International Journal of Theoretical Physics, Vol. 13, No. 5 (1975) pp. 341–361

An Electromagnetic Inertial Mass Theory Applied to Elementary Particles

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Received: 9 *December* 1974

Abstract

A definition of inertial mass is advanced which views this mass property as being due to intrinsic periodic electromagnetic processes characterized by an amplitude R and an angular frequency ω. The existence of a stable E/M composite mass unit, called a hylon, is then postulated composed of two or more of these primitive processes. Selected space-time coherence relations are then imposed on ω and R through ad hoc quantizations based on notions borrowed from historical physical theories. Elementary particles are then investigated to test the efficacy of the mass definition and coherence relations. It is found that by equating the postulated hylon mass with the experimental pion masses, a mass spectrum emerges which has a close correspondence with many of the more stable particles and resonances. A case is then made for considering these particles as being primarily electromagnetic in nature and exhibiting an underlying space-time structure in terms of the theory advanced.

Introduction

The inertial mass of a particle remains a very difficult concept to define univocally in physical theory. By and large in most physics, mass retains its Newtonian status of being a proportionality constant between measurable and meaningful variables, e.g., force and acceleration, kinetic energy and velocity squared, etc. Even special relativity and quantum mechanics have seemingly failed to add insight to this primitive property of matter (Jammer, 1961). The identity of proper mass, mass and energy (Terletskii, 1968), and even the observability of mass itself are questions regarded by many as being unsettled (Schlegel, 1954; Jammer, 1961). It has even been proposed that mass is the average of a stochastic process and not entitled to the attention accorded the primitive concepts of physics (Schrodinger, 1958).

Mach's definition of inertial mass (Berkeley, 1710; Mach, 1883), which characterizes this property as being due to external unknown and as yet unmeasured interactions, has had limited successes. Attempts to incorporate it into physical theories in general relativity (Einstein, 1955) and cosmology

(Sciama, 1959) when viewed from the perspective of time have been sparse. Even the experiments (Cocconi and Saltpeter, 1958) attempting to verify its validity have been subject to conflicting interpretations (Dicke, 1961).

This paper attempts in a limited way to remedy the situation of mass in physical theories by reviving an old view of inertial mass which was held by Thompson (1881), Heaviside (1889), Poincare (1929), Abraham (1903), and many others (Wein, 1900; Rohrlich, 1965) at the beginning of this century. In this view the inertial property of matter, inertial mass, is primarily an electromagnetic effect or process. This is due to an intrinsic electromagnetic non-radiative process in flat contradiction to Mach's definition. The definition is quantified in terms of charge e, amplitude R, and angular frequency ω based in notions extended from early atomic analogies.

Postulates as to additivity and stability with space-time coherence being invoked are then advanced. These postulates, in effect, partition the periodic electromagnetic processes involved in these composite stable masses along well tried and highly successful methods employed in several early modern theories and classical mechanics. These take the form of a linear vibration, named a *vibrato,* and a circular oscillation, called a *rotula.* The composite inertial mass composed of two or more of these processes is dubbed a hylon for the sake of brevity.

The inertial mass of the elementary particles are then investigated in terms of the theory and the ad hoc assumptions. By identifying the postulated stable hylon mass with the experimental pion masses, a mass spectrum emerges in terms of the theory which has surprising, but not extremely accurate, correspondence with actual stable elementary particles.

Certain similarities of the numerical mass results with those of more elegant field theories are then discussed. Although the theory is simple the ad hoc postulates could appear fabricated in a manner to yield the best numerical results and indeed they were. Bohr (1913a) had confidence that purely classical physical models could explain physical processes with a few additional ad hoc assumptions and this entire paper can be read in that vein. Then this means that mass is a physical process and the particular choice of the electromagnetic 'hylonic' type chosen in this paper will have to be examined in the future.

1. *Inertial Mass as* E/M *Process*

Most historical efforts which view inertial mass as an electromagnetic process have been enmeshed with the theory of electrons and have failed when applied to the structure of other particles (Rohrlich, 1965). However we can start with a well studied electron analogy. An electron of inertial mass m moving in a circular orbit about a singly charged nucleus $(+e)$ as its inertial mass (cgs. units) given by

$$M = \frac{e^2}{\omega^2 R^3} \tag{1.1}$$

where R is the orbit radius and ω is its angular frequency ($\omega = 2\pi/T$, where T is the period of a single orbit). The above equation can readily be obtained by equating the Coulomb force of the electron with its centripetal force (an inertial effect) due to its motion.

Equation (1.1) is peculiar in some respects since classical physics would have the radially accelerated charge radiate and the resulting motion be aperiodic. However the motion can be considered periodic in real physics and the success of the Bohr model hinges on this consideration (Bohr, 1936b). The relation described by equation (1.1) is also valid for an electron vibrating linearly through the nucleus, similar to a harmonic oscillator of amplitude R, if its motion were not impeded by the nuclear structure. So at least in this relation the inertial mass of the electron is quantifiable in terms of an amplitude R and a frequency ω and we can generalize from this in the form of a postulate.

Postulate 1. (*Definition of Inertial Mass*) Inertial mass in its most primitive form is due to a periodic intrinsic nonradiative electromagnetic process characterized quantitatively by equation (1.1).

The next question that we must answer is exactly how would such processes combine to form a stable composite mass, several of which are well known and accurately determined. Thus we can postulate the existence of a relatively stable composite mass, dubbed a *hylon* (Greek: *Hyle* = basic matter) for convenience by formulating an additivity relation for two, three, or more of these primitive mass processes.

