THE MASSES OF ELEMENTARY PARTICLES CALCULATED
BY A MAGNETIC MONOPOLE MODEL
THEORETIC IMPLICATIONS

by

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Abstract and introductory comments

The results of an investigation into the possibility of using
semi-classical methods in the calculation of energy levels in a
system of magnetic monopoles are presented. It was found that
semi-classical methods can successfully be used for this purpose,
and an approximation procedure has been developed which has
made possible a theoretic calculation of the masses of a long
array of elementary particles with errors mostly lower than 1 %
(see table 5,6A and 7). A machine program is now available which
calculates the mass of an elementary particle whose structure
(configuration) defined in terms of the involved magnetic mono-
poles is punched in an input card. The possibility of using
the program as a means to test various theoretic structures of an
elementary particle (mass testing procedure) by comparing its
theoretic mass calculated by the machine with the experimentally
observed one is found to be a powerful tool in the identification
of particle structures (see table 5).

The first problem which arises when one attempts to apply semi-
classical or any other quantization methods to a system of magne-
tic monopoles is related to the large size of the magnetic charges
which are greater than or equal to $\frac{137}{2}$ times the electronic charge.

The great charge of the magnetic monopoles is generally assumed to
create almost unsolvable difficulties for the calculation of the
energy levels of a system of two opposite magnetic charges in orbit
about each others. A main contribution of the theory presented
in this and the preceeding papers on this subject is the evidence
presented in section 5, that if the semi-classic theory is applied
selfconsistently, the calculation of the energy levels is not at
all an unsolvable problem. If semi-classical methods have been
used at all in this sort of calculations, they must have been used
without being aware (or without taking into account) that the orbits
corresponding to the lowest energy levels are far inside the respec-
tive magnetic monopoles (their semi-major axes are far smaller than
the classical radius of the magnetic monopoles involved). Inside
the magnetic monopoles the attraction force between two charges
does not grow to infinity in a coulombian fashion, but on the con-
trary it decreases towards zero when the distance between their
centers approaches zero. As a result the force and potential field
can never become large enough to create unsolvable difficulties for
the calculation of energy levels as proved in section 5 (see tables

3A, 3B, 3C showing an example of calculated energy levels).

Inside magnetic monopoles the coulombian field must be replaced by
an "asymptotic coulombian" field which fulfills a few requirements
imposed by semi-classic theory. One of these requirements is that
in stead of going to - ∞, the potential field must go to a finite
limit calculated in section 5 when the distance r between the two
charges goes to zero. One of these asymptotic coulombian fields
(presented in the appendix) which gives a good fit between calcula-
ted and observed masses of many elementary particles has been used
in our machine programs.

The structures of elementary particles identified by the mass testing
procedure mentioned above is in many cases substantially different

from conventional structures. Besides the three quarks, which in our model are ascribed a magnetic monopole charge $g = \frac{137.0}{2} e$ (e being the electronic charge), an other monopole, called baric and designated by the letter B, with a triple magnetic charge -3g and spin 0 is included in every bariyon. The triple negative magnetic charge of the baric neutralizes the three positive charges of the quarks, leading to magnetically neutral baryons. Moreover, by ascribing to the baric a single negative electric charge, it is possible to add a positive electric charge + 1/3 to every quark without changing the electric charges of the baryons or any other kind of hadrons. The use of integer electric charges has made it possible to interpret also the masses and other properties of leptons, considered as structures formed by magnetic monopole associations like the other elementary particles, without running into difficulties created by the use of fractional electric charges.

Substantial differences from conventional quark models are also introduced in the interpretation of mesons. Several mesons are ascribed structures different from the quark-antiquark associations usually ascribed to them. The main characteristic discriminating mesons from other particles in our model is that their structures always include two and only two fermions, whereas baryons include three fermions, and leptons only one fermion. The modified meson structures present startling symmetries related to the various meson families, and reminiscent of the symmetric properties ascribed to them in conventional quark models.

1. Introduction

The aim of this paper is to give an elementary presentation of the
method of calculating the masses of elementary particles (Barricelli
1978 B and 1980) based on a magnetic quark model, and present several
implications of the results obtained. We shall start by presenting
some of the main groups of elementary particles whose masses have
been calculated by our model. We assume that the reader is familiar
with the subdivision of elementary particles into the groups and
families listed in table 1 and with some of the basic ideas for
their interpretation by various quark associations based on the 4
quarks u, d, s and c according to conventional quark models. A
rudimentary magnetic quark interpretation to be better specified sub-
sequently, is also hinted for baryon families in table 1. The mas-
ses of all the particles listed in table 1 have been theoretically
calculated by applying a magnetic quark model which will be presen-
ted in this paper. All but three of the calculated masses present
errors lower than 1% and none has errors greater than 2.5% (see
tables 5, 6A and 7).

The model which has made these results possible is based on the
assumption that each quark has an elementary magnetic monopole charge
+g called "Dirac monopole" (see next section. It is unknown
whether the positive charge is a South or North magnetic charge).
Besides the usual three quarks, an other magnetic monopole, a boson
of spin 0 and magnetic charge -3g (hereafter called "baric" and
designated by the symbol B^3 or briefly B, see interpretations in
table 1) is supposed to be part of each baryon. The triple nega-
tive magnetic charge of the baric makes up for the positive magne-
tic charges of the three quarks, leading to magnetically neutral
baryons. The magnetic monopole charges of the quarks and the
baric are assumed to be much stronger than their electric charges
(see next section). In the semi-classical model we are going to
use, the quarks are assumed to move in orbits about the baric,
much the same way as the electrons which move in orbits about an
atomic nucleus.

Table 1

BARYONS

A. The 8 lightest spin ½ baryons (Octett).
p=proton, n=neutron

Mass MEV	Strange-ness			
1320	-2	Ξ⁻	Ξ⁰	
1190	-1	Σ⁻	Σ⁰	Σ⁺
1115	-1		Λ	
938	0		n	p
Charge	→	-1	0	+1

Interim magnetic quark model interpretation.
B is assumed to have spin equal to zero, and
a magnetic monopol charge 3 times larger and
opposit to that of a quark.

-2	BDSS	BUSS	
-1	BDDS	BUDS	BUUS
-1		BUDS	
0		BUDD	BUUD

B. Spin 3/2 baryons (Decaplett).

Mass MEV	Strange-ness				
1672	-3	Ω			
1535	-2	Ξ⁻	Ξ⁰		
1385	-1	Σ⁻	Σ⁰	Σ⁺	
1232	0	Δ⁻	Δ⁰	Δ⁺	Δ⁺⁺
Charge	→	-1	0	+1	+2

Interim interpretation.

-3	BSSS			
-2	BDSS	BUSS		
-1	BDDS	BUDS	BUUS	
0	BDDD	BUDD	BUUD	BUUU ·

C. Charmed Λ$_c$ baryon of spin ½.

Mass(MEV)	Charm	Strangeness	Charge	Interpretation
2260	+1	0	+1	BUDC

Table 1 (continued)

MESONS

D. Two nonets of spin 0 and spin 1 respectively.

Spin 0 Nonett

Mass MEV	Strangeness			
960	0		$\eta^{\times}$	
549	0		η	
498	−1 +1	K^-	K^0 K^0	K^+
140	0	π^-	π^0	π^+
Charge →		−1	0	+1

Spin 1 Nonett

Mass MEV	Strangeness			
1020	0		ϕ	
783	0		ω	
894	−1 +1	$K^{\times -}$	$K^{\times 0}$ $K^{\times 0}$	$K^{\times +}$
771	0	ρ^-	ρ^0	ρ^+
Charge →		−1	0	+1

E. Mesons involving charmed quark.

Spin 0 meson

Mass MEV	
2830	η_c
Charge	0

Spin 1 meson

Mass MEV	
3095	Ψ
Charge	0

Charmed mesons

Spin 0 triplet

Mass MEV	Strangeness		
2040	1	F^+	
1868	0	D^+	D^0
Charge →		+1	0

Spin 1 triplet

Mass MEV	Strangeness		
2140	1	F'^+	
2009	0	D'^+	D'^0
Charge →		+1	0

F. LEPTONS (Spin $\frac{1}{2}$)

Mass MEV		
1807	τ	
106	μ	
0		ν_μ
0.511	e	
0		ν_e
Charge	±1	0

An other difference from conventional quark models was introduced
by the following consideration. By ascribing to the baric also an
electric charge -1, and adding an electric charge 1/3 to each
quark it is possible without changing the electric charges of
baryons and mesons, to avoid using quarks with fractional electric
charges. By adding the electric charge 1/3 to the u and c quarks,
which in the conventional quark model have the charge +2/3,
we obtain quarks with the charge +1, and the other two quarks d and
s, which in the conventional theory have a charge - 1/3, obtain
an electric charge equal to zero. All this can be done without
changing the electric charges of the baryons and mesons.

