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The theoretical nature of the neutron and the deuteron

H. Aspden
Department of Electrical Engineering, University of Southampton, Southampton SO9 5NH, England
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A Thomson-charge group model, which in 1975 gave a theoretical proton-electron mass ratio of 1836.15232, is now shown to give equally precise results for the several quantitative properties of both the neutron and the deuteron.

I. INTRODUCTION

The GF11 parallel computer assembled at IBM's Yorktown Research Center comprises 576 floating-point processors, and its main intended application is to perform calculations of certain particle properties, particularly the mass of the proton and the neutron.[1] Although this is unquestionably the largest computing system ever to be given a problem, it is expected that the mass calculation will take about one year. The method involves quantum chromodynamics.

In the short span of this paper it will be shown that such particle masses can be calculated with extreme precision by using what is termed a "Thomson-charge group model" and some data calculated from a three-dimensional lattice theory dating back to 1960.

The method does not fall within "mainstream physics," but in 1972 it did attract the interest of Dr. D. M. Eagles of the CSIRO National Measurement Laboratory in Australia. He had the lattice calculations checked to a limit approximating infinity, which enabled the theory to be given definitive form, based on a resonance, so that it no longer demanded the precision computer analysis to determine the lattice parameters. At that time the author was with IBM, and the collaboration with Dr. Eagles of CSIRO led to two papers, one giving a theoretical formulation for the fine-structure constant and published in 1972,[2] and the other giving a formulation for the proton-electron mass ratio and published in 1975.[3] The theoretical values obtained were astonishing, but did not attract interest, possibly because they relied upon a notional structured lattice state of the vacuum itself, a structure which in many respects had the properties of an adaptive fluid crystal.

It is only recently that measurement techniques have advanced to the point where the proton-electron mass ratio can be measured to within a precision of 41 parts per 10^9. Such a value imposes a very severe test on any theory which aims to calculate this ratio, whether quantum chromodynamics or group-model lattice dynamics. Yet the authors of this experiment, Van Dyck, Moore, Farnham, and Schwinberg,[4] writing in 1985, have been able to say:

> The value that they [Aspden and Eagles] calculate is remarkably close to our experimentally measured value (i.e. within two standard deviations). This is even more curious when one notes that they published this result several years before direct precision measurements of this ratio had begun.

At the time of writing, therefore, the author feels somewhat ahead in the contest with the Goliath computer, but awaits with interest the value that it will come up with and wonders how anyone will ever be able to check what is found. This paper serves to extend the challenge, by showing that the neutron and deuteron properties can be computed, with high precision, by the mere use of a hand calculator and the Thomson-charge group principles on which the author's theory is founded.

II. THE THEORETICAL METHOD

The lattice is conceived as a three-dimensional cubic space array of identical electric charges e immersed in a uniform continuum charge of opposite polarity. Each charge is displaced from a neutral position in concert with all other such charges, and the linear restoring-force rate between the charge lattice and the continuum defines a natural frequency ν_0, which is found to be that at which a photon relates to the rest-mass energy of an electron or positron. The harmonic motion is that of a two-dimensional oscillator, a circular motion, and it means that energy added to the system and shared by the charges e, as they move faster in slightly expanded orbit, will entail a proportional angular momentum. This is balanced by a small cubic symmetrical sublattice group of charges spinning about a central charge. In doing this the lattice surrounding this spin unit is disturbed at a frequency proportional to the angular momentum. The result is that the energy shed into the field has a characteristic frequency given by the formula $E = h\nu$. Calculation of h in terms of e and the charge speed in orbit is then a mere matter of geometry, taken to be referenced on the smallest possible spin unit, a $3 \times 3 \times 3$ lattice array. This, therefore, is the basis of the 1960 lattice theory.[5] For a full account see the author's book *Physics Unified*.[6]

The theory was advanced in 1966,[7] when it was realized that each cubic cell of the lattice had association with a pair of virtual muons. Later, these muons were recognized as migrating at random in steps at interval of $1/\nu_0$, because this led to the calculation of particle lifetimes, as we shall see when we calculate the neutron lifetime.

