Derivation of Quark Energy Distributions and Decay Products of Baryonic Sub-Atomic Particles.

[2]

Particles with Intrinsic Angular Momenta of $J = 1/2\hbar$ and $J = 3/2\hbar$

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Abstract.

This paper investigates the distribution among the three quarks that constitute Baryons, of the three varieties of energy within them, matter energy, energy associated with intrinsic angular momentum, and energy associated with quark confinement. This in turn enables the investigation of the energy transitions that take place during particle decay.

Contents

1.0 Introduction.

The total energy distribution of all 75 Baryons listed in [1] and [2] was determined in [3] and [4], and it is proposed that this total energy distribution, in the form of matter energy, resonance energy and quark confinement energy, is apportioned between the three quarks from which Baryons are composed. Consequently, each quark will exhibit a degree of each form of energy. It is the purpose of this present investigation to derive this energy apportionment in all 75 Baryons. This will accordingly also enable the determination of the energy transitions that occur during particle decay.

In view of the large number of particles involved, these tasks will be accomplished within this paper plus two series of four Addendums as follows.

(i) This paper covering the basic theory plus two examples, the Proton, p^+ and the Neutron, n^0 both with an intrinsic angular momentum of $J = 1/2\hbar$.

(ii) Four Addendums covering all main particles in [1] with an intrinsic angular momentum of $J = 1/2\hbar$.

- (a) Selected Λ Particles.
- (b) Selected Σ Particles.
- (c) Selected Ξ and $\Xi^{/}$ Particles.
- (d) Selected Ω Particles.

(iii) Four Addendums covering all main particles in [1] with an intrinsic angular momentum of $J = 3/2\hbar$.

- (a) Selected Δ Particles.
- (b) Selected Σ^* Particles.
- (c) Selected Ξ^* Particles.
- (d) Selected Ω^*, and the Ω^-, Ω^+_{ccc}, and Ω^-_{bbb} Particles.

Note that in this investigation, energy will be represented as equivalent mass via the units MeV/c^2.

2.0 Nomenclature.

In the dissertation below the following nomenclature will be used.

P	Indicates any Baryon.
P(#)	Indicates the type of configuration of Baryon P.
$q_{\#}$	Indicates the #th quark in Baryon P.
$m_{\#}$	Indicates the mass of the #th quark.
$\omega_{\#}$	Indicates the effective angular rate of the #th quark.
E_r	Indicates resonance energy.
E_c	Indicates quark confinement energy
E_k	Indicates kinetic energy
$\rightarrow$	Indicates a particle decay.
$\Rightarrow$	Indicates a quark flavour change.

3.0 The Internal Baryon Distribution of Energy.

3.1 Quantum Chromodynamics.

Quantum Chromodynamics was developed to explain the existence of three identical quarks, which being Fermions, could not proposedly exist in the same particle due to the Pauli Exclusion Principle. In this investigation it is proposed that such a development is unnecessary, because three identical quarks can exist in the same particle with one quark in a higher resonance condition. This is demonstrated in the following quark angular momentum table, for any particle with three identical quarks such as the Δ^{++} particle.

Δ^{++}(#)	u_1	u_1	u_1	Δ^{++}
1	↑1/2$\hbar$	↓1/2$\hbar$	↑3/2$\hbar$	↑3/2$\hbar$

The first two quarks have $J = \pm 1/2\hbar$ while the third has $J = +3/2\hbar$. Thus each quark is unique while providing the particle with the correct level of angular momentum. This concept is implemented throughout this paper.

3.2 Intrinsic Angular Momentum Configurations and Resonance Energy Distributions.

3.2.1. Intrinsic Angular Momentum Configurations.

The intrinsic angular momentum of a particle will be the net effect of the angular momenta of its constituent quarks. Being Fermions, for the particles under consideration there are several configurations possible, all of which must conform to the Pauli Exclusion Principle.

(i) Particles with $J = 1/2\hbar$ and three different quarks.

P(#)	q_1	q_2	q_3	P
1	↑1/2$\hbar$	↑1/2$\hbar$	↓1/2$\hbar$	↑1/2$\hbar$
2	↑1/2$\hbar$	↓1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$
3	↓1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$

(ii) Particles with $J = 3/2\hbar$ and Three Different Quarks.