This choice of electric charges proved very convenient because it
has made possible an interpretation of the leptons by the same
magnetic monopoles used in the interpretation of baryons and
mesons. By the interpretation obtained this way the masses of
leptons can be calculated theoretically just as the masses of ba-
ryons and mesons. Such interpretation of lepton properties would
have been impossible with the conventional quark charges without
assigning to the leptons fractional electric charges such as 1/3
and 2/3 of the electron charge.

Main properties of the baric and the various quarks are listed in
table 2, where the symbols B^3, U_1, D_1, S_1, C_1 are used in order
to designate the baric and the four quarks u, d, s, c. The corres-
ponding antiparticles are designated by the symbols B_3, U^1, D^1, S^1,
C^1 where low indexes identify the number of positive magnetic char-
ges, upper indexes the number of negative ones, expressed in Dirac
monopole units.

The dynamic assumptions we will use in this presentation involve
only concepts familiar to every one who has been exposed to the
basic ideas of Bohr's atomic theory. It does not require any know-
ledge of gauge theory or any theory involving exchange of inter-
mediate particles (or vectors). A quite elementary presentation
has therefore been possible.

The methods of calculating the masses and selecting the structures
of elementary particles will be the primary object of this presen-
tation.

Table 2

Magnetic constituents of baryons, according to the integer charge model.[*]

Name	Symbol full notations	Symbol brief notations	Magnetic charge $g=1$	Electric charge $e=1$	Spin $\hbar=1$	Strange-ness	Charm
Baric	B^3	B	-3	-1	0	0	0
u-quark	U_1	U	1	1	1/2	0	0
d-quark	D_1	D	1	0	1/2	0	0
s-quark	S_1	S	1	0	1/2	-1	0
c-quark	C_1	C	1	1	1/2	0	1

[*] The respective antiparticles B_3, U^1, D^1, S^1, C^1 have opposit magnetic and electric charges, and opposit strangeness and charm. Lower indexes identify positive magnetic charges; upper indexes identify negative ones.

2. The elementary magnetic monopole charge.

The theory we are going to use is based on the assumption that elementary particles are formed by association of magnetic monopoles which are kept together by magnetic forces, much the same way as the nucleus and the electrons of an atom are kept together by reciprocal electric attraction forces. In each elementary particle the number of positive and negative (or North and South unknown whichone) elementary magnetic monopole charges are assumed to be equal. As a result the elementary particles are magnetically neutral, just as the atoms, containing an equal number of positive and negative electric charges, are electrically neutral.

According to Dirac (1931 and 1948), if there are magnetic monopole charges, they will under certain conditions be multiples of an elementary charge g, hereafter designated as "Dirac monopole", fulfilling the relation:

(1)
$$g \, e = \frac{\hbar \, c}{2}$$

where e = electronic charge, $\hbar = \frac{h}{2\pi}$ where h is Plank's constant, and c = velocity of light.

Since $\frac{e^2}{\hbar c} = \frac{1}{137.036}$ is known to be a pure number designated as "the fine structure constant", it follows:

(2)
$$g = \frac{137.036}{2} \, e = \frac{\sqrt{137.036 \, \hbar c}}{2}$$

According to this formula the elementary magnetic charge (or Dirac monopole) g is about $\frac{137}{2}$ times greater than the elementary electric charge e. The large size of the elementary magnetic charge g has major consequences, which, however, do not create unsolvable difficulties for the calculation of energy levels by Bohr's or Sommerfeld's quantization methods, if the semi-classical theory is applied in a self consistent manner (see next three sections).

The use of magnetic monopole charges expressed by integer numbers in terms of g has made possible a theoretic calculation of the masses of a long arrey of elementary particles listed above. We do not

know whether this achievement would have been possible by using
a different elementary magnetic charge.

3. The size of the magnetic monopoles and the energy level problem.

Niels Bohr's semi-classical theory is well fit to convey an under-
standing of the conditions which must be fulfilled in order to allow
a calculation of the energy levels in a system of two or more mag-
netic monopoles. This applies in spite of the objections one may
rise about the use of a semi-classical method on the basis of Heisem-
berg's indetermination principle.*

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* A consequence of the indetermination principle is that a number
  of parameters which are used in Bohr's atomic theory cannot be
  measured by usual methods without fulfilling conditions or accept
  errors which rise doubts about the parameters physical meaning
  and measurability. Nevertheless, if one uses Bohr's theory in
  order to calculate the energy levels and spectral lines of the
  hydrogen atom, one finds (especially if relativistic corrections
  are taken into account) results which in many cases rival or
  agree very well with those one obtains by using wave mechanical
  methods. The essential is that one applies the semi-classical
  theory selfconsistently and uses exclusively parameter values
  obtained by semi-classical methods. If an "analogical" para-
  meter which can be used in a physical theory presents analogies
  with an other physical (for example celestial mechanical)
  parameter, it is not necessary to require that it shall be pos-
  sible to measure it by the same procedure; only that it leads
  to correct results.

The first problem arises when one tries to calculate the orbits and energy levels of two magnetic charges of opposite sign moving about each others. If for example the two charges have the same mass m and the charges g and -g (where g is given by formula 2), and if they are assumed to be moving in circular orbits about a common baricenter, then we can calculate the orbits and the distance between the two monopoles by using Bohr's quantization formula

(3)
$$mvr = n\hbar$$

where n is a positive integer identifying the energy level, v is the velocity of the two monopoles relative to the barisenter, and r is their reciprocal distance which is constant when n (energy level) is given. By requiring that the centrifugal force shall be equal to the coulombian force between the two charges

$$\frac{g^2}{r^2} = \frac{2\ mv^2}{r}$$ we can eliminate v from formula (3) and we obtain:

$$r = \frac{2n^2\hbar^2}{m\ g^2}$$

or if we take formula (2) into account

(4)
$$r = \frac{8\ n^2\hbar}{137\ mc}$$

For the lowest energy levels (from n=1 to n=17) this distance is smaller than the classical radius r_o of the magnetic monopole g (classical monopole radius), which is given by the formula

$$r_o = \frac{g^2}{2\ m\ c^2}$$ or according to (2):

(5)
$$r_o = \frac{137 \, \hbar}{8 \, m \, c}$$

This classical radius is a measure of the lowest radius one can ascribe the monopole g if it is assumed that its entire mass is equivalent to its magnetostatic energy.*

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* In the classical electromagnetic selfinduction interpretation as well as in relativity theory is the mass m of the electron identified with its electrostatic energy:

$$m \, c^2 = \frac{e^2}{2r_o}$$

Even if the magnetic monopoles are not ascribed an additional positive mass of their own (there are no negative masses in classical theory) besides their magnetostatic energies, the mass of a monopole of charge g will be given by the formula:

$$m \, c^2 = \frac{g^2}{2 \, r_o}$$

from which formula (5) is derived.

Experimental measurements of the electron radius by methods based on classical theory (Hylleräs 1952) have confirmed this result. More recent measurements by methods based on wave mechanical theory give far smaller values for the upper limit of the radius, and fit better the hypothesis that the radius is 0.

In actual fact the electron radius is one of those parameters which, because of Heisemberg's indetermination principle, can not be measured by conventional methods without an error, more than 100 times greater than the radius to be measured (see appendix 1 and Barricelli 1978 A). This does not, however, apply for the classical radius of the magnetic monopoles, in which case the minimum error is around 10 % of the radius r_o to be measured. The radius of the electron should be considered an analogical parameter which in each theory must be ascribed the value the theory requires, irrespective of measurements, if the theory is to be used in a selfconsistent manner.

If the magnetic monopole also has a positive mass of its own in addition to its magnetostatic energy, then its radius must be larger than r_o.

Shall we use the semi-classical theory consistently, and that is what we will have to do if we will use it at all, we have to take into account the fact that inside the classical radius r_o the attraction force between two monopoles does not continue to grow to infinity but on the contrary it will decrease and approach 0 when the distance between the centers of the two magnetic monopoles goes to 0. Within the distance r_o the potential field will therefore have to be weaker than the coulombian field would have been.

If one is aware of this situation, one may not use formulas based on coulombian potentials in order to calculate the energy levels.

But let us see what would happen if one were not aware of this situation and should try to calculate energy levels mistakenly assuming coulombian potenials.

4. Prevailing opinions concerning the energy level problem.

If we try to calculate energy levels by using coulombian potential
and forget that, according to the semi-classical theory we are
applying, the potentials can not be coulombian inside the magnetic
monopoles, then we will face an unpleasant surprise. Both in
the relativistic and the non relativistic approach several of
the lowest energy levels become completely absurd and meaningless,
as one might expect. Taking the non relativistic case first, the
bindings energy W, which is the sum of kinetic and potential ener-
gy becomes a negative quantity greater than the total rest-mass
energy of the two monopoles a short distance inside the classical
radius. In other words the total mass of the system becomes
negative. One finds, in fact, by taking formulas (2), (3) and
(4) into account that

$$W = - \frac{(137)^2 mc^2}{64 \, n^2}$$

whereas the total rest-mass energy of the two monopoles is $2mc^2$.
The total mass energy $2mc^2 + W$ of the system is therefore negative
for all energy levels with $n^2 < \frac{(137)^2}{128}$ or $n < 12.5$.

