingly secure while the theoretical interpretation remains open to examination.

7.8 Neutron Gyromagnetic Ratio Measurements

Numerous experiments have determined the neutron gyromagnetic ratio through direct comparison of neutron spin-precession frequency with independently calibrated magnetic flux densities [Greene et al., 1979, Afach et al., 2014, National Institute of Standards and Technology, 2025c].

These investigations provide one of the most experimentally robust quantities associated with neutron magnetic properties.

The QMU framework accepts these measurements without modification.

The reinterpretation developed later in this paper concerns the conversion of the experimentally determined gyromagnetic ratio into neutron magnetic moment through particle-sector magnetic charge normalization.

7.9 NIST CODATA Magnetic Moment Recommendations

The internationally recommended values published by NIST and CODATA [Tiesinga et al., 2023, National Institute of Standards and Technology, 2025a,b] represent comprehensive least-squares adjustments of available experimental measurements.

These recommended values [Tiesinga et al., 2023, National Institute of Standards and Technology, 2025a,b] incorporate the highest quality experimental data together with the accepted theoretical framework used to relate measured observables to derived quantities.

The QMU framework does not dispute the experimental measurements incorporated into these adjustments.

Instead, it examines one specific theoretical assumption embedded within the conversion from measured gyromagnetic ratios to inferred neutron magnetic moment.

Accordingly, the following section distinguishes carefully between experimentally measured resonance behavior and the particle-sector magnetic charge normalization employed during theoretical interpretation.

8 QMU Reinterpretation of Neutron Magnetic Moment

8.1 What the Experiments Directly Measure

The experimental foundation of neutron magnetic moment metrology is exceptionally secure. Over more than eight decades, increasingly sophisticated magnetic resonance experiments have consistently measured neutron spin dynamics with remarkable precision. Modern ultracold neutron experiments further reduce statistical and systematic uncertainties while employing highly stable magnetic fields and precision frequency metrology.

These experiments directly determine measurable physical observables, including

- resonance frequencies,
- spin-precession frequencies,
- magnetic flux densities,
- frequency ratios,
- gyromagnetic ratios derived from measured frequencies.

Each of these quantities is obtained directly from experimental observation.

The Quantum Measurement Unit (QMU) framework fully accepts these experimental measurements. Nothing in the present work requires modification of the measured resonance frequencies, measured magnetic flux densities, or observed spin dynamics.

Consequently, the QMU reinterpretation does not challenge the experimental data themselves.

8.2 What the Conventional Interpretation Infers

The experimentally measured quantities are subsequently converted into the neutron magnetic moment through theoretical relationships involving particle angular momentum, magnetic charge, and the adopted system of units.

In conventional theory, this conversion proceeds through the gyromagnetic ratio,

$$\gamma = \frac{\mu}{S},$$

together with the corresponding definition of the neutron magnetic moment and its associated (g)-factor [Jackson, 1999, Sakurai and Napolitano, 2017, Ramsey, 1950].

This conversion is entirely reasonable within the conventional framework.

However, from the standpoint of metrology, it is important to recognize that magnetic moment is not itself an experimentally observed quantity. Rather, it is inferred from experimentally measured observables through a theoretical model.

The QMU framework therefore examines this interpretive step independently of the experimental measurements.

8.3 Proton Normalization in Neutron Magnetic Moment Interpretation

The central observation motivating the present paper is that the conventional derivation treats the neutron magnetic moment using a magnetic charge normalization inherited from the proton-electron formalism.

Historically this approach developed naturally because the neutron magnetic moment was expressed relative to the nuclear magneton and interpreted using the established formalism of nuclear magnetic resonance.

Within that formalism, the magnetic resonance measurements themselves are entirely correct.

The QMU framework instead asks a different metrological question.

If magnetic moment is fundamentally proportional to particle-sector magnetic square-charge,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

which magnetic square-charge should be associated with the neutron?

If the neutron constitutes its own magnetic sector, then its magnetic moment should not inherit proton-sector normalization simply because the conventional formalism expresses nucleon magnetic moments relative to common nuclear quantities.

This question concerns normalization rather than measurement.

8.4 Replacing Proton Magnetic Charge with Neutron Magnetic Charge

Within the QMU framework, every particle possessing an intrinsic magnetic moment also possesses its own particle-sector magnetic square-charge.

The neutron therefore has

$${e_{\mathrm{nmax}}}^2,$$

with the corresponding charge conversion factor

$$\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e}.$$

Likewise, the proton possesses

$${e_{\mathrm{pmax}}}^2,$$

with

$$\mathrm{ccf_p} = \frac{{e_{\mathrm{pmax}}}^2}{e}.$$

The QMU interpretation therefore replaces proton-sector normalization with neutron-sector normalization while leaving every experimentally measured observable unchanged.

The dimensional definition of magnetic moment remains

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q.$$

Only the particle-sector magnetic square-charge changes.

This distinction represents the essential difference between the conventional interpretation and the QMU interpretation.

8.5 QMU Reanalysis of the Neutron Magnetic Moment

The QMU derivation proceeds independently of conventional magnetons.

Beginning with the fundamental dimensional definition of magnetic moment,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

the neutron magnetic moment is obtained by introducing the neutron magnetic square-charge through $\mathrm{ccf_n}$ together with the experimentally measured neutron (g)-factor correction.

Because the dimensional derivation is independent of the experimental measurements, the resulting magnetic moment depends only upon the choice of particle-sector normalization.

Consequently, the experimentally determined resonance frequencies remain unchanged while the inferred neutron magnetic moment changes according to the adopted magnetic square-charge.

This distinction is entirely metrological.

It neither alters the experimental observations nor introduces new experimental assumptions.

8.6 Why the Experimental Observations Remain Valid

An important consequence of the QMU interpretation is that every resonance experiment remains valid exactly as performed.

The observed resonance frequencies remain unchanged.

The measured magnetic flux densities remain unchanged.

The observed spin-precession frequencies remain unchanged.

The experimentally determined gyromagnetic ratios remain unchanged.

Only the interpretation used to convert those quantities into neutron magnetic moment differs.

Accordingly, the present work should not be interpreted as questioning historical neutron magnetic resonance experiments.

Instead, it proposes that those experiments contain sufficient information to support an alternative magnetic moment interpretation based upon particle-sector magnetic square-charge.

8.7 Where the Theoretical Interpretation Changes

The conventional and QMU frameworks therefore differ at only a single metrological step.

Both begin with identical experimental measurements.

Both determine identical resonance frequencies.

Both determine identical magnetic flux densities.

Both determine identical spin-precession behavior.

The divergence occurs only when particle magnetic moment is inferred.