It suffices here to summarize the theory by two equations:

(i) the fine-structure equation

$$\alpha^{-1} = A\sqrt{2s}, \tag{1}$$

(ii) the virtual-muon equation

$$\frac{4\pi}{3}2\mu = A^3 s^4, \tag{2}$$

where $A = 108\pi$ and $(1/s)^3 = 1843$. The number A is a measure of the cell spacing of the lattice in units of Thomson electron radius, to be defined below, and s is the energy notionally assigned to the charge e at each lattice site, s being in electron rest-mass energy units. The value of A depends principally upon the factor 36, which, in lattice spacing units, is the square of the radius of gyration of the $3 \times 3 \times 3$ cell about any central axis. The value of s is such that $(1/s)^3$ is an odd integer. Physically it works out as the number of electrons and positrons that would occupy the same volume as the Thomson-charge formula assigns to the s charge. It is calculated by working out the minimum displacement of the charge to assure that the interaction energy between the lattice and the continuum is not negative. The calculation by computer is reported elsewhere,[2] the zero energy value giving $(1/s)^3$ as a little over 1844. This explains why $(1/s)^3$, being an odd integer owing to the resonance of the interactions between s and the electron state, is uniquely 1843.

From these values of A and s, the reader may calculate α^{-1} as 137.0359148 and the combined energy of the two virtual muons in their cell proximity as twice 206.333 electron rest-mass energy units.

The basic formula relating the energy of a charge e and the space occupied by the charge is that advocated by J. J. Thomson, namely

$$E = 2e^2/3a, \tag{3}$$

where a is a radius bounding the charge.[8] The Thomson-charge group model involves at least two such charges of opposite polarity forming a touching pair or string, with adjacent charge boundaries in contact. This means that two opposite polarity charges e, $-e$ of energy E_x and E_y and radius x and y, respectively, will have a combined energy W, denoted $(X\!:\!Y)_E$ and given by

$$W = (X\!:\!Y)_E = E_x + E_y - \frac{e^2}{x+y}, \tag{4}$$

which, from (3), can be written

$$W = (X\!:\!Y)_E = E_x + E_y - \frac{3E_xE_y}{2(E_x+E_y)}. \tag{5}$$

If E_x is constant and E_y is a variable, then the minimal energy of W, representing a quasistable group form is found to be

$$W_{\min} = (X\!:\!Y^*)_{\min} = E_x\left[1 - \left(\frac{\sqrt{3}}{\sqrt{2}} - 1\right)^2\right] \tag{6}$$

when E_y has a value Y^* given by

$$Y^* = E_x\left(\frac{\sqrt{3}}{\sqrt{2}} - 1\right). \tag{7}$$

This seemingly classical method of particle analysis is hardly plausible in the light of modern particle theory, but it does appear to represent some kind of statistical picture of energy relationships having real meaning. This is simply because it gives the right answers in numerous situations and, as with the use of the Riemann curvature tensor in relativity, this can be sufficient justification.

The above methods were used[9] by the author in 1969 in associating the meson with the proton. It was only in 1974 that[10] the minimal-energy-group idea emerged, and with it the realization that if E_x was the proton rest-mass energy then the term Y^* in (7) was the energy of two virtual muons. Therefore, in 1975, when the proton theory was published,[3] the formula (2) for the double virtual-muon energy 2μ was combined with (7) to give a proton-electron mass ratio calculated from the numbers A and s to be 1836.15232.

As already mentioned, this has proved to be well within one part in ten million of the best measurement of this quantity of record to date.

One small question outstanding from the earlier theory of the proton was the physical justification for E_x being constant and E_y varying, bearing in mind that we see the muon as more fundamental. The answer to this, now favored by the author, is summarized in the proton equation:

$$n\mu + (k\mu:z)_{\min} \rightarrow (P:k\mu)_{\min} + z \rightleftharpoons P. \quad (8)$$

This says that if k virtual muons come together and adjust to a minimal-energy Thomson-charge group and n additional muons impact and coalesce with this group, then we can create a proton of energy P which has an intermediate form comprising three components. These are a form P in Thomson-group association with $k\mu$ and the transiently separate component z. The value of z is the Y^* value of Eq. (7) with E_x as $k\mu$. Here n and k are minimal integers giving a solution to the equations in (8).