Postulate 2. (*An Additivity Relation*) There exists a relatively stable electromagnetic composite inertial mass unit M, a hylon, such that

(a) for a two process composite

$$M = m_1 + m_2 = \frac{e^2}{\omega_1{}^2 R_1{}^3} + \frac{e^2}{\omega_2{}^2 R_2{}^3} \tag{1.2}$$

and

(b) for a three process composite

$$M = m_1 + m_2 + m_3$$
$$= \frac{e^2}{\omega_1{}^2 R_1{}^3} + \frac{e^2}{\omega_2{}^2 R_2{}^3} + \frac{e^2}{\omega_3{}^2 R_3{}^3} \tag{1.3}$$

In both equations (1.2) and (1.3) m_1 signifies a primitive mass characterized by ω_1 and R_1, m_2 a primitive mass characterized by ω_2 and R_2, and similarly for m_3.

Since the processes characterized by (1.2) and (1.3) yield a relatively stable mass unit we would expect that these periodic processes characterized by m_1 and m_2 (and m_3) would interfere constructively with each other both in space and time. Several possibilities present themselves in this regard when we invoke this constructive interference or coherence. The types chosen are advanced through the following ad hoc quantization postulates which in effect requires coherence both in time and space.

Postulate 3. (*Principle of Space Coherence*) In order to be stable over several oscillation periods an ad hoc time quantization is invoked such that

(a) for a two process composite

$$\omega_1 = n\omega_2 \tag{1.4}$$

and

(b) for a three process composite besides (1.4) the condition

$$\omega_1 = n\omega_3 \tag{1.5}$$

must be added.

In the above equations $n = 1, 2, 3, \ldots$ an integer.

Postulate 4. (*Principle of Space Coherence*) An ad hoc space quantization or partitioning can be assigned to the amplitude of the processes such that

(a) for a two process composite

$$R_2 = j\pi R_1 \tag{1.6}$$

and

(b) for a three process composite besides (1.6) the condition

$$R_3 = k\pi R_1 \tag{1.7}$$

must be added.

In equations (1.6) and (1.7) j, k = an integer ÷ 2.

This space quantization was arrived from mechanical analogies (Charles' theorem (Goldstein, 1959)) and other models employed in several branches of physics. Landau (1941) successfully introduced the notion of partitioning energy into phonons and rotons to explain the properties of superfluids. Equation (1.6) and (1.7) in effect imposes a partitioning of the hylon into two forms or degree of freedom modes; one being a linear vibration or degree of freedom characterized by the ω_1 and R_1 of m_1 while the other is a circular vibration characterized by ω_2 and R_2 of m_2 (and in the case of a three process composite ω_3 and R_3 of m_3). This is somewhat analogous to an s-state of the

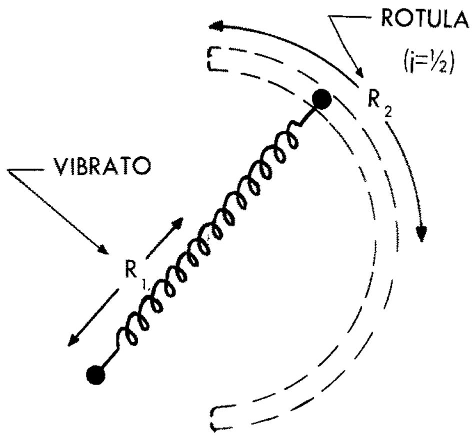

Figure 1—Model of rotula-vibrato space phasing

atom for the linear vibration while the p-state would correspond to the circulatory oscillation. For the sake of brevity the circulatory oscillation m_2 and m_3 is called a *rotula* (Latin: little wheel) and the linear mode is called a *vibrato* (Latin: small vibration). Figure 1 shows a simple model of a rotula-vibrato scheme. It should be noted that the rotula is not a simple rotation but rather similar to the circular oscillation of a torsion pendulum or balance wheel of a watch.

Incorporating these quantization conditions into the two process additivity relation of equation (1.2) we obtain

$$M = \frac{e^2}{\omega_2{}^2 R_1{}^3} \left[\frac{1}{n^2} + \frac{1}{\pi^3 j^3} \right] \tag{1.8}$$

Next for convenience we substitute

$$\alpha(j, n) = \left[\frac{1}{\pi^3 j^3} + \frac{1}{n^2} \right]^{-1} = \frac{n^3 \pi^3 j^3}{\pi^3 j^3 + n^2} \tag{1.9}$$

and

$$M_c = \frac{e^2}{\omega_2{}^2 R_1{}^3} \tag{1.10}$$

Here M_c is a coupled mass consistant with the definition of equation (1.1).

The two process coupled mass M_c then becomes

$$M_c = \alpha(j, n)M \tag{1.11}$$

The three process additivity relation given by equations (1.3) becomes

$$M_c = \alpha(j, k, n)M \tag{1.12}$$

where

$$\alpha(j, k, n) = \left[\frac{1}{\pi^3 j^3} + \frac{1}{\pi^3 k^3} + \frac{1}{n^2}\right]^{-1} \tag{1.13}$$

and M_c is defined by equation (1.10).

2. *Inertial Mass of Elementary Particles*

To test the efficiency of the mass definition advanced and the additivity and coherence conditions one is directed towards the elementary particles for the following reasons (Bernstein, 1968):

(a) All the known relatively stable elementary particles have charges of $\pm e$, or 0 so multiple charge interactions can be neglected in equation (1.1).

(b) The coupling of the photon (*E/M* interaction carrier) to all the elementary particles is the same as that of the photon to the electron. This could augment the notion that nonradiative periodic *E/M* processes, or virtual photon exchanges, are responsible for particle structures just as they are for the Bohr atom.