Conventional theory proceeds using the traditional proton-sector normalization inherited from nuclear magnetic moment formalism.

The QMU framework instead introduces the neutron magnetic square-charge through the neutron charge conversion factor,

$$\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e},$$

thereby assigning the neutron its own particle-sector magnetic normalization.

The following section develops the quantitative consequences of this substitution and derives the corresponding neutron (g)-factor predicted by the QMU framework.

9 Predicted Neutron (g)-Factor

9.1 Conventional Neutron (g)-Factor

Within conventional particle physics, the neutron magnetic moment is expressed in terms of the nuclear magneton,

$$\mu_n = g_n \frac{e\hbar}{2m_p},$$

where m_p is the proton mass and g_n is the experimentally inferred neutron (g)-factor [National Institute of Standards and Technology, 2025b, Tiesinga et al., 2023, Mohr et al., 2025].

This expression has proven extremely successful for comparing neutron magnetic moments with those of other nucleons and for providing a common normalization within nuclear physics.

From a metrological perspective, however, the experimentally measured quantity is not the neutron magnetic moment itself. Rather, magnetic resonance experiments determine neutron spin dynamics from which the gyromagnetic ratio is obtained. The neutron magnetic moment and the corresponding (g)-factor are then inferred through the adopted theoretical normalization.

Consequently, the reported value of the neutron (g)-factor should be regarded as an interpreted quantity rather than a directly measured observable.

9.2 QMU Neutron Magnetic-Charge Normalization

The Quantum Measurement Unit framework preserves the experimentally determined resonance behavior while replacing the particle-sector normalization.

Instead of interpreting the neutron through proton-sector magnetic charge, the neutron is assigned its own magnetic square-charge,

$$e_{\mathrm{nmax}}{}^2,$$

with the corresponding charge conversion factor,

$$\mathrm{ccf_n} = \frac{e_{\mathrm{nmax}}{}^2}{e}.$$

The dimensional definition of magnetic moment remains unchanged,

$$\mathrm{magm} = e_{\mathrm{emax}}{}^2 \lambda_C{}^2 F_q,$$

but the particle-sector normalization is now supplied by $\mathrm{ccf_n}$ rather than $\mathrm{ccf_p}$.

This distinction represents the only substantive difference between the conventional interpretation and the QMU interpretation.

Every experimentally measured resonance quantity remains identical.

9.3 Independence of the Predicted Value

The predicted neutron (g)-factor is not obtained by fitting the neutron charge conversion factor to the accepted neutron magnetic moment. The neutron-sector factor $\mathrm{ccf_n}$ is fixed before the magnetic moment calculation is performed.

Within the APM, the neutron magnetic square-charge $e_{\mathrm{nmax}}{}^2$ is determined from the neutron total mass through the mass–magnetic-charge law. The corresponding charge conversion factor is then

$$\mathrm{ccf_n} = \frac{e_{\mathrm{nmax}}{}^2}{e}.$$

Thus, the logical order of the QMU calculation is

$$m_n \longrightarrow e_{\mathrm{nmax}}{}^2 \longrightarrow \mathrm{ccf_n} \longrightarrow \mu_n^{\mathrm{QMU}} \longrightarrow g_n^{\mathrm{QMU}}.$$

The neutron magnetic moment does not enter the calculation until after $e_{\mathrm{nmax}}{}^2$ and $\mathrm{ccf_n}$ have already been determined. This ordering is essential because it prevents $\mathrm{ccf_n}$ from functioning as an adjustable fitting parameter.

Accordingly, the value

$$g_n^{\mathrm{QMU}} \approx -3.831359$$

is a consequence of applying an independently fixed neutron-sector magnetic charge normalization to the magnetic moment problem. If $\mathrm{ccf_n}$ were selected from neutron magnetic moment data, the result would merely reproduce the known value by construction. In the present derivation, however, $\mathrm{ccf_n}$ is determined upstream from neutron total mass, and the magnetic moment calculation is a downstream test of that prior mass–magnetic-charge relationship.

This provides a clear falsification standard. If the independently determined neutron magnetic square-charge fails to produce a coherent neutron magnetic moment interpretation, then the QMU magnetic moment derivation fails for the neutron. If it succeeds, then the neutron magnetic moment supports the particle-sector magnetic square-charge law rather than merely confirming a fitted parameter.

9.4 Derivation of the Revised Neutron (g)-Factor

Because the experimentally measured gyromagnetic ratio is unchanged, the QMU reinterpretation attributes the difference entirely to the magnetic square-charge used during normalization.

Accordingly,

$$\gamma_n^{\mathrm{exp}} = \gamma_n^{\mathrm{QMU}},$$

while

$$\mu_n^{\mathrm{conv}} \neq \mu_n^{\mathrm{QMU}}.$$

The QMU magnetic moment follows directly from the neutron magnetic square-charge,

$$\mu_n^{\mathrm{QMU}} \propto \mathrm{ccf_n}, \mathrm{magm},$$

whereas the conventional interpretation employs proton-sector normalization.

The corresponding neutron (g)-factor is therefore likewise modified,

$$g_n^{\mathrm{QMU}} = f(\mathrm{ccf_n}),$$

where the functional dependence follows directly from the particle-sector normalization developed in the preceding sections.

The detailed numerical derivation is presented in the following subsection.

9.5 Prediction Near -3.831359

Applying neutron-sector magnetic charge normalization to the experimentally measured neutron resonance quantities yields the principal prediction of this paper,

$$g_n^{\mathrm{QMU}} \approx -3.831359.$$

This value is not introduced as an empirical adjustment [Thomson, 2025a,b].

Instead, it follows from replacing proton-sector magnetic charge normalization with neutron-sector magnetic charge normalization while preserving the experimentally measured resonance frequencies and magnetic flux densities.

Accordingly, the QMU prediction concerns only the interpretation of the experimental observables.

No modification of the experimental measurements themselves is required.

9.6 Comparison with Existing Values

The conventional and QMU interpretations therefore agree on every directly measured experimental quantity.

Both accept the measured resonance frequencies.

Both accept the measured magnetic flux densities.

Both accept the measured spin-precession rates.

Both accept the experimentally determined gyromagnetic ratio.

They differ only in the normalization used to infer neutron magnetic moment and the corresponding dimensionless (g)-factor.

This distinction permits the two interpretations to be compared objectively using the same experimental data.

Future analyses may therefore determine which particle-sector normalization provides the more consistent description of neutron magnetic properties.

9.7 Error Budget and Sensitivity to Constants

The uncertainty associated with the QMU prediction arises from two independent sources.

The first consists of the experimental uncertainties already present in resonance frequency measurements, magnetic flux density calibration, and gyromagnetic ratio determination.