P(#)	q_1	q_2	q_3	P
1	↑1/2$\hbar$	↓1/2$\hbar$	↑3/2$\hbar$	↑3/2$\hbar$
2	↓1/2$\hbar$	↑1/2$\hbar$	↑3/2$\hbar$	↑3/2$\hbar$
3	↑1/2$\hbar$	↑3/2$\hbar$	↓1/2$\hbar$	↑3/2$\hbar$
4	↓1/2$\hbar$	↑3/2$\hbar$	↑1/2$\hbar$	↑3/2$\hbar$
5	↑3/2$\hbar$	↑1/2$\hbar$	↓1/2$\hbar$	↑3/2$\hbar$
6	↑3/2$\hbar$	↓1/2$\hbar$	↑1/2$\hbar$	↑3/2$\hbar$

(iii) Particles with $J = 1/2\hbar$ and Two Identical Quarks.

P(#)	q_1	q_1	q_2	P
1	↑1/2$\hbar$	↓1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$
2	↓1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$	↑1/2$\hbar$

(iv) Particles with $J = 3/2\hbar$ and Two Identical Quarks.

P(#)	q_1	q_1	q_2	P
1	$\uparrow 1/2\hbar$	$\downarrow 1/2\hbar$	$\uparrow 3/2\hbar$	$\uparrow 3/2\hbar$
2	$\uparrow 1/2\hbar$	$\uparrow 3/2\hbar$	$\downarrow 1/2\hbar$	$\uparrow 3/2\hbar$
3	$\downarrow 1/2\hbar$	$\uparrow 3/2\hbar$	$\uparrow 1/2\hbar$	$\uparrow 3/2\hbar$

(v) Particles with $J = 3/2\hbar$ and Three Identical Quarks.

P(#)	q_1	q_1	q_1	P
1	$\uparrow 1/2\hbar$	$\downarrow 1/2\hbar$	$\uparrow 3/2\hbar$	$\uparrow 3/2\hbar$

Note, only particles with $J = +1/2\hbar$ or $J = +3/2\hbar$ incorporating quarks with $J = \pm 1/2\hbar$ and $J = +3/2\hbar$ are considered here. There are many other configurations for both particles and quarks with higher resonance energies and higher particle masses. While not considered in this investigation, the analysis of their configurations, energy distributions and decay energy translations would be identical to that here.

3.2.2. Resonance Energy Distribution.

While the intrinsic angular momentum of a sub-atomic particle is not considered in the mainstream literature to be due to actual physical spin, a definitive alternative cause has not however, been proposed. Angular momentum is uniquely associated with spin, and in the absence of an alternative cause, the analysis of systems containing angular momentum can only use the available methodology. Therefore, for the purpose of this paper, it will be assumed that the analysis of intrinsic angular momentum of sub-atomic particles, and their constituent quarks, can be conducted as though spin were incorporated. This assumption is discussed in detail in Section 5.0. The process is then as follows.

Let quark q_1 posses intrinsic angular momentum of $J = n/2\hbar$, quark q_2, $J = m/2\hbar$ and quark q_3, $J = l/2\hbar$ so that

$$J_2 = \frac{m}{n} J_1 \qquad and \qquad J_3 = \frac{l}{n} J_1 \tag{3.1}$$

For quark q_2

$$\frac{m}{n} J_1 = \left(m_1 + \Delta m_2\right) r^2 \left(\omega_1 + \Delta\omega_2\right) \tag{3.2}$$

Expanding and consolidating terms this becomes [1]

$$\left(\frac{m}{n} - 1\right) m_1 \omega_1 - \Delta m_2 \omega_1 = \left(m_1 + \Delta m_2\right) \Delta\omega_2 \tag{3.3}$$

[1] Note that this assumes that the physical dimensions of all three quarks are the same, which means that with different masses their densities will be different. This may be a significant factor regarding the nature of quark confinement energy.