There is a unique solution to be found from (6), (7), and (8), and this is that n is 7 and k is 2, giving the value of $P/2\mu$ as $(\sqrt{3}/\sqrt{2}-1)^{-1}$, as expected.

III. THE LEPTON GROUP EQUATIONS

A characteristic feature of the author's theory is that the charges bounded by the radius set by the Thomson formula are immersed in a continuum which contrives to keep the volume occupied by discrete charge constant. This is why the resonance condition mentioned above requires an odd number of electrons and positrons to occupy the same space as the charge of the s element. Again, the author can point to numerous applications of this principle and appeal to the fact that, however naive it might seem, it does work by giving some good answers. One example concerns the lifetime of a particle moving at high speed.[11]

On this basis we have three conservation conditions: (i) charge conservation, (ii) energy conservation, and (iii) space conservation. Imagine now that two virtual muons come together to form the $(X:Y)_E$ group with $W=2\mu$ and $Y=\mu$. We find that X is a charge e occupying the space assigned to an energy 2μ. Energy and charge are conserved, but not space.

The muon field must, therefore, in its multiplicity of simultaneous actions, somehow keep the balance. It may do this with leptons by pair creation and annihilation and by setting up the lower-energy Thomson group $(\mu:\mu)_E$, which is simply two muons touching. Note that in this excited and balanced state the muon interactions do not involve energy minimization of the groups, and we are not concerned with that rare event when enough muons happen to coalesce to create the proton.

From this argument we are led to formulate two lepton group equations:

$$[n_1(2\mu:\mu)_E + n_2(\mu:\mu)_E]:$$
$$[n_1(2\mu:\mu)_V + n_2(\mu:\mu)_V] = \mu_E:\mu_V, \quad (9)$$

$$N(\mu)_E = n_1(2\mu:\mu)_E + n_2(\mu:\mu)_E. \quad (10)$$

Just as E signifies the energy of the group, V signifies the volume of the space occupied by the charges in the group. n_1, n_2, and N are integers.

From Eq. (5) it is readily seen that $(2\mu:\mu)_E$ is $2\mu_E$ and that $(\mu:\mu)_E$ is $1.25\mu_E$. From (3) it can be shown that $(2\mu:\mu)_V$ is $1.125\mu_V$ and $(\mu:\mu)_V$ is $2\mu_V$. Energy and space conservation are assured if n_1 is 24, n_2 is 28, and N is 83, meaning that if 83 muon pairs coalesce we can have all conservation conditions satisfied and find that the two types of Thomson-charge groups exist in the resulting neutral "gas."

As we have seen, the proton seems to emerge from creation processes coupled with minimization of energy of one group constituent of such a gas, but we will now extend the argument to the neutron, which depends heavily upon the admixture defined by Eqs. (9) and (10), though in relation to the electron counterpart of this muon system. First, however, it helps to explain the nature of the neutron lifetime.

IV. NEUTRON LIFETIME

The proton is believed to comprise three quarks: two up quarks and one down quark. The neutron similarly comprises two down quarks and one up quark. Neutron decay is believed to involve the down quark changing into an up quark to give the proton and shedding an electron and an antineutrino. Unfortunately, the quark model does not tell us precisely why the neutron has the measured lifetime of 898 seconds.[12]

The proton equation (8) admits a proton state nucleated on three charges $+e$, $-e$, and $+e$, two in a grouped pair, but these are not the fractionally charged quarks u, u, d. Possibly there is such a third translational state, helping us to formulate particle hierarchies on quark theory. Indeed, though it is beyond the scope of this paper, there is a way in which the fractional charges of the three quarks can be deduced from the space conservation principles outlined above. It is the only way in which a charge $+e$ can divide between an equilaterally spaced group of three space spheres having the same volume as that given by the Thomson formula. Putting this aside, we now address the neutron decay problem as depending upon a neutron state in which we have $+e$ and $-e$ charges only.