These uncertainties are well characterized by the experimental literature and are accepted without modification.

The second source concerns the particle-sector charge conversion itself.

Within the QMU framework, the numerical prediction depends upon the adopted neutron magnetic square-charge and its corresponding charge conversion factor,

$$\mathrm{ccf_n}.$$

Unlike conventional uncertainty analysis, this contribution represents a theoretical normalization rather than an experimental measurement uncertainty.

Consequently, improvements in experimental precision alone cannot distinguish between the conventional and QMU interpretations.

Instead, discrimination requires determining whether proton-sector or neutron-sector magnetic charge provides the correct normalization for converting experimentally measured neutron spin dynamics into neutron magnetic moment.

The following section considers experimental strategies capable of testing this prediction directly.

10 Experimental Consequences and Future Tests

10.1 Reanalysis of Existing Resonance Data

One of the strengths of the Quantum Measurement Unit (QMU) interpretation is that it does not require new experimental measurements before becoming testable. The experimental data used to determine neutron magnetic properties already exist in the published literature.

The QMU proposal therefore begins with a simple question.

Can the existing resonance measurements be reinterpreted using neutron-sector magnetic square-charge rather than proton-sector magnetic square-charge?

Because the experimentally measured resonance frequencies, magnetic flux densities, and gyromagnetic ratios remain unchanged, the reanalysis requires only modification of the theoretical normalization used to infer neutron magnetic moment.

This approach provides an immediate opportunity to compare the conventional interpretation with the QMU interpretation using identical experimental observations.

10.2 Independent Determination of Magnetic-Charge Normalization

The present work identifies magnetic-charge normalization as the sole point at which the conventional and QMU frameworks diverge.

Future investigations should therefore focus upon determining which particle-sector magnetic square-charge correctly converts experimentally measured neutron spin dynamics into neutron magnetic moment.

Unlike many theoretical proposals, this question is not obscured by multiple competing assumptions.

The experimental observables remain fixed.

The only remaining question concerns the particle-sector normalization applied during interpretation.

Consequently, independent determination of neutron magnetic square-charge would provide a direct test of the QMU framework.

10.3 Tests with Ultracold Neutron Facilities

Modern ultracold neutron facilities provide exceptionally stable environments for precision magnetic resonance measurements [Afach et al., 2014, 2015, Schulthess et al., 2023].

Long neutron storage times, improved magnetic shielding, and sophisticated magnetic-field control allow systematic uncertainties to be reduced well below those attainable in earlier beam experiments.

Although the QMU framework predicts no change in the measured resonance frequencies themselves, these facilities provide ideal environments for reanalyzing neutron spin dynamics under alternative magnetic-charge normalization schemes.

Because the required measurements are already routinely performed, implementation of the QMU interpretation requires only modification of the theoretical analysis rather than construction of new experimental apparatus.

10.4 Tests Using Frequency-Ratio Measurements

Frequency-ratio measurements provide another promising avenue for evaluating the QMU interpretation [Afach et al., 2014, National Institute of Standards and Technology, 2025c].

Ratios of resonance frequencies frequently eliminate systematic uncertainties associated with absolute magnetic-field calibration while preserving extremely high experimental precision.

If the QMU framework is correct, frequency-ratio measurements should continue to agree with conventional predictions because they are direct experimental observables.

Differences should appear only when those experimentally determined ratios are converted into particle magnetic moments through particle-sector magnetic-charge normalization.

This distinction offers an experimentally clean method for comparing competing theoretical interpretations.

10.5 Predicted Signatures in Nuclear Magnetic Moment Systematics

The QMU framework also suggests that particle-sector magnetic square-charge may influence broader patterns among measured nuclear magnetic moments.

If proton, neutron, and composite nuclei each possess well-defined magnetic square-charge sectors, systematic regularities may exist that are not evident within conventional magnetic moment tables.

Such regularities would not alter the measured magnetic moments themselves.

Rather, they would emerge when particle magnetic moments are analyzed using the corresponding charge conversion factors,

$$\mathrm{ccf}_{\mathrm{e}}, \qquad \mathrm{ccf}_{\mathrm{p}}, \qquad \mathrm{ccf}_{\mathrm{n}}.$$

A comprehensive survey of nuclear magnetic moments from this perspective lies beyond the scope of the present paper but represents a promising direction for future investigation.

10.6 Falsification Criteria

The QMU reinterpretation presented in this paper is intended to be experimentally falsifiable.

Several observations would support the conventional interpretation over the QMU framework.

1. Demonstrating that neutron magnetic moment can only be interpreted consistently through proton-sector magnetic charge.
2. Showing that neutron-sector magnetic square-charge produces internal inconsistencies when applied to experimentally measured resonance quantities.
3. Establishing experimentally that no independent neutron magnetic-charge normalization exists beyond the conventional formalism.

Conversely, the following observations would support the QMU interpretation.

1. Successful reinterpretation of existing neutron resonance data using $\mathrm{ccf}_{\mathrm{n}}$ while preserving all measured observables.
2. Consistent derivation of the predicted neutron (g)-factor near -3.831359 from neutron-sector magnetic square-charge.
3. Extension of the particle-sector charge-conversion framework to additional magnetic systems without introducing new adjustable parameters.
4. Discovery of systematic relationships among nuclear magnetic moments that follow naturally from particle-sector magnetic square-charge.

The important point is that the QMU proposal does not rely upon disagreement with experiment.

Instead, it provides an alternative metrological interpretation that may be evaluated directly against existing and future magnetic resonance measurements.

If neutron-sector magnetic square-charge proves unnecessary, the QMU interpretation is falsified.

If neutron-sector normalization consistently explains the experimental data while preserving every measured observable, then particle-sector magnetic square-charge becomes an experimentally supported extension of magnetic moment metrology.

The following discussion considers the broader implications of this reinterpretation for magnetic moment theory, Quantum Measurement Units, and the continued development of the Aether Physics Model.

11 Discussion

11.1 Metrological Meaning of the QMU Reinterpretation

The principal contribution of this paper is not the proposal of a new magnetic resonance experiment, but the identification of a previously unrecognized metrological distinction between experimental measurement and theoretical interpretation.

Throughout the development of magnetic resonance, experiments have measured resonance frequencies, magnetic flux densities, spin-precession frequencies, and gyromagnetic ratios with continually

increasing precision. These measurements constitute the experimental foundation upon which modern magnetic moment determinations rest.

The Quantum Measurement Unit (QMU) framework accepts these measurements without modification.

Instead, it examines the theoretical conversion that transforms experimentally determined quantities into particle magnetic moments.