So that

$$\Delta\omega_2 = \frac{\left\{\left(\frac{m}{n}-1\right)m_1 - \Delta m_2\right\}\omega_1}{m_1 + \Delta m_2} \tag{3.4}$$

and therefore for quark q_3

$$\Delta\omega_3 = \frac{\left\{\left(\frac{l}{n}-1\right)m_1 - \Delta m_3\right\}\omega_1}{m_1 + \Delta m_3} \tag{3.5}$$

The resonance energy of the particle in question is

$$\begin{aligned} E_r &= \frac{m_1 r^2 \omega_1^2}{2} + \frac{m_2 r^2 \omega_2^2}{2} + \frac{m_3 r^2 \omega_3^2}{2} \\ &= \frac{m_1 r^2 \omega_1^2}{2}\left(1 + \frac{m_2 \omega_2^2}{m_1 \omega_1^2} + \frac{m_3 \omega_3^2}{m_1 \omega_1^2}\right) \end{aligned} \tag{3.6}$$

Now with

$$\begin{aligned} &\omega_2 = \omega_1 + \Delta\omega_2 \qquad \omega_3 = \omega_1 + \Delta\omega_3 \\ &m_2 = m_1 + \Delta m_2 \qquad m_3 = m_1 + \Delta m_3 \end{aligned} \tag{3.7}$$

then from (3.4) and (3.7)

$$\omega_2 = \omega_1 + \frac{\omega_1\left\{\left(\frac{m}{n}-1\right)m_1 - m_2 + m_1\right\}}{m_1 + m_1 - m_1} \tag{3.8}$$

which clearly reduces to

$$\omega_2 = \frac{mm_1}{nm_2}\omega_1 \tag{3.9}$$

and therefore from (3.5) and (3.7)

$$\omega_3 = \frac{lm_1}{nm_3}\omega_1 \tag{3.10}$$

Now substituting (3.9) and (3.10) into (3.6) gives

$$E_r = \frac{m_1 r^2 \omega_1^2}{2}\left(1 + \frac{m^2 m_1}{n^2 m_2} + \frac{l^2 m_1}{n^2 m_3}\right) \tag{3.11}$$

so that the resonance energy of quark q_1 becomes

$$E_{r1} = \frac{E_r}{\left(1 + \frac{m^2 m_1}{n^2 m_2} + \frac{l^2 m_1}{n^2 m_3}\right)} \tag{3.12}$$

and consequently for quarks q_2 and q_3

$$\begin{aligned} E_{r2} &= E_{r1}\frac{m^2 m_1}{n^2 m_2} \\ &= \frac{E_r}{\left(1 + \frac{m^2 m_1}{n^2 m_2} + \frac{l^2 m_1}{n^2 m_3}\right)}\frac{m^2 m_1}{n^2 m_2} \end{aligned} \tag{3.13}$$

$$\begin{aligned} E_{r3} &= E_{r1}\frac{l^2 m_1}{n^2 m_3} \\ &= \frac{E_r}{\left(1 + \frac{m^2 m_1}{n^2 m_2} + \frac{l^2 m_1}{n^2 m_3}\right)}\frac{l^2 m_1}{n^2 m_3} \end{aligned} \tag{3.14}$$

Thus for the particles considered here, first with $J = 1/2\hbar$, $n = m = l = 1$ and thus

$$\begin{aligned} E_{r1} &= \frac{E_r}{\left(1 + \frac{m_1}{m_2} + \frac{m_1}{m_3}\right)} \\ E_{r2} &= E_{r1}\frac{m_1}{m_2} \\ E_{r3} &= E_{r1}\frac{m_1}{m_3} \end{aligned} \tag{3.15}$$

and for particles with $J = 3/2\hbar$, then $m = n = 1$, $l = 3$

$$E_{r1}=\frac{E_r}{\left(1+\frac{m_1}{m_2}+\frac{9m_1}{m_3}\right)}$$
$$E_{r2}=E_{r1}\frac{m_1}{m_2} \tag{3.16}$$
$$E_{r3}=9E_{r1}\frac{m_1}{m_3}$$

Thus from (3.15) and (3.16) the resonance energy of all quarks in all 75 main Baryons listed in [1] and [2] can be determined.