In the relativistic case one finds that the total mass of the
system becomes imaginary or complex for $n < \frac{137}{8}$. In both cases
the lowest energy levels, which are the ones with the highest
actuality for the calculation of the masses of elementary particles,
become completely absurd.

It is difficult to say whether the relationship between these
absurdities and the classical radius of the monopole has not been
discovered before, or whether one has preferred to ignore it on
the consideration that since the electron is assumed to have a
radius equal to 0 in the commonest wave-mechanical theories (but
"nota bene" not in semi-classic theory, see preceeding footnote)
one has taken for granted that magnetic monopoles would also have
a radius equal to 0.

The result has been quite depressing. A typical attitude towards this subject is reflected by the following kind of pronouncement some times found in the literature: "Valid quantitative calculations of bindings energies have not been obtained yet. Because of the strong forces acting between the magnetic charges it is difficult with the present theory to make reliable calculations." Similar considerations are offered by Schwinger (1968) and others.

The next statement on this subject is taken from a referee report:

These papers show praiseworthy efforts to create new ideas, but the methods employed are quite inadequate for the purpose.

(i) Extremely strong magnetic fields are involved, and these will produce large currents in the vacuum, and these currents then interact in such a way as to modify strongly the original fields.

(ii) The dynamics of such magnetic quark systems cannot be treated by Bohr-Sommerfeld quantization, nor can it be treated by Dirac's formula for H-like atoms. One must use some quantum field theory method which makes it possible to include all the large quantum field effects. Anything less is hopeless.

Unnecessary to say that whoever delivered this prescription has given no evidence that it would lead to the calculation of any energy level and/or any mass of an elementary particle. Moreover, his statement to the effect that "the dynamics of such magnetic quark systems cannot be treated by Bohr-Sommerfeld quantization" is erroneous and fundamentally false, as will be shown in the next section.

5. The calculation of the energy levels

Let us now find out what the calculation of the energy levels will look like if one is aware that, inside magnetic monopoles, the coulombian potential must be replaced by a weaker potential field fulfilling the requirements posed by classic electromagnetism. Potentials fulfilling these requirements are called "asymptotic coulombian potential approximations". Their common properties are:

1. They approach asymptotically coulombian potentials when the distance r between the two charges goes to infinity ($r \to \infty$).

2. Within a distance comparable to the classical radius r_o they become gradually much weaker than the coulombian potential; and when the distance approaches zero ($r \to 0$) the potential energy U for two monopoles of opposite equal charges g and -g and equal mass $m = \dfrac{g^2}{2r_o c^2}$ will approach a finite lower limit $-2mc$

$$U \to -2mc^2 \qquad\qquad \text{for } r \to 0$$

This requirement is a way to express that two opposite equal charges occupying the same position (r=0) cancel out. Their magnetostatic energy $2mc^2$ is neutralized by their potential energy $-2mc^2$ when the magnetic field is everywhere equal to zero.

An implication of this requirement is that the bindings energy W which is the sum of kinetic and potential energy can never be lower than $-2mc^2$:

$$W \geq -2mC^2$$

and the mass $\dfrac{2mc^2 + w}{c^2}$ can never be negative. The absurdities mentioned above can not occur when the potential field is consistent with the rules of classical electromagnetism.

A simple example of this kind of potential is the "exponential coulombian" one which for two monopoles of charges g_1 and g_2 is defined by the formula:

(6) $$U(r) = \frac{g_1 g_2}{r_0} (1 - \mathrm{Exp}(-r_0/r))$$

The force generated by it (its derivative with respect to r) is:

(7) $$F(r) = - \frac{g_1 g_2}{r^2} \mathrm{Exp}\,(-r_0/r)$$

In fig. 1 a plot of this potential - calculated for the case $g_1 = g$ and $g_2 = -g$ - and the force generated by it are compared with the respective coulombian diagrams.

If we now repeat the calculation of r in the non relativistic case, we find, by requiring that the centrifugal force shall be equal to the attraction force:

$$\frac{2mv^2}{r} = F(r) \quad .$$

which if we eliminate v by using Bohr's quantization formula (3) gives:

(8) $$\frac{2n^2 \hbar^2}{mr^3} = F(r)$$

If the force is coulombian, $F(r) = \frac{g^2}{r^2}$, this will bring us back to

the relation $r = \frac{2n^2 \hbar^2}{mg^2}$ and to formula (4). But if the force

is not coulombian, then we must either solve the equation (8) with respect to r, or we must use a data processing machine in order to calculate r from formula (8) by successive approximations. We have a computor program which can do this not only in the special case we have considered in which $g_1 = g$ and $g_2 = -g$, but in general for any g_1 and g_2 values, and for nearly all of the (more than 50) asymptotic coulombian fields we have tested so far.

When r is identified, v can be calculated by formula (3), and the bindings energy is then given by formula
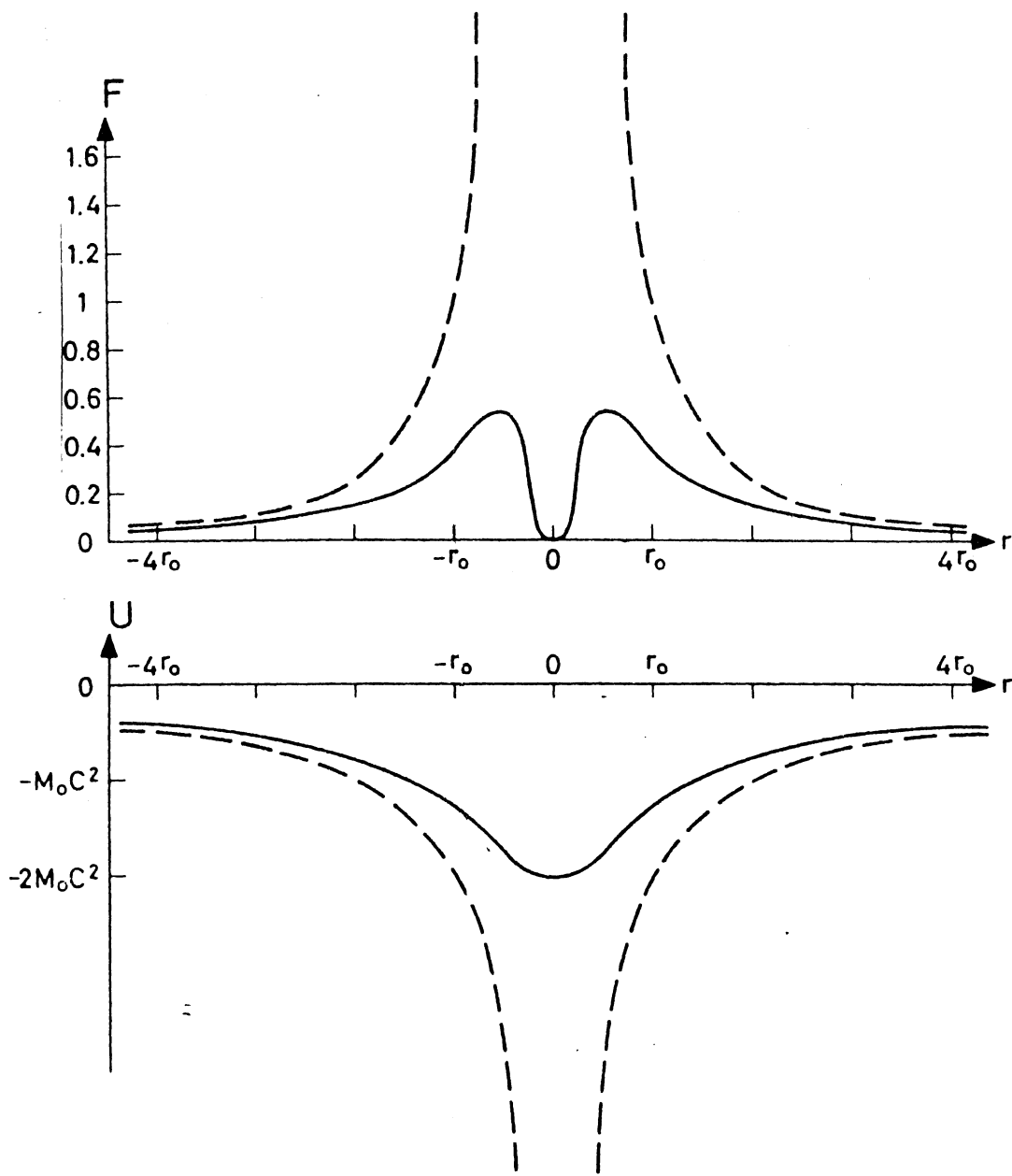
(9) $$W = U(r) + mv^2$$

Fig. 1
Exponential coulombian approximation force F and potential U (solid lines)
are compared with the respective coulombian diagrams (dashed lines). Both
are given as a function of distance r between two magnetic monopoles of
charges g and -g respectively (g being the Dirac monopole). F is mesured
in units of g^2/r^2, U in units of $M_o c^2 = g^2/r_o$.