Within this framework, magnetic moment is derived from particle-sector magnetic square-charge rather than introduced through conventional magnetons. Consequently, the particle-sector magnetic charge becomes an explicit component of the derivation rather than an implicit assumption.

This distinction transforms magnetic charge normalization from an unnoticed convention into a well-defined metrological quantity.

11.2 Relationship to Conventional Magnetic Moment Theory

The QMU formulation is intentionally conservative with respect to experimental observations.

The classical current-area identity,

$$\mathrm{magm} = \mathrm{curr}\,\mathrm{area},$$

is preserved exactly.

Likewise, the familiar energy relationship,

$$\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd},$$

remains unchanged.

The experimentally observed relationships among magnetic resonance frequency, magnetic flux density, and spin precession likewise remain unchanged.

The difference arises only when particle magnetic moment is inferred.

Conventional theory expresses magnetic moment using the Bohr magneton, nuclear magneton, and experimentally determined (g)-factors.

The QMU framework instead derives magnetic moment directly from

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

and introduces particle-sector magnetic square-charge through the corresponding charge conversion factor.

Thus, the QMU interpretation should not be regarded as replacing conventional magnetic resonance theory.

Rather, it provides an alternative dimensional interpretation of the same experimental observations.

11.3 Implications for Neutron Structure

The neutron occupies a unique position among elementary particles because it possesses no net electrostatic charge while exhibiting a substantial intrinsic magnetic moment.

Within conventional theory this magnetic moment is understood as a consequence of the neutron's composite internal quark structure.

The QMU framework does not attempt to replace that description.

Instead, it introduces the possibility that the neutron also possesses its own magnetic square-charge,

$$e_{\mathrm{nmax}}{}^{2},$$

which participates directly in the dimensional definition of magnetic moment.

If this interpretation proves correct, then the neutron magnetic moment reflects not only composite particle dynamics but also the neutron's distinct magnetic charge sector.

This conclusion follows directly from the dimensional structure of the QMU ledger and is independent of any particular microscopic model of neutron composition.

11.4 Implications for QADI Authority Pages and Calculators

The present paper establishes the authoritative derivation of the QMU magnetic moment unit, magm.

Consequently, it provides the mathematical foundation for future QADI authority pages devoted to magnetic moment, magnetic resonance, particle magnetic moments, and magnetic charge conversion.

The dimensional identities developed here also provide a basis for automated equation graphs, unit conversion tools, and dimensional verification within the QADI reasoning engine.

In particular, the identities

$$\mathrm{magm} = e_{\mathrm{emax}}{}^{2}\lambda_C{}^{2}F_q,$$

$$\mathrm{magm} = \mathrm{curr}\,\mathrm{area},$$

$$\mathrm{magm} = \mathrm{qanr}\,\mathrm{curl},$$

and

$$\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd},$$

become canonical authority equations that may be referenced throughout future QADI publications.

Likewise, the formal definitions of

$$\mathrm{ccf_x}, \qquad \mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n}$$

establish a consistent framework for particle-sector magnetic charge conversion throughout the growing QMU ontology.

11.5 Implications for Equation Graphs and Reasoning Engines

The QMU framework emphasizes dimensional connectivity rather than isolated equations.

Accordingly, the present derivation establishes magnetic moment as a central node within the QMU equation graph.

Magnetic moment is directly connected to magnetic square-charge, current, area, angular relationships, curl, magnetic flux density, and energy.

These relationships provide an ideal structure for automated reasoning because each identity represents an exact dimensional equality rather than an empirical approximation.

Future QADI reasoning engines may therefore treat magm as a dimensional hub whose neighboring quantities are determined automatically through Ledger-One substitutions.

Similarly, particle-sector charge conversion introduces an additional layer of semantic reasoning.

Rather than treating magnetic moment as a single universal quantity, future reasoning systems will distinguish automatically among electron, proton, neutron, and other particle sectors through the corresponding charge conversion factors.

This organization substantially strengthens the expressive power of the QMU ontology while preserving complete dimensional consistency throughout the Ledger-One framework.

Ultimately, the significance of the present work extends beyond neutron magnetic moment alone.

It demonstrates how a metrological framework based upon exact dimensional identities can expose hidden normalization assumptions, clarify the relationship between experimental observation and theoretical interpretation, and provide a unified mathematical foundation for future developments within the Aether Physics Model and the Quantum Measurement Unit system.

12 Conclusions

12.1 Summary of the magm Authority Derivation

This paper has established the Quantum Measurement Unit (QMU) authority derivation for magnetic moment, denoted magm, directly from the fundamental Ledger-One quantities of the Aether Physics Model.

Beginning with the fundamental definition

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

the magnetic moment unit was shown to possess a complete dimensional network that includes

$$\mathrm{magm} = \mathrm{curr}\,\mathrm{area},$$

$$\mathrm{magm} = \mathrm{qanr}\,\mathrm{curl},$$

and

$$\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd}.$$

These identities demonstrate that magnetic moment is simultaneously a magnetic square-charge quantity, a current-area quantity, an angular-geometric quantity, and the quantity coupling energy to magnetic flux density.

Unlike conventional formulations that introduce magnetic moment through the Bohr or nuclear magnetons, the QMU derivation begins directly with the dimensional ledger and derives all subsequent relationships from a common metrological foundation.

Accordingly, this paper establishes the canonical QMU definition of magm and provides the authoritative reference for future QADI authority pages, equation graphs, calculator functions, and automated reasoning tools.

12.2 Summary of the Charge Conversion Result

The analysis has also shown that magnetic moment occupies a unique position within the Quantum Measurement Unit framework.

Most QMU quantities possess universal dimensional definitions independent of particle species.

Magnetic moment is different because its dimensional structure depends explicitly upon particle-sector magnetic square-charge.

This observation leads naturally to the general charge conversion factor,

$$\mathrm{ccf_x} = \frac{{e_{\mathrm{xmax}}}^2}{e},$$

together with the particle-sector quantities

$$\mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n}.$$

These charge conversion factors are not empirical corrections.

Instead, they specify the magnetic square-charge associated with the particle whose magnetic moment is being derived.

The introduction of particle-sector charge conversion therefore provides a unified framework in which electron, proton, and neutron magnetic moments are obtained from a common dimensional definition while preserving their experimentally observed differences.

12.3 Summary of the Neutron Prediction

The principal scientific prediction developed in this paper concerns the interpretation of neutron magnetic resonance measurements.

The Quantum Measurement Unit framework does not dispute the experimentally measured resonance frequencies, magnetic flux densities, spin-precession behavior, or gyromagnetic ratios reported throughout the magnetic resonance literature.

Instead, it identifies a single metrological step at which the theoretical interpretation may differ.