(c) By the fact that these are elementary particles their composition should be simple, that is, two and three process composites should cover most experimental particles and resonances.

In nearly all the stable particles the pions play a pronounced role, at least when we observe the heavier ones decay. The π^0 is perhaps the longest lived wholly *E/M* particle besides being the least massive particle identical to its own antiparticle. It would be expected then that the uncharged pion would play a strong role in any electromagnetic mass theory emerging strictly from *E/M* considerations. Also in terms of the stability and coherence notions advanced in Postulates 2, 3, and 4 it would be a most likely candidate for M, the mass of our postulated *hylon.*

Testing the π^0 mass in place of M in equations (1.11) and (1.12) surprising correspondences for experimental masses and resonances were found with M_c when the following multiplication rule was obeyed:

$$n = \text{even integer} \qquad M = m(\pi\pm) = 139.58 \text{ MeV} \tag{2.1}$$

$$n = \text{odd integer} \qquad M = m(\pi^0) = 134.96 \text{ MeV} \tag{2.2}$$

Several of the resulting calculated M_c values are listed in Table 1 (equation (1.11)) and Table 2 (equation (1.12)) with the alleged corresponding experi-

TABLE 1. Calculated M_C-values for two-process composite masses† compared to experimental particles‡ and resonances (all mass values in MeV).

$j \backslash n$	= 1	= 2	= 3	= 4
3			1201.71 Σ^-(1197.34)	2191.4 T(2200)
5/2			1192.47 Σ^0(1192.48) Σ^+(1189.41)	2161.9
3/2		549.40 η(548.8)	1172.17	2098 ρ(2100)(?)
3/2		537.71	1118.46 Λ^0(1115.59)	1937 S(1930)
1	130.75	494.48 $K^\pm$(493.72) K^0(497.71)	941.44 N(939.55) P(938.26)	1473 X(1440)
1/2	107.28 μ(105.66)	274.7	365.56	435.4
−1/2	181.91	−17,410	−918.75	−713.91
−1	139.46 $\pi^\pm$(139.58)	640.6	1711.45 N(1700) ? Ω^-(1673)	4614
−3/2		580.5	1328.9 Ξ^-(1321.3) Ξ^0(1314.9)	2636 X( )
−2		567.7	1260.5	2387 U(2360) N^-(2375)
−5/2			1237.61 Δ^+(1236)	2309
−3			1227.88 $\Delta^{\bar{0}}$(1236)	2277 ρ(2275)

† Calculated via equation (1.11) and underlined.
‡ From Review of Particle Properties (1973) and in parenthesis 0.

TABLE 2. Calculated M_C-values for three-process composite Masses† compared to experimental particles‡ and resonances (all mass values in MeV).

$k \backslash j$	$= -1$	$= -3/2$	$= -1$
3	1685 $\Lambda(1690)$ or $N(1690)$ $\Omega^-(1683)$	1313.5 $\Xi^0(1314.9)$	1455 $X(\quad)$
5/2	1667 Λ, Σ, or $N(1670)$	1302	1442 $X(1440)$
2	1627 $\Sigma(1620)$	1278	1413 $E(1413)$
3/2	1526.5 $\Xi^*(1531.6)^0$ $\Xi^*(1535.0)^-$		1338 $A_2(1310)$
1		1008	1009 $A_1(1100)$
−1	2926 $\Sigma(3000)$	1947 $\Delta(1950)$	
−3/2	1947 $\Delta(1950)$	1467 $N(1470)$	1638 $A_3(1640)$
−2	1804 $\Delta(1815)$	1383.9 $\Sigma'(1383)^+$ $\Sigma'(1386)^-$	1538
−5/2	1758 $\Sigma(1765)$	1357	1506 $f'(1500)$
−3	1738 Σ or Λ (1750)	1345	1492
	$n = 3$		$n = 4$

† Calculated via equation (1.11) and underlined.
‡ From Review of Particle Properties (1973) and in parentheses ( ).

mental masses. Negative j-values are included in these tables for heuristic reasons and this has the net effect of subtracting the masses in the additivity relations. This can be viewed as a phasing effect in the rotula-vibrato shceme. In addition $|j| < n$ for both tables.

The surprising success of the pion = hylon mass equivalence prompted investigations as to the similar identity of multiple pion resonances in similar roles. The ρ^0 and f^0, among many others for example, behave very similarly in that they appear wholly electromagnetic in nature and are equivalent to their antiparticle. Table 3 represents a selected single column $n = 1$, $|j| < 1$ for selected mesonic resonances in lieu of the uncharged pion $= M$ equivalance. Several mesonic families seemingly emerge which gives credence to the two-process composition notions.

TABLE 3. Calculated M_c using multiple pion resonances as hylonic mass† compared to alleged experimental particles‡ and resonances (all mass values in MeV).

	Hylonic mass M =				
j	$\pi^0(134.9645)$	$\rho^0(757)$	$\eta'(958.1)$	$f(1270)$	$g(1680)$
1	130.74	733.4	928.2	1230	1627
			$\delta(970)$	$B(1237)$	$\rho(1600)$
−1/2	107.28	601.8	761.6	1010	1336
	$\mu(105.66)$				
−1/2	181.91	1020.3	1291.3	1712	2264
		$\phi(1019.6)$	$D(1286)$	$X(1690)$	$\rho(2275)$
−1	139.46	782.2	990	1312	1736
	$\pi(137.57)$	$\omega(783.8)$	$S^*(997)$	$A2(1310)$	$X(1795)$

† Calculated via equation (1.11) with $n = 1$ with values underlined.
‡ From Review of Particle Properties (1973) and in parentheses ( ).