The total mass of the system becomes then:

(10)
$$Mc^2 = 2mc^2 + U(r) + mv^2$$

Since the minimum value of the potential $U(r)$ is $-2m^2c^2$ in every asymptotic coulombian field (according to the above rules 1 and 2 which define these fields), the mass M can <u>never</u> be negative. The above mentioned absurdities can not occur with these kind of fields.

The corresponding relativistic formulas can be derived by the same sort of argument if m is replaced by $\dfrac{m_0}{\sqrt{1-v^2/c^2}}$ in every

formula and the total kinetic energy for the two monopoles is replaced by $2m_0 c^2 \left(\dfrac{1}{\sqrt{1-v^2/c^2}} -1 \right)$ in the formula (10), where m_0 is the rest mass of each monopole.

Analogous formulas can be derived for the more general case in which g_1 and g_2 are any kind of magnetic monopole charges.

Besides circular orbits like those we have described, one may consider also other orbits for two monopoles bound to each other. The simplest ones, which have greatest actuality for their applications in elementary particle theory are the linear oscillation orbits described by two particles subject to oscillations on a straight line through their common baricenter. Both particles move simultaneously through their center of gravity in opposite direction. They reach simultaneously their respective maximum distances from the center of gravity and are pulled back by their reciprocal attraction to repeat in reverse the same movements (fig. 2).

The main characteristic discriminating linear oscillation orbits from other orbits is that their orbital angular momentum is equal to zero.

In stead of Bohr's quantization method expressed by formula (3) one may use Sommerfeld's quantization conditions which have more
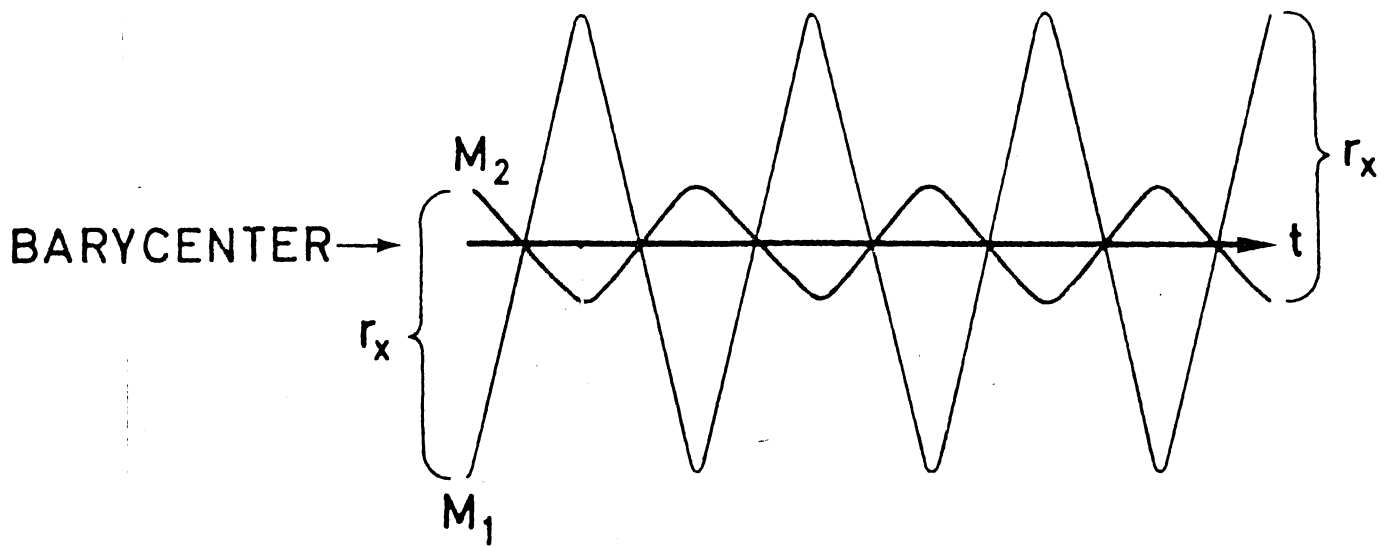
Fig.2
Linear oscillation movements in a binary system in which the rst-mass
of one particle is 4 times greater than the rest-mass of the other
one $(M_{20}=4M_{10})$.

general applicability (see appendix 2).

We have computer programs (both relativistic and none relativistic ones) which can calculate the energy levels and orbital parameters for a system of two magnetic monopoles in a linear oscillation orbit about each others. Also these programs will calculate the total mass M of the system. Moreover they will calculate the maximum distance r between the two monopoles and their maximum velocities v_1 and v_2 which are reached when they move through the baricenter (in stead of the constant distance and the constant velocities, which are calculated by the program for circular orbits by using formulas (6) and (3) or the corresponding formulas for the case of two mono- poles with different charges and masses). These energy levels (masses) and orbital parameters are listed for the energy levels n=1 and n=2 in the tables 3A, 3B, 3C. These tables are calculated by using an asymptotic coulombian potential $U_g(r)$ specified in appendix 2 and quite different from the one given by formula (6). The potential U_g depends on a single free parameter whose best value (giving the best fit between calculated and observed masses of elementary particles) is found to be $\frac{g}{\sqrt{\hbar c}}$ or $\frac{\sqrt{137}}{2}$ according to formula 2, and that is the reason for its name (see appendix 2).

The masses in table 3A are measured by using the magnetostatic rest- mass (energy) M_o (see formula (5) and preceeding discussion) as a unit of mass:

(11)
$$M_o = \frac{g^2}{2r_o c^2} = 2399 \text{ M.E.V.}$$

The translation into million electron volt M.E.V. is made by assu- ming that r_o is the classical radius of the electron defined by

$r_o = \frac{e^2}{2M_e c^2}$, M_e being the mass of the electron.

We may read from table 3A that the total mass of a system of two monopoles with the respective charges g and -g and the same rest

Table 3A

Masses of binary systems of magnetic monopoles with respective rest masses M_{10}, M_{2} and the respective magnetic charges g_1, g_2 (g being the Dirac monopole, and $M_0 = \dfrac{g^2}{2r_0}$ the monopolar unit of mass).

	M_{20}	Energy level n=1			Energy level n=2		
		M_0	$4M_0$	$9M_0$	M_0	$4M_0$	$9M_0$
M_{10} g_1	g_2	$-g$	$-2g$	$-3g$	$-g$	$-2g$	$-3g$
M_0 g		0.08307	1.07933	4.08467	0.19111	1.18723	4.20033
$4M_0$ $2g$		1.07933	0.05671	1.05279	1.18723	0.13884	1.12998
$9M_0$ $3g$		4.08467	1.05279	0.04416	4.20033	1.12998	0.10952

Table 3B

Maximum reciprocal distance ($r_0 = 1$) reached by the two monopoles in their linear oscillations.

	M_{20}	Energy level n=1			Energy level n=2		
		M_0	$4M_0$	$9M_0$	M_0	$4M_0$	$9M_0$
M_{10} g_1	g_2	$-g$	$-2g$	$-3g$	$-g$	$-2g$	$-3g$
M_0 g		0.36882	0.29541	0.26802	0.48906	0.38309	0.34473
$4M_0$ $2g$		0.29541	0.22168	0.19500	0.38309	0.28423	0.24893
$9M_0$ $3g$		0.26802	0.19500	0.16717	0.34473	0.24893	0.21268

Table 3C

Maximum velocities v_1/c, v_2/c of the two monopoles (c being the speed of light).

		M_{20}	Energy level n=1			Energy level n=2		
			M_0	$4M_0$	$9M_0$	M_0	$4M_0$	$9M_0$
M_{10} g_1		g_2	$-g$	$-2g$	$-3g$	$-g$	$-2g$	$-3g$
M_0 g	v_1/c		0.27955	0.33946	0.36895	0.40842	0.49080	0.52941
	v_2/c		0.27955	0.08986	0.04407	0.40842	0.13946	0.06917
$4M_0$ $2g$	v_1/c		0.08986	0.11848	0.13418	0.13943	0.18392	0.20833
	v_2/c		0.33946	0.11848	0.06007	0.49080	0.18392	0.09425
$9M_0$ $3g$	v_1/c		0.04407	0.06007	0.06991	0.06917	0.09425	0.10981
	v_2/c		0.36895	0.13418	0.06991	0.52941	0.20833	0.10981

mass M_O is only 8.3% of M_O in the energy level 1, and 19.1% of M_O
in the energy level 2. If the two monopoles have the respective
charge 2g and -g and the respective masses $4M_O$ and M_O, the total
mass of the system will be 1.07937 M_O in the energy level 1 and
1.18723 M_O in the energy level 2, etc. The total mass of the system
is in each case far lower than the sum of the rest masses of the two
monopoles. In table 3B we can read that in the first case the maximum
distance between the centers of the two monopoles is 0.36882 r_O
for the energy level 1 and 0.48906 r_O for the energy level 2; in the
second case the maximum distance becomes 0.29541 r_O for the energy
level 1 and 0.36309 r_O for the energy level 2. In each case the
maximum distance becomes far lower than the classical radius r_O
of the Dirac monopole. In table 3C we can read the maximum veloci-
ties of the two particles compared with the velocities of light c.
All energy levels give real positive values of quite normal orbital
parameters.

