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A Geometric Model for the Proton and Neutron

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Abstract

This work, building upon T.N. Lockyer's *Vector Particle Physics* (1992), presents a simplified geometric model for the proton and neutron, enabling the calculation of the proton-to-electron mass ratio (m_p/m_e) with remarkable accuracy of seven significant digits ($m_p/m_e \approx 1836.1521964$, relative error -2.6×10^{-7}) compared to the CODATA value of 1836.15267343. The neutron-to-electron mass ratio ($m_n/m_e \approx 1838.68982960$, error 3.35×10^{-6}) yields six significant digits.

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1. Introduction

Quantum Chromodynamics (QCD) describes nucleon masses through quark-gluon interactions, at the cost of significant computational complexity. *Vector Particle Physics* by Thomas N. Lockyer [1] proposes nucleons based on leptons, whose masses originate from the momentum of photons trapped in a layered structure of increasing energies nested like Russian dolls. This article formalizes and simplifies Lockyer's model by eliminating a corrective term, deemed unnecessary and ad hoc, inspired by quantum electrodynamics (QED). This simplification improves the accuracy of the proton-to-electron mass ratio calculation from six to seven significant digits.

2. Brief Description of Lockyer's Model

Lockyer's model conceptualizes the positron as a cube whose edges have a length based on the reduced Compton wavelength ($\lambda'_e = \hbar/(m_e c) \approx 3.8615932 \times 10^{-13}$ m). The proton is modeled as a positron (level 0) containing 18 nested energy layers (levels 1–18). The edge of the positron 'cube' has a length shortened by a factor deduced from the electron's magnetic moment, using only physical constants. For the complete description of Lockyer's original model, refer to the bibliography [1,2].

Projected onto a plane perpendicular to the rotation axis giving the magnetic moment, the cube appears as a square. Each 'square' of the inner layers is inscribed with a 45° rotation relative to its containing square, and consequently sees its dimensions reduced by a factor of $\sqrt{2}$:

$$L_{\text{inner}} = \frac{L_{\text{outer}}}{\sqrt{2}}. \tag{1}$$

The rest mass originates from the momentum of photons ($p = h/\lambda$) confined in the rotating layers, with energy contributions:

$$m = \frac{e^2}{m_e 4\pi c^2 \lambda'_e d\epsilon_0}, \quad d = \frac{1-\sqrt{2}/2}{2} - \frac{a_u}{\sqrt{2}}, \quad a_u = 2\left(\sqrt{1+\frac{\alpha}{2\pi}} - 1\right). \tag{2}$$

The mass contributions per level i (1 to 19) are:

$$m_1[i] = \frac{(\sqrt{2})^{i-1}}{1-\sqrt{2}a_u}, \quad m_2[i] = m \cdot \frac{(\sqrt{2})^{i-1}}{1-\sqrt{2}a_u}. \tag{3}$$

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The neutron, in turn, adds an electron (mass m_e, charge $-e$) sharing level 0 with the positron (mass m_e, charge $+e$), and doubles the energy of level 1.

3. Calculations

The proton mass ratio is:

$$m_p/m_e = \sum_{i=1}^{19}(m_1[i] + m_2[i]). \tag{4}$$

The neutron mass ratio includes the doubling of the first two levels:

$$m_n/m_e = \sum_{i=1}^{19}(m_1[i] + m_2[i]) + \sum_{i=1}^{2}(m_1[i] + m_2[i]). \tag{5}$$

Implementation details are in Appendix A.

4. Results and Discussion

The JavaScript implementation yields:

- Proton: $m_p/m_e = 1836.1521964$, error -2.6×10^{-7} relative to CODATA 1836.15267343 (seven significant digits).
- Neutron: $m_n/m_e = 1838.6898296$, error 3.35×10^{-6} relative to CODATA 1838.68366173 (six significant digits).

_-_ Calculation of the proton/electron mass ratio _-_

Level	m1	m2	m1+m2	Sum
1	1.000000	0.050110	1.050110	1.050110
2	1.416540	0.070983	1.487523	2.537633
3	2.003289	0.100386	2.103675	4.641308
4	2.833079	0.141967	2.975046	7.616354
5	4.006579	0.200771	4.207350	11.823704
6	5.666158	0.283933	5.950091	17.773795
7	8.013158	0.401542	8.414700	26.188495
8	11.332316	0.567867	11.900183	38.088678
9	16.026315	0.803085	16.829400	54.918078
10	22.664632	1.135733	23.800365	78.718443
11	32.052631	1.606169	33.658800	112.377243
12	45.329265	2.271466	47.600731	159.977974
13	64.105261	3.212338	67.317599	227.295573
14	90.658530	4.542932	95.201462	322.497035
15	128.210522	6.424676	134.635199	457.132234
16	181.317059	9.085864	190.402924	647.535157
17	256.421045	12.849353	269.270397	916.805554
18	362.634119	18.171729	380.805848	1297.611402
19	512.842089	25.698705	538.540794	1836.152196

Calculated proton/electron mass ratio : 1836.15219639
--- Official proton/electron mass ratio : 1836.15267343 (CODATA 2020)
Relative error = -2.60e-7 = -0.00000026 = -0.000026%

Calculated neutron/electron mass ratio : 1838.68982960
--- Official neutron/electron mass ratio : 1838.683662 (CODATA 2020)
Relative error = 3.35e-6 = 0.00000335 = 0.000335%

Figure 1. JavaScript code result, showing mass contributions per level.

Note: The contribution of each line $(m_1[i] + m_2[i])$ is exactly equal to the previous one multiplied by $\sqrt{2}$.