The numerical mass spectra emerging from the theory will be analyzed in the subsequent section as to possible strengths and weaknesses. It must be remembered that j, k, and n, the ad hoc quantization numbers of Postulate 3 and 4, are not physical parameters adjusted to give a best fit with experimental data. They exist to give space-time coherence, a reasonable demand that should be expected in any stable composite process. Then too the base mass unit, the hylonic mass M, is in each case a firmly established experimental mass value and not a new phenomenological input to give best agreement between the calculated values and known experimental masses. The odd-even multiplication rule, equations (2.1) and (2.2), can be regarded as a phenomenological choice of many possible alternatives but not ever as a new phenomenological mass input.

3. *Analysis of Mass Spectra*

The three numerical tables yield a definite mass spectra consistent with the mass definition and the related postulates with the additional odd-even n-multiplication rule of equations (2.1) and (2.2). Certain trends appear to be evident and these are analyzed in terms of groupings, stability, decay schemes, vacancies, and predictions which emerge from this theory.

Groupings. The groupings which emerge from looking at these three tables appear to be considerably different from those in present particle theories, although there are similarities. For instance all the baryons and baryon resonances have $n = 3$ which has hints of *SU*-3 and *SU*-6 which have these particles as being composed of a basic triplet (Han and Nambur, 1965). As in several symmetry theories we find the mesons at $n = 2$ and $n = 4$ (missing bosons) (Namiki, *et al.*, 1972). The use of multiple pion resonances as hylonic mass units in Table 3 yields good results and emergent mesonic families such as the vector mesons in the second column, but its relative success is hardly explainable. Little can be claimed for the other meson families suggested by this table due to their experimental mass widths.

In Table 1 with $n = 3$ we find a total of twelve relatively stable baryons if we include the Ω^- at $(-1, 3)$ and the Ξ^0 at $(-3/2, 3)$. Six have $j > 0$ while the other six have $j < 0$. The Δ^{++} does not appear since Postulate 1 is valid only for singly charged particles. If we relegate the Ω^- and Ξ^0 to Table 2 there would remain only 10 baryons with the Ξ^0 the only stable member with $j < 0$. There appears to be no reason why the Σ' (1384) at $(-3/2, -2, 3)$ and the Ξ^* (1527) at $(-1, 3/2, 3)$ should be accorded prominent status over any of the other resonances of Table 2. Several theories assign them prominent baryon roles.

As for the mesons appearing in the $n = 4$ column of Table 1 and the last column of Table 2 (again with $n = 4$) little can be claimed due to the experimental widths of the alleged sited particles. Only a few are known to 10 MeV and little or no family status emerges although the often mentioned mesonic nonets do not seemingly appear. For instance the K does not appear at all with the vector mesons ρ, ω, ϕ either in Table 3. However, the $K^\pm$, K^0, n and $\pi^\pm$ seemingly belong together in Table 1. At least several of the emergent mesonic families are different in this theory than in others suggested so far.

However since only mass was considered in these formulations it is obvious that symmetries which hint of underlying space-time structures should be important when yielding observables concerning these particles such as spin, magnetic moments, etc. These will be considered later when predictions are suggested.

Stability. In general two process composites yield more stable and recognizable masses than do three process composites. This can readily be seen from glancing at the alleged sited particles in Tables 1 and 2. Of particular importance is the $j = 1$ dominance in the $n = 2, 3$ columns of Table 1 thus hinting strongly of a space closure property, that is, a rotula completely encloses a vibrato. The lack of alleged particles at the $j = \frac{1}{2}$ sites further augments this notion. From Figure 1 it can readily be seen that $j = 1$ for closure. Invoking this property further adds to the mystery of the muon at the $(\frac{1}{2}, 1)$ site but the muon is a mysterious particle in all theories.

The Σ^0 at $(5/2, 3)$ and the η at $(2, 2)$ perhaps represent the best agreement in Table 1. This could be expected since they are totally E/M in nature and thus recognizable as fulfilling Postulate 1. The Δ (1236) could also be claimed as strong or good agreement. It is evident that in most cases the uncharged particles come closest to the calculated mass values. A charge localization energy could be implied if we were to consider the difference between the calculated values and the experimental values to be a binding energy or sorts. A value of about 3.2 MeV close to the photon with wavelength of an electron Compton wavelength, appears to be common value. The negative 3.2 MeV binding energy for the K^0 is hardly understandable in this context.

Decay Schemes. On the basis of the prime or dominant decay schemes which for instance has

$$\Sigma^0(5/2, 3) \to \Lambda^0(3/2, 2) + \gamma \qquad \Delta j = -1$$

$$\eta(2, 2) \to 2\gamma \qquad \Delta j = -2$$

there is a pronounced tendency to equate the photon with a $j = 1$ transition. Thus it could very well be that a rotula is a photon circulating coherently.

When we examine the prime decays of all the $j > 1$, $n = 3$ baryons we see that all the half integral Δj-transitions between 0 and -2 are filled. As shown in Table 4 these transitions yield the surprising results that integral Δj-transitions result in uncharged baryon products while half integer (nonintegral) transitions give both charged and uncharged products or residue baryons. If we adopt this trend as a rule we can assign the $\Delta(1237)$ to the appropriate sites as is done in Table 1 and Table 4. Considering only the magnitude of Δj