The results we would have obtained by using circular orbits with
the potential and force fields defined by formulas (6) and (7)
resemble, especially as far as the masses are concerned, to the re-
sults presented in the tables 3A, 3B and 3C (see Barricelli 1978 A).

We will see in the following sections how the calculation of energy
levels can be used in order to interpret the masses and other pro-
perties of elementary particles. The fact that before now no method
to calculate the energy levels and the mass of a system of monopoles
has been available, must have been a major handicap which may have
seriously hampered the ability to find which consequences the various
theoretic hypotheses introduced could have for the masses of elemen-
tary particles. One should not be surprised if the light brought
on by this new possibility may reveal new and unexpected features
about the structure of elementary particles, not all of them neces-
sarily in agreement with common belief.

6. Other magnetic monopoles and their masses.

The baric and the quarks are not the only magnetic monopoles involved
in the theory. Other magnetic monopoles can be constructed by so-
called "zero-level" or (L-0) associations between charges of differ-
ent sign. An (L-0) association is a monopole whose electric and
magnetic charges are the sums of the respective charges in the as-
sociated monopoles. Its spin is either $\frac{1}{2}$ or 0 depending on whether
the association includes an odd or an even number of particles of
spin $\frac{1}{2}$ (fermions). Particles of spin greater than $\frac{1}{2}$ can not be
members of an (L-0) association.

For example the (L-0) association of a baric B^3 with the quark U_1
will be a monopole designated by the symbol $(B^3U_1)0$, which from
now on will be called F^2 with spin $\frac{1}{2}$, magnetic charge $-3g+g=-2g$
and electric charge $-e+e=0$. Its antiparticle F_2 will be called
"heavy fermion" (see table 4). Schwinger introduced monopoles
with similar magnetic charges and spin properties, when he assumed
that a quark could absorb a magnetically triply charged boson of
spin zero. But in our semi-classical interpretation we consider
(L-0) associations as the result of a binding at the lowest possible
nergy level (n=0), where n is the quantum number in the Bohr
formula (3) or in the corresponding Sommerfeld formula. This energy
level is characterized by resting associated monopoles at the
lowest energy position, namely the systems barycenter.

More (L-0) associations will be introduced later on. We may, how-
ever, give notice that (L-0) associations of a monopole and its
anti-particle, such as $(U^1U_1)0$ $(B^3B_3)0$ or $(F^2F_2)0$ will be con-
sidered as annihilations. This kind of association does not
give a true particle. Moreover will the (L-0) association of a
monopole, such as for example B^3, with an other (L-0) association-
product, such as $F_2=(B_3U^1)0$, which includes its antiparticle, be
considered as equivalent to the result obtained by removing (anni-
hilating) the two monopoles (B^3 and B_3) from the result:

$$(B^3F_2)0=(B^3B_3U^1)0=U^1$$

An other monopole, a boson of spin equal to zero, magnetic charge $-g$

and no electric charge, which is called "light boson" and is designated by the symbol L^1 (see table 4) was originally introduced as a means to interpret the properties of the strange quark S_1 (see below).

The three monopoles B^3, U_1, L^1 are the primary monopoles we will use in order to construct all the other particles by (L-0) or higher energy associations. It is likely that also an other group of three monopoles, namely B^3, F_2, L^1 could have been used in their place.

In order to obtain approximately correct theoretic values for the masses of elementary particles, we have found it necessary to select a common classical radius r_o for all magnetic monopoles. If we take r_o like the classical radius of the electron

(12)
$$r_o = \frac{e^2}{2M_e c^2}$$

where M_e is the mass of the electron, then the mass of the electron can also be calculated by the same rules which apply for the masses of magnetic monopoles and the other particles (in many publications $2r_o$ instead of r_o is designated as the classical radius of the electron, as opposed to the convention we have used).

Our unit of mass M_o, to be designated as monopolar mass unit, is defined by the preceeding formula (11). The mass M_e of the electron is then according to (12) and (11):

(13)
$$M_e = \frac{e^2}{2r_o c^2} = 0.000213 M_o = 0.511 \text{ M.E.V.}$$

If the mass M of a magnetic monopole with a magnetic charge ig and an electric charge je is originated exclusively by its magnetostatic and electrostatic energy, it can be calculated by the formula:

(14)
$$M = i^2 M_2 + j^2 M_e$$

which in monopolar units becomes:

Table 4

Description of monopoles used (for split S and C quarks see section 10)

Name	Symbol	Mass M_0-Units	Electric charge	Magnetic charge	Spin $\hbar=1$	Definition brief notat.
Baric	B^3	9.000213	-1	-3	0	B
Light boson	L^1	1.000000	0	-1	0	L
u-quark	U_1	1.000213	1	1	1/2	U
Heavy fermion	F_2	4.000000	0	2	1/2	(BU)0
d-quark	D_1	1.000000	0	1	1/2	(FL)0
s-quark (compact)	S_1	1.079326	0	1	1/2	(FL)1
s-quark (split)	T_1	1.068	0	1	1/2	--
c-quark (normal)	C_1	1.572278	1	1	1/2	((BS)2L)3
c-quark (I-version)	I_1	L.562069	1	1	1/2	((BT)2L)3

(15)
$$M=(i^2+j^2 \times 0.000213)M_o$$

This is assumed to be the case for the primary monopoles B^3, U_1, L^1 and their (L-0) associations, whose masses, calculated this way, are given in table 4.

How one calculate the masses of associations at an energy level higher than 0, namely (L-1) associations, (L-2) associations etc., will be explained in the next section.

In the brief notations used in table 4 in order to define the various particles the indexes are omitted. For example (FL)0 stands for $(B^3U_1)0$ or its antiparticle $(B_3\overline{U}^1)0$; (FL)1 stands for $(F_2L^1)1$ or its antiparticle $(F^2L_1)1$, etc. Except for the ambiguity between a particle and its antiparticle, which is unimportant for the calculation of masses, there are no other ambiguities created by the use of brief notations.

7. The calculation of masses for energy levels higher than zero.

Two of the quarks listed in table 4 namely the s-quark and the c-quark, are ascribed masses which are larger than those calculated by formula (15). It was soon discovered that in order to interpret the masses of "strange" and "charmed" particles it would be necessary to ascribe these two quarks greater masses than those required by their magnetostatic and electrostatic energies, and approaching those indicated in table 4.

This led to an interesting discovery. It was found that the mass one would have to ascribe to the s-quark would, in many cases, lie close to the mass of a binary system formed by an (L-1) (energy level 1) association of two monopoles with the respective magnetic charges $-g$ and $2g$, which is listed in table 3A. This led to the hypothesis that the s-quark is not a single monopole, but an (L-1) association of a fermion and a boson with the mentioned magnetic charges, as for example the association*$(F_2L^1)1$ or $(FL)1$ which is indicated in table 4 as a definition of the s-quark (compact). We have a machine program which calculate the mass of such an association when its definition is indicated in an input card by its "configuration" (FL)1. This interpretation of the s-quark was what led to the introduction of the light boson L^1, which later on also proved useful in the interpretation of the c-quark and other particles. This way was the identity between the mass $1.079325 M_o$ of the s-quark and the mass of a bynary $(-g,2g)$ system at the energy level 1 - which is indicated in table 3A - explained.

Later on also the mass of the c-quark (compact) was explained by assuming that it is an (L-3) association $((BS)2L)3$ between $(BS)2$ and L. Split s and c-quarks will be interpreted in section 10.

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* An other alternative which has been considered is the (L-1) association of the u-antiquark U^1 and the monopole $(B_3L^1)0$, which would ascribe to the s-quark a configuration $((BL)0U)1$ in stead of (FL)1.

A question which arises in this connection is how one goes about
in order to calculate the mass of a system consisting of more than
two monopoles or (L-0) associations. The machine programs we have
for the time being can handle only two-particle systems either with
circular orbits or with linear oscillation orbits.

Similar situations have arised earlier for example in atomic theory,
and the solutions one has found can in part be applied also in our
case in order to obtain approximate results. There are also special
solutions which are appearently applicable for the approximation
we need (with errors not substantially greater than 1% of the re-
spective particle masses), even if they have not been used in atomic
theory. Solutions of the following kinds will be used:

1. If one wishes to calculate the mass of an association of two partic-
les of which one or both are associations of other particles, it is
possible in many cases to obtain the needed approximation by ignor-
ing that the two particles can themselves be associations. For
example the s-quark, which is an (L-1) association, and the c-quark,
which is an (L-3) association, will in many cases (unless it is
split, see section 10) be treated the same way as the other quarks
which are single monopoles or (L-0) associations. Likewise the
mass of the (L-3) association ((BS)2L)3 defining the c-quark is
calculated as if (BS)2 and L were two single monopoles.