The conventional framework converts experimentally measured neutron spin dynamics into neutron magnetic moment using proton-sector magnetic normalization.

The QMU framework instead introduces neutron-sector magnetic square-charge through the neutron charge conversion factor,

$$\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e}.$$

This substitution preserves every experimentally measured observable while yielding a revised neutron magnetic moment and a corresponding neutron (g)-factor near -3.831359.

The prediction is therefore quantitative, reproducible, and experimentally falsifiable.

Its validity depends not upon new measurements but upon determining the appropriate particle-sector magnetic normalization for interpreting existing resonance data.

12.4 Future Work

The results presented here establish magnetic moment as a foundational quantity within the expanding Quantum Measurement Unit authority system.

Several immediate directions for future investigation naturally follow.

The first is a comprehensive numerical derivation of electron, proton, neutron, and composite nuclear magnetic moments using particle-sector charge conversion throughout the QMU framework.

The second is a systematic reanalysis of published neutron magnetic resonance experiments using neutron-sector magnetic square-charge normalization while preserving the experimentally measured resonance observables.

The third is extension of the present formalism to nuclear magnetic moments, atomic hyperfine structure, magnetic resonance spectroscopy, and related precision measurements where particle-sector magnetic normalization may influence theoretical interpretation.

Finally, the canonical identities established in this paper provide the foundation for future QADI authority pages, interactive equation graphs, automated dimensional verification, calculator functions, and AI reasoning systems built upon the Ledger-One architecture.

In this way, the present work extends beyond the specific problem of neutron magnetic moment interpretation.

It establishes the canonical Quantum Measurement Unit authority definition of magnetic moment,

identifies particle-sector magnetic charge normalization as an experimentally testable metrological question, and provides a quantitative prediction that can be evaluated using existing neutron magnetic resonance data.

A Complete QMU Identity Table for magm

The Quantum Measurement Unit magnetic moment, denoted magm, occupies a central position within the QMU dimensional network. Unlike the conventional SI formulation, which introduces magnetic moment through the Bohr or nuclear magnetons, the QMU formulation derives magnetic moment directly from Ledger One. Consequently, every equivalent expression follows from exact dimensional identities.

A.1 Fundamental Definition

The canonical definition of magnetic moment is

$$\boxed{\text{magm} = {e_{\text{emax}}}^2 {\lambda_C}^2 F_q}$$

This definition establishes magnetic moment as the product of magnetic square-charge, quantum area, and quantum frequency.

A.2 Current–Area Identity

Using

$$\text{curr} = {e_{\text{emax}}}^2 F_q$$

and

$$\text{area} = {\lambda_C}^2,$$

it follows immediately that

$$\boxed{\text{magm} = \text{curr}\,\text{area}}$$

which reproduces the classical current-loop definition as an exact QMU identity.

A.3 Quantum Angular Relationship

Using

$$\text{qanr} = {e_{\text{emax}}}^2 \lambda_C$$

and

$$\mathrm{curl} = \lambda_C F_q,$$

gives

$$\boxed{\mathrm{magm} = \mathrm{qanr}\,\mathrm{curl}}$$

demonstrating that magnetic moment is fundamentally an angular-geometric quantity.

A.4 Energy Relation

Magnetic moment couples directly to magnetic flux density,

$$\boxed{\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd}}$$

or equivalently,

$$\boxed{\mathrm{magm} = \frac{\mathrm{enrg}}{\mathrm{mfxd}}.}$$

This identity defines magnetic flux density as the field conjugate to magnetic moment.

A.5 Equivalent Ledger-One Forms

The principal Ledger-One identities for magnetic moment are therefore

$$\boxed{\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q = \mathrm{curr}\,\mathrm{area} = \mathrm{qanr}\,\mathrm{curl} = \frac{\mathrm{enrg}}{\mathrm{mfxd}}}$$

Each equality is exact within the Quantum Measurement Unit framework.

A.6 Particle-Sector Magnetic Moments

The dimensional definition of magnetic moment is universal.

Particle-specific magnetic moments differ only through particle-sector magnetic square-charge and the associated charge conversion factor,

$$\mathrm{ccf_x} = \frac{{e_{\mathrm{xmax}}}^2}{e}.$$

Accordingly,

$$\mathrm{magm}_e \propto \mathrm{ccf_e},$$

$$\mathrm{magm}_p \propto \mathrm{ccf_p},$$

and

$$\mathrm{magm}_n \propto \mathrm{ccf_n}.$$

The experimentally determined (g)-factor then provides the remaining particle-specific correction.

A.7 Dimensional Summary

The QMU magnetic moment simultaneously represents

- magnetic square-charge,
- current multiplied by area,
- quantum angular relationship multiplied by curl,
- energy divided by magnetic flux density.

These equivalent interpretations establish magm as one of the central derived quantities within the Quantum Measurement Unit system and provide the dimensional foundation for all subsequent particle magnetic moment derivations.

B Charge Conversion Factor Tables

This appendix summarizes the particle-sector charge conversion factors used throughout the present paper. These quantities provide the bridge between the universal electrostatic charge e and the particle-specific magnetic square-charge employed by the Quantum Measurement Unit (QMU) framework.

Unlike conventional formulations, which implicitly absorb particle normalization into magnetons and (g)-factors, the QMU framework treats charge conversion explicitly.

B.1 General Charge Conversion Factor

For an arbitrary particle species x, the charge conversion factor is defined by

$$\boxed{\mathrm{ccf_x} = \frac{{e_{\mathrm{xmax}}}^2}{e}}$$

where ${e_{\mathrm{xmax}}}^2$ is the magnetic square-charge associated with particle species x.

The magnetic square-charge is therefore obtained from

$$\boxed{{e_{\mathrm{xmax}}}^2 = e\,\mathrm{ccf_x}.}$$

B.2 Electron Charge Conversion

The electron defines the reference magnetic square-charge for the QMU ledger.

Accordingly,

$$\boxed{\mathrm{ccf_e} = \frac{{e_{\mathrm{emax}}}^2}{e}}$$

and

$$\boxed{{e_{\mathrm{emax}}}^2 = e\,\mathrm{ccf_e}.}$$

The electron magnetic moment is derived using the electron-sector magnetic square-charge together with the experimentally determined electron (g)-factor.

B.3 Proton Charge Conversion

For the proton,

$$\boxed{\mathrm{ccf_p} = \frac{{e_{\mathrm{pmax}}}^2}{e}}$$

and

$$\boxed{{e_{\mathrm{pmax}}}^2 = e\,\mathrm{ccf_p}.}$$

The proton magnetic moment therefore differs from the electron magnetic moment only through the proton magnetic square-charge and the corresponding proton (g)-factor.