5. Implications and Future Work

The model's accuracy, **using only fundamental constants and a factor of $\sqrt{2}$**, suggests a physical basis. The geometric structure of this model is an idealization and is not the most important aspect to retain, as other structures, and other theoretical explanations, could lead to this same calculation. What should be thought-provoking is that a very simple calculation, using only physical constants and no ad hoc parameters, can achieve a result of extreme accuracy. This simplicity indicates to us that the complexity of our models might emerge from an underlying, simpler physics.

Furthermore, the model's inclusion of an electron-like contribution in the neutron's first layer opens the possibility of exploring links with the strong force that binds nucleons, but such an extension requires further theoretical development.

Future work should:

- Explore a semi-classical approximation of the strong force.
- Derive the condition for the 18 nested energy levels.
- Explain the energy ratio of $\sqrt{2}$ between successive levels.
- Attempt to extend the model to calculate the masses of the muon and tauon.

6. Conclusion

QCD has long proven its computational capabilities. Lockyer's model, favoring electromagnetic interactions based on photons, without reference to quarks, raises questions and invites us to push reflection further to reconcile the two approaches.

Appendix A. JavaScript Implementation

The following code calculates m_p/m_e and m_n/m_e:

```
// Fundamental physical constants (CODATA 2020)
// Speed of light (m/s)
const lightSpeed = 299792458;
// Fine structure constant - dimensionless
const fineStructureConstant = 0.00729735257
const pi = Math.PI;
// Vacuum magnetic permeability
// (Henry per meter: H/m  [N/A^2])
const vacuumPermeability = 4*pi / Math.pow(10,7);
// Vacuum permittivity (8.8541878176 * 10^-12 F/m)
const vacuumPermittivity = 1 / (lightSpeed * lightSpeed * vacuumPermeability);
// Electron charge (A*s)
const electronCharge = 1.602176634 * Math.pow(10,-19);
// Compton wavelength (m)
const comptonWavelength = 2.4263102367 * Math.pow(10,-12);
// Reduced Compton wavelength of the electron (m)
const rationalizedComptonWavelength = comptonWavelength/(2*pi);
// Electron mass (kg)
const electronMass = 9.1093837015 * Math.pow(10,-31);
// Relative electron mass;
const relativeElectronMass = 1;
const sqrt2 = Math.sqrt(2);
const codataProton = 1836.15267343;
const codataNeutron = 1838.683662;

// Reduced fine structure constant
const rationalizedFineStructure = fineStructureConstant/(2*pi);
const scalingfactor = 2 * (Math.sqrt(1 + rationalizedFineStructure) - 1);
// The radius of each level is slightly smaller
const layerSpacing = (1-(sqrt2/2))/2 - scalingfactor/sqrt2;
```

```
var scallingContribution = Math.pow(electronCharge,2)/(electronMass * 4 * pi *
    Math.pow(lightSpeed,2) * rationalizedComptonWavelength * layerSpacing *
    vacuumPermittivity);

document.write ("<table>");
document.write ("<th colspan=5 style='text-align:center;'>_-_   Calculation of the
    proton/electron mass ratio   _-_ </th>");
document.write ("<tr><td>Level</td><td>m1</td><td>m2</td><td>m1+m2</td>
    <td>Sum</td></tr>");

var m1 = new Array(); var m2 = new Array();
m1[1] = relativeElectronMass; m2[1] = scallingContribution;
var totalMass=0;
const denominator = 1-sqrt2*scalingfactor;

// Performs calculations and displays
for(i=1;i<=19;i++){
    m1[i+1]= relativeElectronMass * Math.pow(sqrt2,i) / denominator;
    m2[i+1]= scallingContribution * Math.pow(sqrt2,i) / denominator;
    totalMass += m1[i] + m2[i];
    document.write ("<tr><td>" + i + "</td><td>" +
    m1[i].toFixed(6) + "</td><td>" +
    m2[i].toFixed(6) + "</td><td>" +
    eval(m1[i]+m2[i]).toFixed(6) + "</td><td>" +
    totalMass.toFixed(6) + "</td></tr>");
}
document.write ("</table>");

document.write ("<br>Calculated proton/electron mass ratio: "+ totalMass.toFixed(8)+ "
    <br>--- Official proton/electron mass ratio: 1836.15267343  (CODATA 2020)");
mr = eval((totalMass-codataProton)/codataProton);
document.write ("<br>Relative error = " + Number.parseFloat(mr).toExponential(2) + " =
    " + mr.toFixed(8)+ " = " + (100*mr).toFixed(6) + "%");

// The neutron mass is given by the proton mass + the mass of the first two layers
document.write ("<br><br>Calculated neutron/electron mass ratio: "+
    (totalMass+m1[1]+m2[1]+m1[2]+m2[2]).toFixed(8) + "<br>--- Official
    neutron/electron mass ratio: 1838.683662  (CODATA 2020)");
mr = eval((totalMass+m1[1]+m2[1]+m1[2]+m2[2]-codataNeutron)/codataNeutron);
document.write ("<br>Relative error = " + Number.parseFloat(mr).toExponential(2) + " =
    " + mr.toFixed(8) + " = " + (100*mr).toFixed(6) + "%");
```

References

1. T. N. Lockyer, *Vector Particle Physics*, TNL Press, 1992, ISBN: 0963154605.
2. Thomas. N. Lockyer, *Fundamental Physical Constants Derived From Particle Geometric Structures*, TNL Press, 2007, ISBN: 0-9631546-4-8.
3. CODATA, Recommended Values of the Fundamental Physical Constants, 2020.