The decay condition is that a negative virtual muon encounters the $+e$ charge in the same cycle of migration, at the frequency ν_0, as in a positive virtual muon encounter with the $+e$ charge. The neutron is unique in the particle decay process because it requires the double coincidental encounter with the muon pair. Hence its relatively long lifetime.

The chance of encounter is calculated presuming that the $+e$ charge has the energy of the positron. This means that in a single cycle the chance of the negative muon coming within the Thomson sphere of the positron is $4\pi/3$ divided by A^3. The chance of the other encounter, bearing in mind that the positron and negative muon are collectively neutral, depends solely upon the positive muon coming close enough to $-e$ to create an unstable situation. Let the measure of this proximity be k in units of the electron charge radius a. The condition just discussed is that the energy released to balance $-e^2/ka$ is sufficient, when added with a positive muon to the $-e$ charge (i.e. to the neutron mass energy less a positron), to create a proton-antiproton pair. Then, as the state subsides, the antiproton decays to leave the proton in isolation and the energy released is exchanged between the leptons to reestablish the virtual muons and eject an electron.

This allows k to be estimated as $\frac{1}{1085}$. To verify this note that two proton masses plus a positron mass less a neutron mass less a muon mass is about 1628 electron units, and e^2/ka, from (3), is $3/2k$ electron units. Their equality requires $1/k$ to be about $\frac{2}{3}$ times 1628.

In terms of a time period this second encounter will occur with a probability of $(4\pi/3)k^3/A^3$ every $1/\nu_0$ seconds. It follows that the dual encounter will give the neutron a lifetime τ of

$$\tau = \left(\frac{3}{4}\pi\right)^2 A^6 k^{-3} \left(\frac{h}{m_e c^2}\right), \tag{11}$$

where A is 108π and k is $\frac{1}{1085}$. We know from the Compton electron frequency that $h/m_e c^2$ is 8.09×10^{-21} s, and so calculate the neutron lifetime as 898 s. This is exactly the median of the recommended value based on measurement data,[12] and we must therefore feel that the nature of the neutron has been correctly portrayed as comprising essentially a charge e of electron or positron form and a core charge e of opposite polarity nucleating the remaining mass.

V. THE NEUTRON'S LEPTON FIELD

The least complicated model is often the best in physical theory, but the neutron is a rather special particle. It would be easy to regard it as a very compact hydrogen atom, comprising a proton and an electron quite close together. However, we know that the neutron has a negative spin magnetic moment, whereas that of the proton is positive. Therefore, it seems best to regard it as having an antiproton at its core and a protective lepton field including a positron enveloping that core.

This is hypothesis, but we get the right answers from this model and so it has merit. To proceed, we suppose that the positron charge is statistically uniformly deployed over the whole volume of a sphere of radius λ_c (the Compton wavelength $h/m_e c$ of the electron). Its Coulomb interaction with the central antiproton has a negative energy given by

$$-\frac{3}{4\pi\lambda_c^3}\int_0^{\lambda_c}\frac{e^2}{x}4\pi x^2\,dx \tag{12}$$

which is $-3e^2/2\lambda_c$ or $-(3/4\pi)\alpha$ in electron mass units, α being the fine structure constant $\frac{1}{137}$.

Such a neutron does not have enough mass to explain the actual mass measured, and this means that there is a neutral halo surrounding the core and giving it extra mass. The candidate we see for this is the neutral entities of the lepton groups discussed above, though based on electrons and positrons. The neutron ground state is taken to include one of the smallest such groups, the $(e{:}e)$

state. Migrant muons can induce mutual annihilation of this neutral electron-positron unit, but this only means that it will be reconstituted nearby and so will migrate as part of the neutron halo. These units remain in the system because their reconstitution and transition involves the positron. The radius λ_c applies because this cycle of behavior has connection with the wavelength and frequency of the electron. In effect, the annihilation of the electron and positron in the neutral group can involve reconstitution of the electron with the free positron to form a new neutral entity and leave the new positron to stand in isolation and be bounded by its interaction with the negative core charge. By this process the neutral groups are confined to the same system and do not escape from the neutron.