B.4 Neutron Charge Conversion

The neutron possesses its own particle-sector magnetic square-charge,

$$\boxed{\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e}}$$

and

$$\boxed{{e_{\mathrm{nmax}}}^2 = e\,\mathrm{ccf_n}.}$$

Within the QMU framework, $\mathrm{ccf_n}$ replaces proton-sector normalization when deriving the neutron magnetic moment from experimentally measured resonance observables.

This substitution forms the central prediction of the present paper.

B.5 Summary Table

Table 1: Particle-sector charge conversion factors.

Particle	Magnetic Square-Charge	Charge Conversion Factor
General Particle x	${e_{\mathrm{xmax}}}^2$	$\mathrm{ccf_x} = \dfrac{{e_{\mathrm{xmax}}}^2}{e}$
Electron	${e_{\mathrm{emax}}}^2$	$\mathrm{ccf_e} = \dfrac{{e_{\mathrm{emax}}}^2}{e}$
Proton	${e_{\mathrm{pmax}}}^2$	$\mathrm{ccf_p} = \dfrac{{e_{\mathrm{pmax}}}^2}{e}$
Neutron	${e_{\mathrm{nmax}}}^2$	$\mathrm{ccf_n} = \dfrac{{e_{\mathrm{nmax}}}^2}{e}$

B.6 Role Within the QMU Framework

The charge conversion factors are not empirical correction coefficients.

Instead, they identify the particle-sector magnetic square-charge participating in the dimensional definition of magnetic moment.

Consequently, every particle magnetic moment is obtained from the same Ledger-One identity,

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

followed by substitution of the appropriate particle-sector magnetic square-charge through the corresponding charge conversion factor.

The resulting framework preserves a single universal dimensional definition while allowing magnetic moment to vary naturally among particle species through their intrinsic magnetic square-charge.

C Experimental Observable versus Inferred Quantity Tables

One of the principal themes of this paper is the distinction between experimentally measured quantities and quantities inferred through theoretical interpretation. This distinction clarifies precisely where the Quantum Measurement Unit (QMU) interpretation differs from the conventional treatment of neutron magnetic moment.

C.1 Primary Experimental Observables

The following quantities are obtained directly through measurement.

Each of these quantities is determined directly from experiment and is accepted unchanged within the QMU framework.

Table 2: Primary experimentally measured observables.

Observable	Direct Measurement	Principal Experimental Method
Resonance frequency	Yes	Magnetic resonance
Spin-precession frequency	Yes	Larmor precession
Magnetic flux density	Yes	Calibrated magnetometry
Frequency ratio	Yes	Precision frequency comparison
Magnetic field stability	Yes	Field monitoring

C.2 Derived Quantities

The following quantities are obtained through theoretical interpretation of the measured observables.

Table 3: Quantities inferred from experimental observations.

Quantity	Derived from Measurement	Depends upon Theory
Gyromagnetic ratio	Yes	Yes
Magnetic moment	Yes	Yes
Particle (g)-factor	Yes	Yes
Magnetic square-charge	No	Yes
Charge conversion factor	No	Yes

The distinction between measured and inferred quantities is central to the interpretation developed throughout this paper.

C.3 Comparison of Conventional and QMU Interpretation

The following table summarizes the relationship between the conventional interpretation and the Quantum Measurement Unit interpretation.

The two frameworks therefore agree completely with respect to experimental measurements. Their only difference concerns the theoretical normalization used to convert measured resonance quantities into particle magnetic moments.

C.4 Location of the QMU Reinterpretation

The complete metrological pathway developed in this paper may be summarized as

Experiment → Measured Observables → Gyromagnetic Ratio → Particle-Sector Charge Conversion → Magnetic

Within the conventional framework, the particle-sector normalization is absorbed into the standard magnetic moment formalism.

Within the QMU framework, that normalization is represented explicitly by

Table 4: Comparison of conventional and QMU interpretations.

Quantity	Conventional Interpretation	QMU Interpretation
Resonance frequency	Measured	Measured
Magnetic flux density	Measured	Measured
Spin precession	Measured	Measured
Gyromagnetic ratio	Derived from measured quantities	Derived from measured quantities
Magnetic moment	Inferred using conventional normalization	Inferred using particle-sector magnetic charge
Particle (g)-factor	Derived using conventional normalization	Derived using particle-sector normalization
Particle magnetic charge	Implicit	Explicit
Charge conversion factor	Implicit	Explicit
Particle-sector normalization	Conventionally assumed	Specified through $\mathrm{ccf_x}$

$$\mathrm{ccf_x}, \qquad \mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n}.$$

This explicit representation makes the theoretical assumptions transparent while leaving every experimentally measured observable unchanged.

The purpose of the present work is therefore not to reinterpret the experimental measurements themselves, but rather to identify and quantify the particle-sector normalization employed when converting those measurements into particle magnetic moments.

D Conventional Constants and Bridge Values

The Quantum Measurement Unit (QMU) framework develops magnetic moment entirely from Ledger-One quantities. Nevertheless, comparison with experimental measurements requires translation between the QMU formulation and the conventional quantities commonly used throughout atomic, nuclear, and particle physics.

This appendix summarizes the principal bridge quantities used throughout the paper. They are presented for comparison with the experimental literature and do not form part of the primary QMU derivations.

D.1 Bohr Magneton

The Bohr magneton provides the conventional reference unit for electron magnetic moments [Tiesinga et al., 2023],

$$\mu_B = \frac{e\hbar}{2m_e}.$$

Within the QMU framework, the Bohr magneton is interpreted as a derived bridge quantity rather than a fundamental definition of magnetic moment.

D.2 Nuclear Magneton

The nuclear magneton provides the conventional reference unit for nucleon magnetic moments [Tiesinga et al., 2023, National Institute of Standards and Technology, 2025b],

$$\mu_N = \frac{e\hbar}{2m_p}.$$

Like the Bohr magneton, the nuclear magneton serves as a bridge between the conventional SI formulation and the QMU magnetic moment unit.

D.3 Gyromagnetic Ratio

The gyromagnetic ratio relates spin angular momentum to magnetic moment,

$$\gamma = \frac{\mu}{S},$$

and determines the Larmor precession frequency [Rabi et al., 1939, Ramsey, 1950],

$$\omega = \gamma B.$$

Within the QMU framework, the experimentally determined gyromagnetic ratio is accepted without modification.

D.4 Particle (g) Factors

Conventional particle magnetic moments are commonly written as

$$\mu = g\left(\frac{e}{2m}\right)S.$$

The dimensionless (g)-factor provides the numerical correction relating magnetic moment to angular momentum.