TABLE 4. Baryon transitions in rotula–vibrato model

Prime Decay†	Transition
$P(1, 3)$ to $N(1, 3)$ $N(1, 3)$ to $P(1, 3)$	$\Delta j = 0$
$\Lambda(3/2, 3)$ to $P(1, 3)$ or $N(1, 3)$	$\Delta j = -1/2$
$\Sigma^\circ(5/2, 3)$ to $\Lambda^\circ(3/2, 3)$	$\Delta j = -1$
$\Sigma^+(5/2, 3)$ to $P(1, 3)$ or $N(1, 3)$	$\Delta j = -3/2$
$\Sigma^-(3, 3)$ to $N(1, 3)$	$\Delta j = -2$
$\Omega^-(-1, 3)$ to $\Lambda^\circ(3/2, 3)$ or $\Xi(-3/2, 3)$	$\Delta j = +5/2$ $\Delta j = -1/2$
$\Omega^-(-1, 3, 3)$ to $\Lambda^\circ(3/2, 3)$ $\Omega^-(-1, 3, 3)$ to $\Xi(-3/2, 3)$	Δj or $\Delta k = 5/2, -3/2$ Δj or $\Delta k = -1/2, -9/2$
$\Xi^{\bar{\circ}}(-3/2, 3)$ to $\Lambda^\circ(3/2, 3)$	$\Delta j = 3$
$\Delta^+(-5/2, 3)$ to $N(1, 3)$ or $P(1, 3)$	$\Delta j = 7/2$?
$\Delta^{\bar{\circ}}(-3, 3)$ to $N(1, 3)$	$\Delta j = 4$?

† From *Review of Particle Properties* (1973).

we see that all the $|\Delta j| = 0$ to $|\Delta j| = 4$ transitions are filled with only the Ω^- displaying the bifurcated decay scheme.

On the other hand if we consider the Ω^- as having the additional rotula as in Table 2 the two possible transitions exist where Δj (or Δk) $= -9/2$ and $3/2$. Thus there seems to be a repeatability in these decays in terms of $\Delta j = 3$ as might be expected from symmetry considerations.

Vacancies. Vacancies occur in many sites in Table 1, 2, and 3 and some of these could have been remedied by the insertion of very risky resonances, e.g., the $\epsilon(600)$. However when we view the model of the two-process rotula vibrato phasing in space time as in Figure 1 we can see immediately that space-time degeneracies exist. For instance with $n = 2$ it would be impossible to differentiate the $j > 0$ hylons from those with $j < 0$ in space and time. Thus the mass vacancies that exist for $j < 0$ can be considered degenerate states insofar as symmetries are concerned of the $j > 0$ states. Now if again in the $n = 2$ column we exclude the $j = \frac{1}{2}$ sites due to the required closure property, we are left then with only three sites (2, 2), (3/2, 2), and (1, 2) two of which have well established resonances. The vacancy at (3/2, 2) could perhaps be part of the η resonance since there appears to be two separate cases in its dominant decay, one charged and the other uncharged.

The vacancies that exist in the $n = 3$ column of Table 1 at $|j| = 2$ and $|j| = \frac{1}{2}$ can be explained in a similar manner. The $j = 2$ and $j = -1$ symmetries appear identical as do the $j = -2$ and $j = 1$ cases. The $n = 1$ column is the most difficult to explain in Table 1 since there is a particle at $(\frac{1}{2}, 1)$ and none at (1, 1). The muon chooses the small mass value while the charged pions choose the largest of the two available. However it should be mentioned that had the charged pions been used as the hylonic mass in the $n = 1$ column the π^0 would have appeared at the (1, 1) site. However the muon would not have appeared at all under these conditions.

It might be argued that $\Sigma'(1385)$ at (–2, –3/2, 3) of Table 2 fills the $j = 2$ site of Table 1 by adding another rotula or degree of freedom to remove the degeneracy. Thus this additional degree of freedom removes the possibility of the 1260 MeV mass predicted at this site.

Predictions. Several predictions can be made based on groupings, decay schemes, stability criteria and vacancies as explained in the previous discussions. Of the multiple possibilities that present themselves the following are worth considering since they for the most part are different than expected from present theories:

(a) The spin of the $\Xi^-(3/2, 3)$ should be $3/2\hbar$ rather than the $\frac{1}{2}\hbar$ suggested by most theories. This also should be the case of the Ξ^0. All $j < 0$ baryons should be distinguishable physically from $j > 0$ baryons if j is to be meaningful and spin is the most likely candidate.
(b) The $\Delta(1236)$ baryon resonance (spin = 3/2) should be partitioned with the Δ^+ at (–5/2, 3) and the $\Delta^{\bar{0}}$ at (–3, 3) as is done in the Tables. This

is based on the j-transition rule observed in the decay schemes of the baryons and energy conservation.

(c) Fragile baryon resonances should exist at 1172 and 1260 MeV.

(d) A mesonic resonance should exist at 537 MeV (3/2, 2) which might aid in explaining the multifurcated η decays. The observed η could consist of a mixture of both the (3/2, 2) and the (2, 2) sites.

(e) The Ω^-, whose decay is perhaps the least understood of all the baryons (Namiki, et al., 1972), is a mixture of the (−1, 3) site and the (−1, 3, 3) state. The uncharged Ξ^0 can be considered similarly.

(f) Further spin classifications in terms of the signature of j would indicate that J^P for $E(1413)$ is 1^+ and 2 for $f(1540)$.

(g) Fragile baryon resonances of the three process type should exist at 1008, 1278, 1300, 1345 and 1357 MeV.

(h) Mesonic resonances, perhaps the X mesons (?), should exist at masses of 1442, 1455, and 1492 MeV. An additional mesonic resonance of the vector type should exist at 733.4 MeV.

These eight predictions are listed above since they represent evidence for particle structure different from that suggested by several present theories and in some cases point towards the existence of new resonances. Perhaps a more accurate determination of Ξ spin or Δ(1237) mass splittings can be made which can test the efficacy of this model. Then this rotula vibrato model which arises solely out of mass considerations can be compared and evaluated with the other theories arising mostly out of symmetry considerations.