However, the cyclic creation and annihilation involves vacuum fluctuations and regulated but balanced exchanges with other neutrons. We have to consider the creation criteria for these lepton groups and the possibility that there can be more that one neutral unit in the neutron complex.

We have seen that the free lepton gas has a natural group feature of 166 electrons and positrons or 166 muons. When matter gets involved, the energy balance can be made up by creating mesons, but the primary regulating factor is then the space occupied by the electrons and positrons when these have association with neutrons, for example. Imagine, therefore a group of β neutrons having a shared lepton field comprising 166 electrons and positrons. These will mainly be in the ground-state configuration having two such particles in a neutral group and one free positron. This is denoted state A, and it has a mass 2.25 electron units over the antiproton less the term $(3/4\pi)\alpha$. We now suppose that a more energetic state is transiently possible and involves the appearance of another $(e\!:\!e)$ unit. There are two possibilities, and we assume both are equally probable. In state B the new $(e\!:\!e)$ unit appears as a separate unit, and in state C it appears attached in a string to the existing unit to form $(e\!:\!e\!:\!e\!:\!e)$. This is an alternative in-line grouping of two electrons and two positrons. It has an energy easily calculated from the Thomson formula as 2.25 electron units.

The reverse process in response to a change stimulus is for C to change back to the lower energy state A or to change state to D at constant energy. This is deemed to occur with equal probability. The state D involves the separation of the $(e\!:\!e\!:\!e\!:\!e)$ unit into two $(e\!:\!e)$ units and the positron attaching itself to the antiproton to release energy based on Eq. (5) sufficient to cause the separation just mentioned and, in addition, the creation of a further $(e\!:\!e)$ unit. These transitions occur with equal probability because in the C to D transition an $(e\!:\!e)$ unit is created and in the C to A transition such a unit is annihilated. State D reverts to the equal-energy state C upon the next change stimulus, and state B decays directly to state A.

The chance of such transitions for states B, C, and D is proportional to their pair populations, namely in the ratio 3 : 3 : 2. Then, when we take into account the mode of transition, we find the the equilibrium ratio of states B, C, and D is 2 : 3 : 1. The number of electrons and positrons in the B, C, and D states is 5, 5, and 7, respectively. Therefore, for each D state there are 32 electrons and positrons in the combined system. We wish as many states A for 166 electrons and positrons as possible, in order to accept minimal but positive-energy excitation, and since there are three electrons and positrons in state A, the number 166 offset by 32 or a multiple thereof must be divisible by 3. The multiple must be 2 or 5, and we rule out the latter because it leaves only 4.3% of the neutrons in state A. We find that the 166 electrons and positrons divide between 34 states A, 4 states B, 6 states C, and 2 states D.

Now, this may seem a rather tortuous procedure, but the author has followed it through, hoping that the earlier quantitative success would be matched by something similar in estimating the neutron mass. In fact, what now emerges is a double bonus from the same analysis.

First, the neutron mass can be calculated from the data summarized in Table I. The mass given for each state is the incremental mass in electron units over that of the antiproton (symbol P) and without the offset for the free charge interaction with the antiproton.

When the effective additional mass of the neutron over that of the proton is calculated from the data in the table and the weighting given by the abundance ratio, we obtain 2.5326087 electron units. There are $\beta = 46$ neutrons sharing in this action,

TABLE I

State	Composition	Mass	Abundance	e no.
A	$(P) + (e\!:\!e) + (e)$	2.25	34	102
B	$(P) + (e\!:\!e) + (e\!:\!e) + (e)$	3.50	4	20
C	$(P) + (e\!:\!e\!:\!e\!:\!e) + (e)$	3.25	6	30
D	$(P\!:\!e) + (e\!:\!e) + (e\!:\!e) + (e\!:\!e)$	3.25	2	14

and a single neutron will be changing state in a cycle of 46 transitions, exchanging energy with the other neutrons in the environment. In two of these transitions the antiproton is closely coupled with the positron, and so cannot react freely to develop a magnetic moment, nor can it develop the offset interaction energy $(3/4\pi)\alpha$ during such periods. We must subtract $\frac{22}{23}(3/4\pi)/137$ from the mass difference just calculated and obtain 2.5309419 units of energy 0.511004 MeV, or 1.2933214 MeV.