These procedure is analogous to the one used in atomic theory when
one for example calculates approximate values for the energy levels
of the external (third) electron of the Litium atom by treating the
rest of the atom (the nucleous + the two internal electrons) as
a single positively charged particle.

2. Even if one has a suspicion that the orbits may not be linear
oscillation orbits, and may for example have an angular momentum
different from zero, it does not follow that the masses we calcu-
late by our linear oscillation program are not usable for the
approximation we need. It is well known from atomic theory that
different elliptical orbits corresponding to the same energy level
(same n-value) give approximately the same bindings energy. It
is reasonable to assume that some thing like that may occur also

with magnetic monopole orbits differing from linear oscillation ones.
A method to estimate the maximum error one may expect by this pro-
cedure is to replace the suspected orbit by a circular one, and use
our circular orbits program in order to calculete the mass of the
system. The masses we will find this way will usually be lower
than what would be obtained by the oscillation orbits program, and
the difference will give a high estimate of the error.

Why quarks and other fermions dislike circular orbits even when
they would lead to lower masses and energy levels is unknown. But a
similar tendency for electrons to avoid circular orbits is well known
also from semi-classical atomic theory.

3.   An association of three monopoles can also take a form which can not
be described by the outline presented in point 1. For example will
some of the baryons, including the Proton, be interpreted by assuming
that two quarks, namely an u and a d-quark, oscillate in an internal
orbit about the baric B^3 in such a way that they always keep together
and behave as a single monopole with a double magnetic charge and a
correspondingly high mass calculated by formula (15). Two monopoles
with the same magnetic charge, which, in spite of their resiprocal
repulsion, keep together and occupy all the time a common position
are called "positionally associated". An (L-n) association of this
kind is designated by the symbol $(B^3U_1D_1)n$ or briefly (BUD)n. Our

machine program is capable of calculating the mass of such a composit
particle defined by its brief expression (or configuration) (BUD)n
punched on an input card.

An other kind of movement one could imagine in this sort of a system,
is to assume that the baric B^3 may all the time be at rest in the
center, and the two quarks U_1 and D_1 may oscillate about B^3 in such
a way that their respective distances from B^3 will all the time be
equal. We do not know whether there is a way to calculate the mass
of such a system by our present programs with adequate approximation.

8. Exclusion principles

A very strong exclusion principle applies for positionally associa-
ted fermions. The maximum number of fermions allowed in a positional
association is 2. The lowest energy level allowed for a system
of two positionally associated fermions is n=4. There is moreover
a very strong exclusion principle which applies at this energy
level, requiring that the two fermions must be different ones and
must moreover have different spins. This principle is obviously
stronger than Pauli's exclusion principle requiring that only one
of these two conditions must be followed by two fermions in a com-
mon orbit, which, however, is not the same as two positionally
associated fermions. Moreover the strong exclusion principle
applies for energy level n=4, but not for the energy level n=5.
The last point will be discussed below.

An example of an (L-4) system with two positionally associated

fermions is defined by the configuration $(B^3U_1D_1)4$ and is represen-

ted in the structures of the Proton, the neutron and the $\Lambda(1115)$
barion, whose configurations are respectively ((BUD)4U)1, ((BUD)4D)1
and ((BUD)4S)1 (see table 5). Moreover in this case the s and c-
quarks are excluded from the positional association. As a result
(BUD)4 is the only permitted (L-4) association between B and two
positionally associated quarks.

The restrictions we have described for positionally associated
fermions do not apply for positional associations which do not
include more than one fermion. For this kind of associations we
have found no restrictions either concerning the energy level or
concerning the number and spin of the positionally associated
monopoles. For example the charged pion Π+ is ascribed the (L-1)

configuration $(F^2U_1L_1)1$ which involves the positional association

of one fermion U_1 and one boson L_1 associated at the energy level

n=1 (not n=4) with the monopole F^2. Likewise is the myon μ⁻ ascri-

bed the configuration $(B^3D_1L_1L_1)1$ which involves the positional

association of one fermion D_1 and two L_1 bosons which are (L-1)

asociated with B^3.

Notice that if one of the members in a positional association
can be expressed as an (L-0) association, it may often be possible
to substitute an other positional association for it, without
changing the masses and charges and spin properties of the position-
al association or of the system as a whole. For example in the

μ^- configuration $(B^3D_1L_1L_1)1$, the fermion D_1 can be replaced by

its expression $(F_2L^1)0$ in terms of F_2 and L^1 (see table 4), and

the positional association $D_1L_1L_1$ becomes $(F_2L^1)0L_1L_1$. If in this

expression we remove the L^1L_1-pair, by following the same rules

which apply in an (L-0) association, we obtain a new association

F_2L_1, which has the same charges and the same mass as the preceeding
one. This new association can therefore be substituted for the pre-
ceeding one in the μ^- configuration, without changing the mass

charges and spin properties of the system, yeilding the configura-

tion $(B^3F_2L_1)1$, which is used in table 5.

Likewise the π^+ configuration $(F^2U_1L_1)1$ given above can be replaced

by the configuration $(F^2(B_3D^1)0)1$ or $((B_3U^1)0(B_3D^1)0)1$ since

$D^1=(F^2L_1)0$ and $F^2=(B^3U_1)0$ (see table 4). Both of the brief con-

figurations (FUL)1 and ((BU)0(BD)0)1 are used as alternative defi-

nitions of $\pi^{\pm}$ in table 5, with the same result.

We should give notice that the above requirements certainly can
not be all the requirements and exclusion rules which apply for
magnetic monopoles. Many associations which would seem possible
by these rules are never found. We will add some more rules which
apply for particle decais in section 11. But we may have discovered
only a slight minority of the rules which actually apply.

We are now in a position to explain how our machine programs can be
used in order to calculate the masses of an array pf elementary
particles.

9. The theoretical calculation of the masses of elementary particles

For every particle whose mass one wishes to calculate an input card
must be entered in the program punched with the name of the par-
ticle, its configuration defining its composition and energy levels
and, if desired, one may include its spin which may be printed in
the last column of the output table as in table 5. The configuration
will be printed in the output table's next-last column and the
particle's name in the third-last. At the top of the input cards
one must include a few cards which define the monopoles and quarks
one wishes to use among them the three primary monopoles B,U,L.
These definitions are printed at the top of table 5, which is an
example of the kind of listings one obtains in the output or reply
from the machine. The other columns from left to right contain the
electric and magnetic charges and the masses of the two monopoles
or associations which are part of the system, their maximum distance
and maximum velocities, and the mass of the system both in monopolar
units (M_o) and in millions electron volts (MEV), together with the
energy level of the system listed under the designation N.

The MEV-masses can be directly compared with the observed masses
of the particles, which are indicated between brackets after the
names of the respective particles. This way one can verify the
ability of the theory and/or the proposed configuration to predict
the masses of the various particles.

One may notice that the interpretations of elementary particle
structures which are given by the configurations listed in table 5
differ in various respects from the interpretations given in
conventional quark models. Some of the differences arise from
the very premisses of our theory. For example the configurations
((BUD)4U)1, ((BUD)4D)1, ((BUD)4S)1 and ((BUD)4C)1 of the proton
P(938), the neutron N(939), the lamda Λ(1115) and the charmed lamda
Λ_c(2260) baryons, reflect our assumption that these baryons have
a structure analogous to that of a Litium atom with two quarks
(in stead of two electrons) in an internal orbit building the
(L-4) association (BUD)4, and a quark (U,D,S or C) in the external
(L-1) orbit. (Notice that the size of the internal orbit measured
by the maximum distance R in the particle (BUL)4 named NUCLEINO
and listed at the bottom of table 5 is smaller than the size of
the external orbit in all of these 4 baryons).

Other spin ½ baryons, namely $\Sigma^-(1197)$, $\Sigma^o(1192)$, $\Sigma^+(1189)$ with the
respective configurations ((BD)1DS)4, ((BU)1DS)4, ((BU)1US)4 have
only one quark in the internal orbit and two positionally associated
quarks in the external one. All of these configurations give spin ½
baryons, since positionally associated quarks have opposite spins,
and linear oscillation orbits have no angular momentum.

Notice that this interpretation not only yields a theoretic calcula-
tion of the masses (which conventional quark models do not give),
but it also yields a natural explanation to the substantial differ-
ence between the mass of $\Lambda(1115)$ and the mass of $\Sigma^o(1192)$, which
has been a problem for conventional quark models.

Baryons which involve split s-quarks, namely Ξ^-, Ξ^o and the "strange"
spin 3/2 baryons will be treated in the next 2 sections.

We notice that in every group of baryons with common strangeness and
common spin, the lowest observed mass is found in the positively

charged particle ($P(938)$ and $\Sigma^+(1189)$),while the lowest theoretically
calculated mass belongs to the neutral particle ($N(939)$ and $\Sigma^o(1192)$)
Electrical interactions and possible electric dipol moments are
either ignored or only rudimentarily treated in our theory which
in its present form always ascribes the lowest mass to the neutral
particle in each group.