The appearance of so many sophisticated particle classification schemes causes one to wonder if this is much more than a rubricizing effort. This would mean that these classifications are a pathologizing of the normal healthy effort to organize and unify a truly experienced world. This effort places the emphasis on the classifying and the schemata rather than the real perceiving and experiencing. For example, we might have physicists evaluate particle theories as to whether or not they belong to SU-3 or SU-6 or some other classification and set its value by this much as in the same way art critics are often accused of looking at the name plate before looking at the painting.

It must be remembered in evaluating these predictions that they are based on a mass classification scheme and the property of inertial mass is perhaps the most universally and immediately perceived of all particle properties (charge excepted). Abraham Maslow (1966), the late great psychologist who defined this rubricizing tendency of the modern sciences went on to say that it is or degenerates to 'a shuffling, classifying, and filing of the non experienced. It is a thin and bloodless activity, rarely happy or enjoyable except at a low level in the hierarchy of pleasures. It is a kind of a relief rather than a positive enjoyment.' Mass at least is immediate and positive.

4. *Mass of the Electron*

The mass of the electron, which is most conspicuous by its absence from the three numerical mass tables, can be found by introducing an alternate form of equation (1.8) in terms of the theory of mass advanced. If we define a reciprocal mass M_c^* in a manner similiar to equation (1.10) of the form

$$M_c^* = \frac{e^2}{\omega_1{}^2 R_2{}^3} \tag{4.1}$$

then the hylonic mass formula takes the form for a two process composite

$$M = M(j, n) = M_c^* \beta(j, n) \tag{4.2}$$

where $\beta(j, n)$ is defined as

$$\beta(j, n) = (n^2 + \pi^3 j^3) \tag{4.3}$$

The following β-values are of extreme interest:

$$\beta(2, 4) = 264.05$$
$$\beta(2, 5) = 273.05$$

These two values are very close (0.033%) to the well known ratio of pion masses to the electron mass. The best available ratios at present are 273.12 ± 0.03 and 264.12 for the charged and uncharged pions respectively (Particle Data Group, 1973).

However it must be noted that the odd-even multiplication rule specified in equations (2.1) and (2.2) had to be interchanged to bring the β-values in agreement with the experimental results. Nonetheless the definition of M_c^* is consistent with equation (1.1) and the quantization conditions specified in equations (1.4 and (1.5) remain the same. The utilization of the $j = 2$ (total closure condition) for stability is enhanced by the above numerical yield.

The distinctions that traditionally exist between leptons and hadrons and leptons and bosons and even between bosons and baryons are greatly diminished in the mass theory of these particles advanced here. If the results expressed numerically above are indicative of a basic electron-pion relationship at the hylonic level rather than mere coincidence then it would be extremely interesting to examine the hadronic or bosonic masses associated with these same (j, n) values. The resulting masses from equation (1.8) are $M_c = 2098$ MeV (2, 4) and $M_c = 3065$ MeV (2, 5). The first of these can be considered as a conjugate bosonic electron mass since $n = 4$. The second can be considered as being a conjugate hadronic electron mass ($n = 5$).

If such particles exist in actual fact they should be unique and have considerable physical significance if for no other reason than that they have the same (j, n) values as that of the electron. In terms of the hylonic model they just represent an interchanging of indices on ω and R in the coupled mass equations (1.10) and (4.1). The $\rho(2100)$ was assigned to the (4, 2) site in Table 1 since it could be considered as being the closest experimental particle if indeed it exists at all. For the sake of brevity and in the absence of experimental particles in their mass ranges (~3000 MeV) the $n = 5$ column was omitted from Table 1.

The fact that the electron has a hadronic and bosonic mass associated with it leads one to inquire as to the possibility of some of the baryons and mesons suggested in Table 1 might not have leptonic masses associated with them calculated from equation (4.3). Thus for the proton a leptonic mass of 3.5 MeV can be calculated for M_c^* and for the other particles of interest several leptonic masses of the order of 1 MeV can easily be calculated.

5. *Some General Considerations*

In its purest form, classical physics, and even modern physics for the most part, is nothing more than a description or picture of mass and charge in space and time. All physics views mass and charge as phenomenological inputs whose basic values are not calculable in any theory. Looking at these four basic primitives

M – mass
Q – charge
R – space
T – time

we can see immediately that Q is quantized in $\pm e$ in fact, or at least in terms of $e/3$ in some theories (Meslow, 1966). There is no present theory which consistently postulates the granularity of mass in a similar manner. The electron still maintains its solitary position of being the smallest experimental inertial mass unit and most historical mass theories have begun with it.

If one is willing to adapt a space-time view of physics as suggested by Feynman and Wheeler (Feynman, 1947) perhaps the small rigid ball concepts and infinite field values can be wholly neglected. All local field theories yield infinite bare masses without renormalization and require an ad hoc introduction of mass. Should inertial mass in its most primitive form be animated in at least having some degrees of freedom in space-time, one could expect these motions (at this lower hylonic level) to be coherent. Analogous to the case of the de Broglie wave picture incoherent motions would be unstable. A definition of inertial mass m as

$$M = m(Q, R, T) \tag{5.1}$$

would appear to just be a use of Occams razor (see footnote 1) in shaving off another primitive or ad hoc input. The definition of mass posed in equation (1.1) and Postulate 1 is such a definition.