The first result obtained is that the mass energy of the neutron is this much greater than that of the proton. This is a very remarkable result, because the Particle Data Group in 1984 report the difference as having the measured value of 1.293323 ± 0.000016 MeV, which is precisely in agreement with the value calculated.

VI. NEUTRON MAGNETIC MOMENT

The second result, the bonus of our analysis, comes from the fact that the neutron, according to Table I, will exhibit the magnetic moment of the antiproton for all but 2 parts in 46 of any period of time. The neutron magnetic moment must then be $\frac{22}{23}$ that of the antiproton.

Now, we are here considering actions in the spin state and must apply the usual g factor of 2 because the neutron magnetic moment is to be expressed in nuclear magnetons. This means that our theory says that the neutron magnetic moment is simply $-\frac{44}{23}$ nuclear magnetons, or -1.9130435 nuclear magnetons. What more can be said when it is found that the measured value of this quantity[13] is $-1.91304308(54)$ (0.28 ppm)?

The theory presented in this paper has given the precise lifetime, mass, and magnetic moment of the neutron. In contrast Ioffe and Smilga[14] in 1983 were claiming to have calculated the magnetic moment of the neutron to within 1% based on assumptions linked to quantum chromodynamics.

VII. DEUTERON STRUCTURE

One can next approach the problem of the deuteron with some hope that the same principles might give similar results. The basic assumption is that, since it appears that the neutron contains an antiproton and a positron, the deuteron might contain two antiprotons and three positrons, or two protons and one electron, or a proton, an antiproton, and an electron-positron pair plus a positron.

The idea that the deuteron could have a transient state in which it contains an antiproton and a proton kept apart by an electron-positron pair may sound off key, but let us see where it takes us and bear in mind that if they mutually annihilate in their respective pairs, all that need happen is the transition to the ground state.

The analysis is simplified because the number of electrons and positrons can be the same in each state, if we admit a field-related positron or electron-positron pair in the excited states. The analysis is complicated by the need to allow for the finite size of the proton or antiproton, but this has very little effect upon the magnetic moment. Our analysis will therefore be limited to the point-charge assumption for these particles and will not extend to full mass calculations. The author has performed these, and the results are a match for those applicable to the neutron, but this paper will conclude with the approximate calculation of the deuteron magnetic moment.

Table II summarizes the deuteron states and presents the Coulomb interaction energy of the core particle in units of e^2/a, which are 1.5 times the unit electron energy. The energy is presented in this expanded form to show its derivation. State A involves ten Coulomb interactions between the five core charges. Since a is the radius of the electrons and positrons, there are four interactions at a separation distance a, accounting for the term $4(-e^2/a)$, contracted to $4(-1)$. In state B there are six interactions. In state C there are three interactions. The electron and positron in the field affect the overall deuteron mass slightly, but not the core mass which is active in the spin reaction.

Because the number of electrons and positrons is not a changing quantity, we need not involve the factor 166 that governed the unstable neutron. Also, the transitions can be at a rate set by perturbation

TABLE II

State	Composition	Units of e^2/a	Abundance
A	$(e{:}P{:}e{:}P{:}e)^+$	$4(-1) + 3(\frac{1}{2}) + 2(-\frac{1}{3}) + 1(\frac{1}{4})$	2
B	$(P{:}e{:}e{:}P)^0 + (e)^+$	$2(-1) + 1(-\frac{1}{2}) + 2(\frac{1}{3}) + 1(-\frac{1}{4})$	1
C	$(P{:}e{:}P)^+ + (e)^- + (e)^+$	$2(-1) + 1(\frac{1}{2})$	4