Baryons with spin 3/2 present a problem with respect to the inter-
pretation of their spin. Their masses can be calculated with errors
lower than 1% by assuming two positionally associated external quarks
at the energy level n=5. For example the mass of the spin 3/2 baryon

$\Delta^-(1232)$ in table 5 is fairly well calculated by the machine by
ascribing to it the (L-5) configuration ((BD)1DD)5. This presupposes
that in the energy level n=5, (as opposed to the energy level n=4)
two identical d-quarks can be positionally associated. But Pauli's
exclusion principle must still apply and two d-quarks must therefore
have opposite spins. If all the orbits are linear oscillation ones,
this may suggest that the spin of the baryon could be 1/2 rather
than 3/2.

The simplest explanation we may suggest in order to solve this

TABLE 5

PROPERTIES OF PARTICLES NOT INVOLVING SPLIT QUARKS

PARTICLE DEFINED: B   MASS: 9.30321301   EL.CHARGE: -1   MAGN.CHARGE: -3   SPIN: 0
PARTICLE DEFINED: L   MASS: 1.33300000   EL.CHARGE: 0   MAGN.CHARGE: -1   SPIN: 0
PARTICLE DEFINED: U   MASS: 1.33321301   EL.CHARGE: 1   MAGN.CHARGE: 1   SPIN: 1/2

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
-1	1	-1	3	1.33021301	9.00021331	3.33303300	0.03000300	0.30030000	4.03300031	0	9595.833	F	(BU)0	1/2
0	0	-1	2	1.33000000	4.00033331	3.30003000	0.80030300	0.00000000	1.03300031	0	2398.952	D	(FL)0	1/2

DEFINITION OF STRANGE- AND CHARMED QUARK:

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	0	-1	2	1.33000000	4.05033331	.29535403	.33936446	.38982903	1.37932591	1	2589.251	S	(FL)1	1/2
0	1	-1	2	1.33000039	4.27224383	.44833314	.58961972	.16843280	1.57227803	3	3771.320	C	((BS)21)3	1/2

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN

BARYONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
1	0	1	-1	1.33021301	1.31436132	.35987412	.28547849	.22107036	.39135060	1	938.831	P(938)	((BUD)4U)1	1/2
0	0	1	-1	1.00000031	1.31436132	.35988233	.28552872	.22106585	.39114323	1	938.334	N(939)	((BUD)4D)1	1/2
0	0	1	-1	1.37932591	1.31436132	.35700038	.26796517	.22266624	.46850517	1	1123.922	LMDA(1115)	((BUD)4S)1	1/2
1	0	1	-1	1.57227833	1.31436132	.34443766	.19380590	.22998244	.95322820	1	2286.749	LMDC(2263)	((BUD)4C)1	1/2
0	-1	2	-2	4.37932592	4.08486245	.36735438	.27541747	.27537369	.49218792	4	1180.735	SGMA(1197)	((BD)1DS)4	1/2
0	0	2	-2	4.07932592	4.08462164	.36735598	.27541624	.27508620	.49197251	4	1180.219	SGMA(1192)	((BU)1DS)4	1/2
1	0	2	-2	4.07953892	4.08462164	.36735415	.27540414	.27508739	.49218029	4	1180.717	SGMA(1189)	((BU)1US)4	1/2
0	-1	2	-2	4.33303032	4.08486245	.43181665	.31838333	.31212650	.51878061	5	1244.533	DLTA(1232)	((BD)1DD)5	3/2

MESONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	0	-2	2	4.33000061	4.00900031	.22164150	.11844138	.11844138	.05671083	1	136.347	PI0(135)	(FF)1	0
0	0	2	-2	4.00000001	4.00300031	.22164150	.11844138	.11844138	.05671083	1	136.347	PI0(135)	((BU)0(9U))1	0
1	-1	2	-2	4.33021302	4.00021302	.22163734	.11843732	.11843732	.05670993	1	136.044	PI0(135)	((BD)0(BD)0)1	0
-1	0	-2	2	4.33021301	4.00003301	.22164045	.11843570	.11844192	.05692285	1	136.555	PI+(140)	(FUL)1	0
1	0	2	-2	4.00021302	4.00000001	.22164046	.11843570	.11844192	.05692286	1	136.555	PI+(140)	((BU)0(BD)0)1	0
0	0	-1	1	1.00000001	1.13689073	.48273317	.41233962	.36987678	.32133101	2	770.858	RHO0(770)	((BD)1B)1D)2	1
-1	0	-1	1	1.33021301	1.13689073	.48272200	.41227381	.36988338	.32153238	2	771.341	RHO+(770)	((BD)1B)1U)2	1
-1	1	-1	1	1.57227803	1.57227803	.44550292	.29583395	.29583395	1.29147770	2	3098.193	PSI(3397)	(CC)2	1
0	0	2	-2	4.08462164	4.63821347	.21845165	.11766336	.10378108	.77658881	1	1862.999	D0(1863)	((BC)1(BU)1)1	0
1	0	2	-2	4.08484245	4.63821347	.21845055	.11765766	.10378159	.77680861	1	1863.527	D+(1868)	((BC)1(BD)1)1	0
1	0	2	-2	4.16569666	4.63821347	.21807752	.11573317	.10395419	.85232407	1	2044.685	F+(2040)	((BC)1(4S)1)1	0

LEPTONS

E1	E2	G1	G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0	0	-2	2	4.33000000	4.06000331	0.33000000	0.03000000	0.30000000	.00000001	0	.000	NUE(0)	(FLL)0	1/2
0	0	-1	1	1.03000000	1.30300001	0.00000000	0.00000000	0.00030000	.00000001	0	.000	NUE(0)	(DL)0	1/2
0	1	-1	1	1.33003000	1.00021301	0.33003000	0.00030000	0.30000000	.00021301	0	.511	E(0.511)	(JL)0	1/2
0	0	2	-2	4.33000000	4.00300031	0.00000000	0.03000000	0.30030000	.00000001	0	.000	NUMU(0)	(BULL)0	1/2
0	-1	3	-3	9.33000001	9.00021301	.16714446	.06988953	.36988789	.04433512	1	106.358	MYON(106)	(BFL)1	1/2
2	-1	3	-3	9.33085203	9.00021301	.16714174	.06988407	.36988901	.04433446	1	106.356	MYON(106)	(3(BL)0U)1	1/2
1	-1	3	-3	9.33021302	9.00021301	.16714344	.06988831	.36988831	.04412213	1	105.847	MY0	(B(BL)0D)1	1/2
1	-1	3	-3	9.37953892	9.30021301	.16701771	.06933209	.06994019	.12332123	1	295.842	S0	(3(BL)0S)1	1/2
1	-1	3	-3	9.37953892	9.00021301	.21247820	.10890829	.10985665	.18846200	2	452.111	S0	(B(BL)0S)2	1/2
2	-1	3	-3	9.57291705	9.00021301	.24413941	.13473792	.14314109	.75402309	3	1808.858	TAU(1807)	(3(BL)0C)3	1/2
1	-1	1	-3	1.33021301	9.30021301	.26797313	.36884527	.04405721	4.08462164	1	9798.812	NC	(BU)1	1/2
1	-1	2	-3	4.33021302	9.00021301	.32845365	.31610878	.14649296	1.31436132	4	3153.070	NUCLEINO	(BUD)4	0

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apparent contradiction is to assume that the (L-5) orbit is not
a linear oscillation orbit. We may assume for example that the
(L-5) orbit has an angular momentum equal to 1, and that the spin
of the internal quark is parallel to this angular momentum. That
would result in a baryon with an angular momentum 3/2. Also (L-5)
associations with spin 1/2 would be possible with this interpreta-
tion. But their half life time may turn out to be even shorter
than the half life of around 10^{-23} sec. (see table 9C) of all spin
3/2 baryons except Ω. Such a short life time could make their
detection very difficult. Moreover the probability of creating
a spin 1/2 baryon of energy level (L-5) might be small compared
with the probability of creating a level (L-4) baryon with the
same spin.

We have no machine program which can calculate (L-5) orbits with
an angular momentum equal to 1. But we have a program for circu-
lar orbits. Circular (L-5) orbits have an angular momentum equal
to 5. The mass of a system ((BD)1DD)5 where the (L-5) orbit is
circular and the (L-1) orbit for (BD)1 is a linear oscillation
orbit has been calculated by our programs, and is found to be
1153.280MEV. This is substantially lower than the mass 1244.586MEV
(see table 5) which was found by using only linear oscillation
orbits. The unknown mass for an orbit with angular momentum like 1
can be expected to be closer to the mass for angular momentum zero
((L-5) linear oscillation orbit)than to the mass for angular momen-
tum 5((L-5) circular orbit). For example if we assume a linear
relationship between mass and (L-5) angular momentum, the angular
momentum 1 would correspond to a mass of 1226.326MEV, in good
agreement with the observed mass of the Δ(1232) baryon.