The fact is that the inertial mass of all the more stable particles appears to have just minimum mass values when one considers special relativity (*SR*). A finite R or extension in space could imply a finite lower cutoff in mass as well as being consistent with Descartes' notion of mass = extension (Descartes, 1916). A serious question can be asked in considering the mass definition in terms of *SR* but this could be a useless notion. Equation (1.1) of its very nature must be considering only nonradiative E/M interactions while the

[1] Attributed to William of Occam (Ockham), died 1349, which forbids use of superfluous or extra unneeded concepts in describing reality.

fundamental condition for the validity of *SR* is that reception or absorption of *E/M* radiation follows emission of the same (Einstein, 1905).

The role of the pions in being equivalent to the postulated stable hylon is worth further consideration. If we assume the validity of *SR* at this lower level, a good consistent boundary condition that can be made use of is

$$\omega_h R_h \leqslant C = 3 \times 10^8 \text{ m/sec} \tag{5.2}$$

where ω_h and R_h are the angular frequency and amplitude associated with this hylonic motion. The π^0 mass when viewed in terms of equation (1.1) and the above asymptotic limit becomes

$$M(\pi^0) = \frac{e^2}{R_h c^2} \tag{5.3}$$

which yields $R_h = 1.07 \times 10^{-17}$ meters. This value is an excellent candidate for the fundamental length or "hodon" proposed by Heisenberg (1958) and others.

Again assuming the validity of *SR* in a stronger *E/M* radiation case, the decay of π^0 to two photons, energy conservation demands that

$$M(\pi^0)C^2 = \hbar\omega_{r1} + \hbar\omega_{r2} \tag{5.4}$$

where $\hbar$ is Planck's constant divided by 2π and ω_{r1} and ω_{r2} are the angular frequencies of each respective photon. Since $R_h \leqslant c/\omega_h$ from equation (5.2) the result

$$\hbar \geqslant e^2/c \left(\frac{\omega_h}{\omega_r}\right) \text{ if } \omega_{r1} = \omega_r \gg \omega_{r2} \tag{5.5}$$

is of considerable interest since $\hbar$ is explainable in terms of a frequency ratio, hylonic to Planck radiation, scaled by two other universal constants e^2 and c.

These considerations advanced seem to strongly indicate that indeed a 'sub-quantum' mechanics (Bohm, 1957) or electrodynamics exists at this hylonic level. The motions are characterized in space and time with frequencies 137 ($=\hbar c/e^2$) times faster than the normal *E/M* radiation frequency and amplitudes of the order of 10^{-17} meters. The indicated presence of these 'hidden variables' poses the possibility that normal Planck radiation is a fine structure effect on this hylonic level. However, whether or not this hylonic level is observable is not too clear since by its very postulate of existence it does not radiate.

In his philosophy of organism, which he hoped would serve as a good conceptual framework for physics and ultimate reality, Alfred North Whitehead asserts that matter apart from being a periodic process would have no existence. Only the process which is vibratory in nature and coherent in space and time would be real. He further suggests a model for ultimate reality or primitive particles in the following manner:

> A primate (primitive mass process for our purposes) must be associated with a definite frequency of vibratory organic deformation so that when it goes to pieces it dissolves into light waves of the same frequency, which carry off its

> average energy. It is quite easy to imagine *stationary vibrations of the electromagnetic field of definite frequency, and directed radially to and from a center,* which, in accordance with accepted electromagnetic laws, would consist of a vibratory spherical nucleus satisfying one set of conditions and a vibratory external field satisfying another set of conditions . . . . I have not worked out the conditions for stability or for a stable association (Whitehead, 1948).

It would appear that the working out of this model for the case of primitive or elementary particles would give impetus to the organic theory envisioned by Whitehead. At the hylonic level the rotula and the vibrato come close to the "vibratory organic deformation" and the "vibratory locomotion" which were the two fundamental constituents of ultimate reality in his philosophy of organism. Thus the hylonic level is the level at which matter is animated if one were to equate the view proposed here in this paper with that of Whitehead. Incidentally hylozoism is the theory that all matter is animated and thus the choice of hylon is fortuitous in this sense.

Whether this hylonic view of mass as a primitive periodic process coincides with the platonic views of Whitehead is left to time and the reader to evaluate. Nonetheless there is a semblance of identity which is more than superficial. An organic physical theory of primitive particles would be transcendentally interesting and add life to a subject that has been rubricized and mechanized far too much. If it could yield useful physical parameters for the elementary particles besides being aesthetically appealing it would be an excellent theory indeed.

6. *Conclusion*

Bohr's insight which states in effect that classical physics can describe nature provide a few additional ad hoc postulates are added seems to be well borne out in this paper. Regrettably the calculated mass spectrum emerging in Tables 1, 2, and 3 does not have the one part in 40,000 correspondence Bohr's derived formula had with the experimental Balmer series. This perhaps can be excused in terms of the relative strength or magnitude of the energies involved (a few MeV) and forces one once again to come to terms with the uncertainty principle. Another explanation deserving consideration could be that the mass of elementary particles and resonances are not primarily due to E/M processes at all or at least a small part of the mass is not. This is particularly true for the Ω^- in the case of the alleged baryons.

As an elementary particle theory this rotula-vibrato or hylonic model is inadequate for several reasons. Magnetic moments, in order to be calculated, would require further assumption as to what exactly is undergoing these periodic oscillations. Doublet states such as those sited at (1, 3) and (1, 2) or even possible triplets are not explainable. The presence of negative mass at a few $j = -\frac{1}{2}$ sites can be dismissed in terms of a general closure property (a rotula must completely encircle a vibrato) but this is not too clear at least in the case of the muon at $(\frac{1}{2}, 1)$. Additional work on rotation symmetries of possible two process hylonic states was done at length but little or no correspondence with actual observed particle symmetries emerged.