TABLE III

Chance	Transition	Contribution A	B	C
2×1	A to B	-2	$+2$	
2×2	A to C	-4		$+4$
1×2	B to A	$+2$	-2	
4×1	C to A	$+4$		-4

of the core system and the chance of an electron or positron being subject to a change stimulus. Thus in Table III the chances of transition from states A to B and C and reversion to ground state A are presented. The states are found to exist in the ratio $2:1:4$, the balance being evident from the data on the right-hand side of the table.

State A changes to higher-energy state B when the middle positron is hit by the change stimulus. The positron is driven into the surrounding field, and the core finds a new equilibrium state with the same energy, having reconstituted a proton-antiproton pair and an electron-positron pair. State A changes to the higher-energy state C when an outer positron is hit. To settle in a symmetrical core state the energy regroups in this case by ejecting a further electron from the core and consolidating as two protons and one electron. Thus the state B is left with two electron-size charges as a target for decay stimuli and reverts to state A with a lifetime only half that of state C. The latter has one electron as target and decays to state A.

It is relevant to note that the energy assigned to state A in Table I is -4.375 electron units of 0.511 MeV, or -2.23 MeV. Very roughly (since we have not made a rigorous calculation of the separation threshold for rupture), this energy 2.23 MeV should represent the energy needed to convert the deuteron into a proton and a neutron. It compares with an experimental value of 2.22464(4) MeV. This is close enough to reassure us that the analysis is headed in the right direction.

To calculate the approximate mean mass of the deuteron core one has to allow for the 3, 2, and 1 units of electron mass in the A, B, and C states, respectively, as offset by the energy given in the table, and then weight these quantities by the abundance ratio to find an average. The result is $\frac{12}{7}$ less $\frac{167}{56}$, or $-\frac{71}{56}$ in electron units. This is the adjustment to the two proton masses. The deuteron core only develops a magnetic moment when it has a positive charge in states A and C, which is $\frac{6}{7}$ of the time. The deuteron spin angular momentum is $h/2\pi$, so we can express the magnetic moment in nuclear magnetons simply by taking $\frac{6}{7}$, multiplying by the usual g factor of 2, and dividing by the deuteron core mass in proton units. The formula for the deuteron magnetic moment is then

$$\frac{6}{7}\frac{2}{2-\frac{71}{56}/1836}, \tag{13}$$

which is 0.857439. This is within one part in a million of the measured value of 0.857438 nuclear magnetons, found by combining the four measurements:

(i) deuteron/proton spin magnetic moment ratio, 0.307 012 250(56),[15]
(ii) electron/proton spin magnetic moment ratio, 658.210 688 0(65),[16]
(iii) electron anomalous $\frac{1}{2}g$ factor, 1.001 159 652 200(40),[17]
(iv) proton/electron mass ratio 1836.152 470(76).[4]

The extremely simple analysis summarized in Tables II and III has given a precision of one in a million, in keeping with the earlier calculation of the proton-electron mass ratio and the three quantities evaluated for the neutron.

It is submitted, therefore, that Thomson-charge group theory has a major role to play in the understanding of fundamental particles. Some progress in understanding the nature of the pion along similar lines is also of record,[18] and other mesons, including the kaon, are derivable using the same theory.[19]

Whatever prejudice there is against the use of semiclassical and outdated models of charges as finitely bound spherical objects, it does seem worthwhile to adapt one's viewpoint and try to bring the Thomson-charge model into play alongside wave and quantum interpretations. Otherwise, one is turning away from a very comprehensive explanation of a wide spectrum of the most basic constants and is unlikely to find any future theory with quantitative features that can even approach what has already been demonstrated in this paper alone. It is now for the reader to judge what has been presented and make the comparison with the year-long computations by IBM's mammoth computer when its results are announced. Perhaps it will be realized that hadron physics is not as complicated as the use of such computing power suggests.

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