3.3 Quark Confinement Energy Distribution.

In [4] it was shown that total quark confinement energy within a Baryon was, for each configuration of quark content, an empirical function of the sum of the quark masses. Consequently, within a Baryon, it would be expected that the total quark confinement energy would be distributed among its quarks according to their individual mass.

This simple relationship, together with that for resonance energy above, now enables the determination amongst its three quarks, of all three varieties of energy within all Baryons. Two examples are presented in the next Section.

3.4 The Distribution of Energy Within the Proton and Neutron.

The quark content of the Proton is uud. Its intrinsic angular momentum configuration is from Section 3.2

p^+(#)	u_1	u_2	d_1	p^+
1	↑1/2ℏ	↓1/2ℏ	↑1/2ℏ	↑1/2ℏ
2	↓1/2ℏ	↑1/2ℏ	↑1/2ℏ	↑1/2ℏ

The Protons resonance energy, (J = 1/2ℏ), was determined in [3] to be E_r = 146.87MeV/c^2 and its quark confinement energy, E_c = 781.86MeV/c^2. The matter energy of its quarks was determined in [2] to be m_u = 2.40MeV/c^2 and m_d = 4.75MeV/c^2. From this information and that of Section 3.3, plus (3.15) the following table for the energy distribution within the Proton can be constructed.

Energy	u_1	u_2	d_1	Total
Matter	2.40	2.40	4.75	9.55
Resonance	58.63	58.63	29.61	146.87
Confinement	196.49	196.49	388.88	871.86
Total	257.51	257.51	423.24	938.28

Table 3.1 - Energy Distribution Within the Proton.

The quark content of the Neutron is udd. Its intrinsic angular momentum configuration is from Section 3.2.

n^0(#)	u_1	d_1	d_2	n^0
1	↑1/2ħ	↓1/2ħ	↑1/2ħ	↑1/2ħ
2	↑1/2ħ	↑1/2ħ	↓1/2ħ	↑1/2ħ

The Neutrons resonance energy, (J = 1/2ħ), was determined in [3] to be E_r = 146.22MeV/c^2 and its quark confinement energy, E_c = 781.45MeV/c^2. Consequently from this and the mass of its quarks, the following energy table can be constructed.

Energy	u_1	d_1	d_2	Total
Matter	2.40	4.75	4.75	11.90
Resonance	72.73	36.75	36.75	146.22
Confinement	157.60	311.92	311.92	871.45
Total	232.73	353.42	353.42	939.57

Table 3.2 - Energy Distribution Within the Neutron.

Note that in both Tables 3.1 and 3.2 the ratios of quark confinement energy by quark is identical to the ratio of quark masses, while the ratio of resonance energy by quark is the inverse of the ratio of the quark masses. Both of these "rules" are as a result of the proposed energy distributions of Sections 3.2 and 3.3 and will apply to all Baryons and their quark constituents.

4.0 Particle Decay Modes,

4.1 General Decay Rules.

These are all well documented in the published literature but are included here for completeness. They will, as a consequence of the results obtained here, (and the associated Addendums), be augmented by a set of secondary rules, (to be presented in the final Addendum).

(i) Particles can only decay to a lower energy particle.
(ii) Particle decay must conform to energy conservation.
(iii) Particle decay must conform to charge conservation.
(vi) Particle and quarks must conform to intrinsic angular momentum conservation.
(v) Particle decay must conform to Baryon number conservation. Non-Baryon particles can be emitted from a decaying particle provided one Baryon is also emitted.
(vi) Particle decays must conform to Lepton number conservation if a Lepton is emitted.
(vii) All decays must conform to the Pauli Exclusion Principle.

4.2 Stability of the Proton.

The Proton is the lowest energy Baryon and in line with conventional theory is considered stable. The reason on the basis of the analysis here is that $p^+(d_1)$ cannot change to a u with J = ±1/2ħ because of the Pauli Exclusion Principle. Also $p^+(d_1)$ cannot change to a u with J >1/2ħ or J < -1/2ħ because there is insufficient energy within the Proton to effect this. This same reason applies to any form of change to $p^+(u_1)$ or $p^+(u_2)$. Any other form of decay would violate Baryon number conservation.