The most serious criticism might be that several particle masses can be calculated to comparable accuracies by the mysterious Gel-Mann-Okubo mass formula (Gell-Mann, 1962; Okubo, 1962) or the Coleman-Glashow mass splitting formula (Coleman and Glashow, 1961) which rest on more elegant foundations. However it must be remembered that both GMO and the generalized baryon mass formula of *SU*-6 do have several phenomenological mass inputs obtained from statistical fits with experimental data. To date none of these inputs, three distinct ones for GMO and five for the generalized *SU*-6 formula (Beg and Singh, 1964), have corresponded to actual particles or resonances nor was such intended. The strength of the hylonic model is that well known experimental value (the pion masses) serve as the base mass units and the selection of the particular species can be considered a phenomenological choice rather than an input.

Then too if j, k, and n are given the status of quantum numbers in a manner similar to strangness, isospin and supercharge (which are enmeshed in present mass theories) then equations (1.11) and (1.12) represent a considerable improvement over any other theoretical mass formula. All mass theories to date employ several quantum numbers and their success rests on the elegance of their foundations. The elegance of this theory rests on invoking space-time coherence at this new level of matter.

Of the many empirical mass formulas available for baryons (Schwinger, 1968; French, *et al.*, 1967), baryon resonances (George, 1966; Muraki, 1969; Maglic, 1966), and nuclear isobars several are reasonably accurate but nonetheless subject to criticisms (Saleem, 1968a, b) for some reason or other. Nearly all require a composition assumption, i.e., baryon resonance equals baryon plus meson, which may or may not have a sound basis. No good emperical formula is presently available for both mesons and baryons and none distinguish between the more and less stable particles.

What is surprising is that a mass formula of a relatively simple nature yields such a mass spectrum from the considerations advance here. It could be accidental but then why do only the more stable particles emerge in Table 1? Even the appearance of the electron is puzzling and deserving of further consideration. What is contained in these results are hints of underlying structures as being responsible for elementary particles. For instance a rotula could be considered as a bound photon when isolated by itself. Perhaps Jordan's (1935) suggestion of a photon being actually two noninteracting neutrinos is worthy of being revived. If these two massless particles, the neutrino and photon, can be explained in terms of the definitions advanced then it certainly would be a complete particle theory.

In terms of the theory three strong general conclusions can be drawn. These are the following:

(a) Internal structure of the elementary particles in space and time is evident.
(b) The relatively simple composites are the most stable, e.g., $j = 1$ row.
(c) Two process composites are more stable than three process composites.

All of these could be expected for actual elementary particles and any good theory should get these same resulting conclusions.

The theory ultimately rests on the assertion that inertial mass is electromagnetic in nature and rather simple E/M processes are chosen. The fact that this process is nonradiative and exists only on the hylonic level is hauntingly familiar to students of modern physics. Rotulas and vibratos are capable of producing resonances in the minds of those who revive ptolemaic theories or Platonic notions as in Whitehead's philosophy of organism.

Had the numerical results been a little more accurate or the ad hoc assumptions a sounder basis this would be an excellent theory. This regrettably is not the case. However, it is felt that a case is made of considering elementary particles as being primarily electromagnetic in nature and possessing a space-time structure. The case could be stronger. But then mass is a mysterious process, if not electromagnetic, and will require more old concepts, new insights, and hard working physicists to fully comprehend in the future.

7. *Added Note of Interest*

The recent discovery (Auber, *et al.*, 1947; Augustin, 1974; Bacci, 1974) of the new and theoretically unexpected J or $\psi(3105)$ prompts renewed attention on the conjugate mass notions mentioned in this paper. The hadronic conjugate mass M_c calculated by the methods advanced here yields 3065 MeV while employing the electrons quantum rotula-vibrato numbers (2, 5). A claim can be made that this newly discovered particle is the conjugate hadronic mass of the electron.

In terms of the theory advanced here $M_c^* = e^2/\omega_1{}^2 R_2{}^3 = m_e$ when $j = 2$ and $n = 5$ while using the charged pion as the hylonic mass unit. The conjugate hadronic mass for (2, 5) using equation (1.8) is

$$M_c = \frac{e^2}{\omega_2{}^2 R_1{}^3} = 3065 \text{ MeV}$$

which uses the uncharged pion as the hylonic mass unit consistent with equations (2.1) and (2.2). As can readily be noted the distinction between the above two mass equations is strictly interchanging the indices on ω and R,

The 1.3% agreement could admittedly be much better but for mass formulas in general is hardly lamentable. Should another find occur at about 2100 MeV, the electrons conjugate bosonic mass, the claim expressed above would be greatly strengthened. Little need be said at present for looking at the leptonic conjugate mass of the proton at 3.5 MeV.

If indeed the correspondence between the electrons conjugate mass and the J or ψ particle can be made its physical significance should be considerable. An interesting view emerges from the symmetry of the above two mass equations that each baryon would have its leptonic conjugate mass while each hadron or boson would have its conjugate leptonic mass. Thus the division that separates them at present into leptons and hadrons, a division which is largely made on a mass basis, turns out to be a view and really a choice of the frequency and amplitude considered. Thus all are one in the hylonic order of particles.

Since the $n = 5$ column was not included in Table 1 it might be worthwhile at present to predict the following resonances at the mentioned j-sites. The lighter ones of these which should be the most readily detectable are

$n = 5$	$j = 1$	M_c 1870 MeV
	$j = 3/2$	M_c 2720 MeV
	$j = 2$	M_c 3065 MeV
	$j = 5/2$	M_c 3200 MeV
	$j = 3$	M_c 3280 MeV

If it turns out that families of Js or ψs are found in this mass region then these are the more likely mass values in terms of the theory advanced here.

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