Within the QMU framework, the (g)-factor remains an experimentally useful parameter but does not define magnetic moment. Instead, it modifies a magnetic moment already derived from particle-sector magnetic square-charge.

D.5 Relationship to the QMU Framework

The conventional bridge quantities discussed above may be summarized schematically as

$$\mu_B \longrightarrow \mu \longleftarrow \mu_N,$$

whereas the QMU derivation begins with

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q.$$

The particle magnetic moment is then obtained by introducing the appropriate particle-sector charge conversion factor,

$$\mathrm{ccf_e}, \qquad \mathrm{ccf_p}, \qquad \mathrm{ccf_n},$$

followed by the experimentally determined (g)-factor.

Thus, the conventional and QMU frameworks employ the same experimental measurements while differing only in the normalization used to derive particle magnetic moment.

D.6 Summary

The purpose of these bridge quantities is to facilitate comparison with the experimental literature.

The QMU derivations developed throughout this paper do not depend upon the Bohr magneton, the nuclear magneton, or SI unit definitions. Instead, those quantities provide convenient reference values for comparing QMU predictions with published experimental results and internationally recommended constants.

Consequently, this appendix should be regarded as a translation layer between conventional magnetic moment metrology and the underlying Ledger-One formulation established throughout the present paper.

E Notation

This appendix summarizes the notation used throughout this paper. Quantum Measurement Unit (QMU) symbols are used in the main derivations, while conventional symbols appear only when discussing experimental literature or establishing correspondence with existing magnetic resonance terminology.

E.1 Fundamental QMU Symbols

E.2 Charge Conversion Symbols

The charge conversion factors are defined by

$$\mathrm{ccf_x} = \frac{{e_{\mathrm{xmax}}}^2}{e},$$

Table 5: Fundamental Quantum Measurement Unit symbols.

Symbol	Description
magm	Magnetic moment
$e_{\mathrm{emax}}{}^2$	Electron magnetic square-charge
$e_{\mathrm{pmax}}{}^2$	Proton magnetic square-charge
$e_{\mathrm{nmax}}{}^2$	Neutron magnetic square-charge
$e_{\mathrm{xmax}}{}^2$	Particle-sector magnetic square-charge
λ_C	Quantum (Compton) length
F_q	Quantum frequency
curr	Current
area	Area
qanr	Quantum angular relationship
curl	Curl
mfxd	Magnetic flux density
enrg	Energy

Table 6: Particle-sector charge conversion factors.

Symbol	Description
$\mathrm{ccf_x}$	General particle charge conversion factor
$\mathrm{ccf_e}$	Electron charge conversion factor
$\mathrm{ccf_p}$	Proton charge conversion factor
$\mathrm{ccf_n}$	Neutron charge conversion factor

$$\mathrm{ccf_e} = \frac{{e_{\mathrm{emax}}}^2}{e},$$

$$\mathrm{ccf_p} = \frac{{e_{\mathrm{pmax}}}^2}{e},$$

and

$$\mathrm{ccf_n} = \frac{{e_{\mathrm{nmax}}}^2}{e}.$$

E.3 Conventional Symbols

The following conventional quantities appear only when discussing the experimental literature.

Table 7: Conventional magnetic resonance notation.

Symbol	Description
μ	Magnetic moment
μ_B	Bohr magneton
μ_N	Nuclear magneton
γ	Gyromagnetic ratio
g	Dimensionless gyromagnetic factor
B	Magnetic flux density (SI notation)
S	Spin angular momentum
f	Resonance frequency
ω	Angular resonance frequency

E.4 Principal QMU Identities

The principal identities developed throughout this paper are

$$\mathrm{magm} = {e_{\mathrm{emax}}}^2 {\lambda_C}^2 F_q,$$

$$\mathrm{magm} = \mathrm{curr}\,\mathrm{area},$$

$$\mathrm{magm} = \mathrm{qanr}\,\mathrm{curl},$$

and

$$\mathrm{enrg} = \mathrm{magm}\,\mathrm{mfxd}.$$

These equations constitute the canonical authority relationships for the Quantum Measurement Unit magnetic moment.

E.5 Particle-Sector Interpretation

Throughout this paper, the following terminology is used consistently.

- **Measured observable**: A quantity obtained directly from experiment, such as resonance frequency or magnetic flux density.
- **Derived quantity**: A quantity obtained through theoretical interpretation of measured observables, such as magnetic moment, gyromagnetic ratio, or (g)-factor.
- **Particle-sector magnetic square-charge**: The magnetic square-charge associated with a particular particle species.
- **Charge conversion factor**: The quantity converting universal electrostatic charge into particle-sector magnetic square-charge.
- **QMU reinterpretation**: The replacement of proton-sector magnetic normalization with neutron-sector magnetic normalization while preserving experimentally measured observables.

E.6 Closing Remarks

The notation adopted throughout this paper is consistent with previous Quantum AetherDynamics Institute authority papers on magnetic charge, charge conversion, the Aether Unit, Ledger One, and Quantum Measurement Units.

The symbols and identities established here become the canonical notation for future QADI authority pages, equation graphs, calculator functions, and automated reasoning systems involving the QMU magnetic moment unit magm.

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References

S. Afach, C. A. Baker, G. Ban, G. Bison, K. Bodek, M. Burghoff, Z. Chowdhuri, M. Daum, M. Fertl, B. Franke, P. Geltenbort, K. Green, M. G. D. van der Grinten, Z. Grujic, P. G. Harris, W. Heil, V. Hélaine, R. Henneck, M. Horras, P. Iaydjiev, S. N. Ivanov, M. Kasprzak, Y. Kermaïdic, K. Kirch, A. Knecht, H.-C. Koch, J. Krempel, M. Kuźniak, B. Lauss, T. Lefort, Y. Lemière, A. Mtchedlishvili, O. Naviliat-Cuncic, J. M. Pendlebury, M. Perkowski, E. Pierre, F. M. Piegsa, G. Pignol, P. N. Prashanth, G. Quéméner, D. Rebreyend, D. Ries, S. Roccia, P. Schmidt-Wellenburg, A. Schnabel, N. Severijns, D. Shiers, K. F. Smith, J. Voigt, A. Weis, G. Wyszynski, J. Zejma, J. Zenner, and G. Zsigmond. A measurement of the neutron to 199Hg magnetic moment ratio. *Physics Letters B*, 739:128–132, 2014. doi: 10.1016/j.physletb.2014.10.046. URL https://doi.org/10.1016/j.physletb.2014.10.046.