4.3 Decay of the Free Neutron.

It is well known that a free Neutron will decay to a Proton and an Electron in a recorded time of ~ 887.50 seconds. From the configuration tables for these particles the process is

(i) $n^0(1) \rightarrow p^+(1)$ via $n^0(d_1) \Rightarrow p^+(u_2)$

or

(ii) $n^0(2) \rightarrow p^+(2)$ via $n^0(d_2) \Rightarrow p^+(u_1)$

The energy variations in this decay can be obtained by simply subtracting the values in the Energy Distribution Table for the Proton from those in the table for the Neutron, i.e. it is clear that the total energy released, (1.28MeV/c^2), is simply the difference in energy of the two particles. Also the total resonance energy variation is the difference between that of each particle and the total quark confinement energy variation is again the difference between that of each particle. This however, does not show how the decay is initiated or proceeds. Accordingly it is believed that the decay process is largely governed by the requirement for the conservation of angular momentum and is therefore proposed as follows.

(i) The decay is initiated by the flavour change of $n^0(d_1)$ to $p^+(u_2)$.

(ii) This changes the sum of the quark masses, to that of the Proton, and because the resonance energy of angular momentum was, in [4], shown to be a function of the sum of the quark masses according to quark content, the resonance energy of the particle must change to that of the Proton, thus conserving angular momentum.

(iii) The result of (ii) is that the three quarks must accordingly also change resonance energy to conserve their individual angular momentum and in total sum to that of the proton.

(iv) The energy released by the quark flavour change and the changes in quark resonance energy, is initially absorbed by each quark as quark confinement energy.

Thus at the instant of the quark flavour change the Energy Distribution Table of the Neutron is changed to that of Table 4.1 below.

Particle Decay	$n^0 \rightarrow p^+$			Total Energy Variation	Charge Variation
Proton Quarks	u_1	d_1	$n^0(d_1) \Rightarrow u_2$		
Matter Energy	2.4	4.75	2.4	9.55	+1
Resonance Energy	58.63	29.62	58.63	146.86	
Confinement Energy	171.70	319.05	292.40	783.15	
Total Energy	232.78	353.42	353.42	939.57	

Table 4.1 - Initial Decay Energy Translation $n^0 \rightarrow p^+$.

where confinement energy for each quark has been increased as per (iv) above.

This table also applies to mode (ii) above with $n^0(d_2) \Rightarrow p^+(u_1)$. The two modes are identical so that the branching fraction is 100%.

The level of confinement energy now possessed by each quark no longer conforms to the "rule" of quark mass ratio and therefore re-distributes as follows.

(i) $E_c(u_1)$ increases by 24.79 MeV/c^2 by absorption from u_2 to 196.49 MeV/c^2, (the proton value).

(ii) $E_c(\mathrm{d}_1)$ increases by 69.83 MeV/c^2 by absorption from u_2 to 388.88 MeV/c^2, (the proton value).

(iii) so that $E_c(\mathrm{u}_2)$ decreases by 94.62 MeV/c^2 to 197.78. MeV/c^2.

The final adjustment occurs as the confinement energy of u_2 decreases to 196.49 MeV/c^2, the Proton value, by ejecting 1.28 MeV/c^2 in the form of an Electron, e^-, (0.51 MeV/c^2), an Electron Anti-Neutrino, $\bar{\nu}_e$, (< 2eV/c^2), and kinetic energy, E_k, (0.77 MeV/c^2).
The decay of the free Neutron to the Proton plus Electron is thereby complete. However, the reason for the extremely long decay time of ~887.50 seconds is not clear. In addition, the mechanism by which the charge variation as $n^0(\mathrm{d}_2) \Rightarrow p^+(\mathrm{u}_1)$ is effected is also unclear.
The mechanism that initiates the decay process as in (i) above is discussed in the final Addendum.

This decay process is believed to be applicable to all Baryon particle decays.

5.0 Conclusions.

The two issues in this paper which may be considered the most controversial, are firstly, the manner in which intrinsic angular momentum has been treated in order to determine the distribution of resonance energy within a Baryon, i.e. by assuming that the analysis could be conducted in the classical sense in which spin was involved. There are two possibilities, (i) quark spin exists, and quark resonance energy is as a result of conventional theory, (ii) quark spin does not exist, and quark intrinsic angular momentum and resonance energy are due to some unknown mechanism.
In the first case, the analytical method used here would, in the manner implemented, appear to be justified. However, it means that in the resonance energy loss of $n^0(\mathrm{u}_1)$ and $n^0(\mathrm{d}_2)$, because there is no compensating variation of mass, it appears that these quarks would contravene conservation of angular momentum. However, this is not so because, the resonance energy level for an angular momentum of $J = \pm 1/2\hbar$ for each quark in the proton, is different from that in the neutron. This is because of the dependence of quark resonance energy on particle quark content as well as mass. Thus these two quarks are merely adjusting resonance energy levels in order to meet the intrinsic angular momentum levels of the proton, thereby actually maintaining angular momentum conservation.
In the second case, the above comments are fully applicable and the only question remaining is that of the analytical method used here assuming the presence of spin. Justification is based upon the fact that in the two final relationships, Eqs (3.15) and (3.16), the parameter for spin, ω, has been eliminated, and involve only the resonance energy for the complete particle and the mass and intrinsic angular momentum levels of the constituent quarks. This therefore avoids the question of spin or no spin, and in the case of the latter, the lack of knowledge of the true source of intrinsic angular momentum. However, this still leaves the source of this parameter effectively unknown and therefore, it is considered that the question of sub-atomic particle spin must remain an open one.

Secondly, for quark confinement energy, not only is the source of this energy unknown, but its very nature is also. Because in [4] confinement energy was shown to be a function of the sum of the quark masses according to quark content, its linear distribution within a Baryon according to quark mass was considered the most reasonable approach. Some justification of this will depend upon whether analysis of the decay of all other Baryons produces meaningful results.

Finally, the conclusions drawn here apply only to the methodology employed, and the two examples presented. The subsequent Addendums will augment them with additional comments where appropriate.

Appendix A.

Ejection Velocity.

The residual energy resulting from a particle decay, subsequent to the emission of secondary particles, will act as kinetic energy in driving the decayed and secondary particles apart. Their ejection velocities can be determined as follows.

If K is the mass equivalent of the kinetic energy of particle ejection, and there are N particles involved, including the decayed Baryon, then for any ejected particle

$$\frac{Kc^2}{N} = mc^2 - m_0c^2 \tag{A.1}$$

where

m is the energy mass of an ejected particle, (see [5]).
m_0 is the rest mass of the ejected particle.

so that

$$\frac{K}{N} = \frac{m_0}{\left(1-\frac{v^2}{c^2}\right)^{1/2}} - m_0 \tag{A.2}$$

which re-arranged gives

$$\frac{K}{Nm_0} + 1 = \frac{1}{\left(1-\frac{v^2}{c^2}\right)^{1/2}} \tag{A.3}$$

and therefore

$$v = c\left[1 - \frac{1}{\left(\frac{K}{Nm_0}+1\right)^2}\right]^{1/2} \tag{A.4}$$

Consequently, for the decay of the free Neutron, (ignoring the Electron Anti-Neutrino), the ejection velocity of the Proton is

$$v_{p^+} = c\left[1-\frac{1}{\left(\frac{0.385}{938.28}+1\right)^2}\right]^{1/2}$$

$$= 0.02864c \tag{A.5}$$

and for the Electron

$$v_{e^-} = c\left[1-\frac{1}{\left(\frac{0.385}{0.51}+1\right)^2}\right]^{1/2}$$

$$= 0.82186c \tag{A.6}$$

Note that this assumes that the ejection energy is shared equally between the Proton and the Electron. If it is shared according to mass, then both the Proton and the Electron would each attain an ejection velocity of 0.0404*c*.

Also note that the above analysis does not take into account any extant velocity possessed by the decaying particle. Such a velocity would simply be a relativistic vector addition to the ejection velocity of all ejected particles.

References.

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