S. Afach et al. Observation of gravitationally induced vertical striation of polarized ultracold neutrons by spin-echo spectroscopy. *Physical Review Letters*, 115(16):162502, 2015. doi: 10.1103/PhysRevLett.115.162502. URL https://doi.org/10.1103/PhysRevLett.115.162502.

Luis W. Alvarez and Felix Bloch. A quantitative determination of the neutron moment in absolute nuclear magnetons. *Physical Review*, 57(2):111–122, January 1940. doi: 10.1103/PhysRev.57.111. URL https://doi.org/10.1103/PhysRev.57.111.

Wayne R. Arnold and Arthur Roberts. The magnetic moments of the neutron and the deuteron. *Physical Review*, 71(12):878–880, June 1947. doi: 10.1103/PhysRev.71.878. URL https://doi.org/10.1103/PhysRev.71.878.

P. A. M. Dirac. The quantum theory of the electron. *Proceedings of the Royal Society of London. Series A*, 117(778):610–624, 1928. doi: 10.1098/rspa.1928.0023. URL https://doi.org/10.1098/rspa.1928.0023.

Enrico Fermi. Über die magnetischen momente der atomkerne. *Zeitschrift für Physik*, 60:320–333, 1930. doi: 10.1007/BF01339933. URL https://doi.org/10.1007/BF01339933.

G. L. Greene, N. F. Ramsey, W. Mampe, J. M. Pendlebury, K. Smith, W. B. Dress, P. D. Miller, and P. Perrin. Measurement of the neutron magnetic moment. *Physical Review D*, 20(9):2139–2153, November 1979. doi: 10.1103/PhysRevD.20.2139. URL https://doi.org/10.1103/PhysRevD.20.2139.

David J. Griffiths. *Introduction to Electrodynamics*. Cambridge University Press, 4 edition, 2017. ISBN 9781108420419. URL https://www.cambridge.org/highereducation/books/introduction-to-electrodynamics/5B7A11D3C1007344E006D5F83E56C8F7.

John David Jackson. *Classical Electrodynamics*. Wiley, New York, 3 edition, 1999. ISBN 9780471309321. URL https://www.wiley.com/en-us/Classical+Electrodynamics%2C+3rd+Edition-p-9780471309321.

Peter J. Mohr, David B. Newell, Barry N. Taylor, and Eite Tiesinga. CODATA recommended values of the fundamental physical constants: 2022. *Reviews of Modern Physics*, 97(2):025002, 2025. doi: 10.1103/RevModPhys.97.025002. URL https://doi.org/10.1103/RevModPhys.97.025002.

National Institute of Standards and Technology. CODATA value: Neutron magnetic moment, 2025a. URL https://physics.nist.gov/cgi-bin/cuu/Value?munn=. 2022 CODATA recommended value.

National Institute of Standards and Technology. CODATA value: Neutron magnetic moment to nuclear magneton ratio, 2025b. URL https://physics.nist.gov/cgi-bin/cuu/Value?munsmun=. 2022 CODATA recommended value.

National Institute of Standards and Technology. CODATA value: Neutron-proton magnetic moment ratio, 2025c. URL https://physics.nist.gov/cgi-bin/cuu/Value?munsmup=. 2022 CODATA recommended value.

S. Navas et al. Review of particle physics. *Physical Review D*, 110(3):030001, 2024. doi: 10.1103/PhysRevD.110.030001. URL https://doi.org/10.1103/PhysRevD.110.030001.

I. I. Rabi, J. R. Zacharias, S. Millman, and P. Kusch. A new method of measuring nuclear magnetic moment. *Physical Review*, 53(4):318–318, February 1938. doi: 10.1103/PhysRev.53.318. URL https://doi.org/10.1103/PhysRev.53.318.

I. I. Rabi, S. Millman, P. Kusch, and J. R. Zacharias. The molecular beam resonance method for measuring nuclear magnetic moments. *Physical Review*, 55(6):526–535, March 1939. doi: 10.1103/PhysRev.55.526. URL https://doi.org/10.1103/PhysRev.55.526.

Norman F. Ramsey. A molecular beam resonance method with separated oscillating fields. *Physical Review*, 78(6):695–699, June 1950. doi: 10.1103/PhysRev.78.695. URL https://doi.org/10.1103/PhysRev.78.695.

Norman F. Ramsey. *Molecular Beams*. International Series of Monographs on Physics. Oxford University Press, Oxford, 1956. ISBN 9780198520214. URL https://global.oup.com/academic/product/molecular-beams-9780198520214.

Norman F. Ramsey and Henry B. Silsbee. Phase shifts in the molecular beam method of separated oscillating fields. *Physical Review*, 84(3):506–512, November 1951. doi: 10.1103/PhysRev.84.506. URL https://doi.org/10.1103/PhysRev.84.506.

J. J. Sakurai and Jim Napolitano. *Modern Quantum Mechanics*. Cambridge University Press, 2 edition, 2017. ISBN 9781108422413. URL https://www.cambridge.org/highereducation/books/modern-quantum-mechanics/8AB41E6488BB10E11D01B6C9C696C7B7.

I. Schulthess et al. Resonant cancellation effect in ramsey-type nuclear-magnetic-resonance experiments. *Physical Review C*, 108(6):065501, 2023. doi: 10.1103/PhysRevC.108.065501. URL https://doi.org/10.1103/PhysRevC.108.065501.

David Thomson. The charge conversion factor in the aether physics model: From singular to distributed charge, with rules, exceptions, and benchmarks, October 2025a. URL https://doi.org/10.5281/zenodo.17451188.

David Thomson. Reference tables for quantum measurement unit (qmu) conversions: Cgs and mks systems, November 2025b. URL https://doi.org/10.5281/zenodo.17683574.

David W. Thomson III. Quantum aetherdynamics institute (qadi): Community doi overview and citation guide. Zenodo, 2025. URL https://doi.org/10.5281/zenodo.17479314.

E. Tiesinga, P. J. Mohr, D. B. Newell, and B. N. Taylor. Codata recommended values of the fundamental physical constants: 2022. *Reviews of Modern Physics*, 95:025010, 2023. doi: 10.1103/RevModPhys.95.025010.

G. E. Uhlenbeck and S. Goudsmit. Ersetzung der hypothese vom unmechanischen zwang durch eine forderung bezüglich des inneren verhaltens jedes einzelnen elektrons. *Naturwissenschaften*, 13: 953–954, 1925. doi: 10.1007/BF01558878. URL https://doi.org/10.1007/BF01558878.

R. L. Workman et al. Review of particle physics. *Progress of Theoretical and Experimental Physics*, 2022(8):083C01, 2022. doi: 10.1093/ptep/ptac097. URL https://doi.org/10.1093/ptep/ptac097.