The mesons listed in table 5 are those which do not contain split s
and c-quarks, namely the mesons Π°, Π^{+}, ρ°,ρ^{+} and the mesons D°,
D^{+}, F^{+}, η_{c} and ψ involving the compact c-quark. Other mesons
involving split quarks will be presented in the next section and
are listed in table 6A and 6B. As the configurations
show, the mesons differ from baryons by the fact that they contain
only two fermions instead of three. Otherwise our meson inter-
pretations are different from conventional ones, and, with few

exceptions, are not based on the assumption that mesons are associations of a single quark with a single antiquark. Such a requirement would in most cases not give a correct interpretation of their masses. The meson configurations, which are summarized in table 8 present, however, a very suggestive interpretation of their properties.

Lepton configurations, and their theoretically calculated masses are also listed in table 5. As shown by their configurations, each lepton contains only one fermion among its constituents. As a result some leptons (namely the electron and the neutrinos) can be (L-0) associations. No more than one fermion can be part of an (L-0) association, because of annihilations or exclusion rules.

A sum up of baryon, meson and lepton configurations will be presented in table 8.

10. Split s and c-quarks

Several strange or charmed elementary particles have lower masses
than would be predicted by a calculation based on ordinary (com-
pact) s or c-quarks. For example if we use our machine program
in order to calculate the mass of the spin 1/2 (octet) baryon

Ξ^O(1321) by using the configuration ((BS)1US)4, we would find a
theoretically calculated mass 1358MEV in stead of 1321MEV. Similar
deviations are found for the strange spin 3/2 (decaplett) baryons
and for most mesons involving s-quarks. Also elementary particles
involving c-quarks often have lower masses than those calculated
theoretically by using the compact c-quark.

For those baryons which have spin 3/2 we already know a reason
why the mass may be lower than that calculated on the assumption
that only linear oscillation orbits are involved. For example
we have already mentioned that the (L-5) association ((BD)1DD)5
defining the Δ^-(1232) baryon is probably characterized by an
(L-5) orbit of angular momentum 1 in stead of a linear oscilla-
tion (L-5) orbit. Its mass may therefore be intermediate between
that of the linear oscillation orbit given in table 5 and that
of a circular (L-5) orbit, which is substantially lower (see
preceeding section). Similar considerations apply to all the
other members of the spin 3/2 decaplett. Also the strange and
charmed mesons of spin 1 are expected for reasons which will be
presented in the next section, to be formed by associations in-
volving an orbit with angular momentum 1 in stead of a linear
oscillation orbit. Also in this case we can for the same reason
expect lower masses than those calculated by assuming linear
oscillation orbits.

This, however, can not explain the lower masses observed in several
strange or charmed baryons of spin 1/2 and mesons of spin 0, nor
would it be sufficient to explain the substantial difference
observed in some strange or charmed baryons of spin 3/2 and mesons
of spin 1.

In this section we will only deal with the baryons of spin 1/2
and the mesons of spin 0.

The lowered mass exhibited by several strange hadrons can be interpreted by assuming that some of the s-quarks involved may behave in these cases as if they were particles with a lower mass than that ascribed to the normal (or compact) s-quark. The difference between the two is not the same for every hadron showing this phenomenon, and seem to be slightly higher for baryons than for mesons. Nevertheless it is possible in most cases to obtain predictions of hadron masses with errors not substantially greater than 1% by substituting for the normal s-quark of mass $1.0793259\ M_O$ a so called "split" s-quark which is ascribed a mass $1.068\ M_O$.

This split s-quark is designated by the symbol T_1 (see table 4), and its mass and other properties are specified on top of table 6A, where the symbol T_1 is replaced by its brief notation T. Once the T properties are defined, the machine is capable of calculating the masses of strange hadrons with assigned configurations in which T is substituted for S. The masses of several baryons and mesons involving the split s-quark are calculated this way in table 6A. (In earlier presentations of the subject, Barricelli 1978B and 1980, two different split s-quarks, a T-split one for mesons and a Q-split one for baryons have been used. The consideration of orbits with angular momentum 1, see next section, has made the use of an extra parameter represented by the Q-split quark unnecessary.)

The lower mass of the split s-quarks compared with the normal (or compact) version is interpreted by assuming that in some hadrons the s-quark $S_1=(F_2L^1)1$ can be splitted into its two components F_2 and L^1 which may separately be associated to the hadron in different ways. An example to illustrate this phenomenon is presented at the bottom of table 6A whose last 3 items include a normal $\Lambda(1115)=((BUD)4S)1$ baryon with calculated mass 1123.9 a $\Lambda(T)=((BUD)4\ T)1$ baryon with a T substituted for S, whose calculated mass is 1097.4, and a $\Lambda(FL)=(((BUD)4F)1L)1$, whose calculated mass is 1102.8. The mass reduction obtained by splitting $S=(FL)1$ into its two components F and L, added separately to the complex, is in this example quite comparable to the mass reduction obtained by substituting T for S.

PROPERTIES OF PARTICLES INVOLVING SPLIT S-QUARK (T) OR I-VERSION OF C-QUARK

DEFINITION OF SPLIT S-QUARK (T)
PARTICLE DEFINED: T   MASS: 1.06800000   EL.CHARGE: 0   MAGN.CHARGE: 1   SPIN: 1/2

E1 E2 G1 G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
DEFINITION OF I											
0 1 -1 2	1.00000000	4.26194400	.44838048	.58958027	.16881144	1.56206891	3	3747.329	I	((BT)2L)3	1/2

BARYONS

E1 E2 G1 G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0 -1 2 -2	4.06800001	4.16069666	.36681112	.27648221	.27077884	.55517262	4	1331.833	XI-(1321)	((BS)1DT)4	1/2
1 -1 2 -2	4.06821301	4.16069666	.36680542	.27647263	.27078256	.55496080	4	1331.324	XI0(1321)	((BS)1UT)4	1/2

MESONS

E1 E2 G1 G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0 0 -1 1	1.06800000	1.07932591	.36381651	.26613119	.26353345	.22683438	1	544.165	ETA(549)	(ST)1	0
1 -1 2 -2	4.06821301	4.00021301	.36818282	.27557098	.27989129	.39840087	4	955.745	ETA*(958)	((BL)0UT)4	0
-1 1 -1 1	1.56206891	1.56206891	.33881500	.19799139	.19799139	1.18680705	1	2847.093	ETAC(2830)	(II)1	0
0 0 2 -2	4.06800000	4.08462164	.22090656	.11686422	.11639512	.20864151	1	500.521	K0S(498)	((BU)1TL)1	0
1 -1 2 -2	4.00021301	4.14984165	.22092953	.11880492	.11457851	.20567300	1	493.400	K0L(498)	((BT)1UL)1	0
1 -1 2 -2	4.00021302	4.14984165	.22092953	.11880492	.11457851	.20567301	1	493.400	K0L(498)	((BT)1(BD)0)1	0
0 -1 2 -2	4.00000001	4.14984165	.22093266	.11880953	.11457693	.20588596	1	493.911	K+(494)	((BT)1F)1	0
0 -1 2 -2	4.00000001	4.14984165	.22093266	.11880953	.11457693	.20588596	1	493.911	K+(494)	((BT)1(BU)0)1	0
0 -1 2 -2	4.08462164	4.14984165	.28270027	.18106518	.17831069	.37069981	2	889.291	K+*(892)	((BT)1(0U)1)2	1
1 -1 2 -2	4.08484245	4.14984165	.28269611	.18105823	.17831317	.37049484	2	888.799	K0*(892)	((BT)1(0D)1)2	1

SPLITTING TEST

E1 E2 G1 G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
0 0 1 -1	1.07932591	1.31436132	.35700038	.26796517	.22266624	.46850517	1	1123.922	LMDA(1115)	((BUD)4S)1	1/2
0 0 1 -1	1.06800000	1.31436132	.35739190	.27034017	.22244715	.45744441	1	1097.387	LMDA(T)	((BDU)4T)1	1/2
0 0 -1 1	1.00000000	1.38396485	.35835194	.28658895	.21126600	.45970712	1	1102.815	LMDA(FL)	(((BDU)4F)1L)1	1/2

PARTICLES ASCRIBED AN INDEPENDENT ORBIT OF ANGULAR MOMENTUM 1
MASSES TO BE USED FOR INTERPOLATION (SEE TABLE 7)

E1 E2 G1 G2	M1	M2	R	V1	V2	W	N	M	NAME	CONFIGURATION	SPIN
BARYONS											
0 -1 2 -2	4.00000002	4.08484245	.40181465	.31838333	.31212650	.51878061	5	1244.530	DLTA(1232)	((BD)1DD)5	3/2
0 -1 2 -2	4.06800001	4.08484245	.40115096	.31372704	.31256010	.58459650	5	1402.419	SGMA(1385)	((BD)1DT)5	3/2
0 -1 2 -2	4.13600000	4.08484245	.40050418	.30948584	.31298420	.65047329	5	1560.454	XI(1530)	((BD)1TT)5	3/2
0 -1 2 -2	4.13600000	4.14984165	.39988696	.30988811	.30895330	.71345121	5	1711.535	OMGA(1672)	((BT)1TT)5	3/2
MESONS											
0 0 -1 1	1.06800000	1.06800000	.57825823	.47534060	.47534060	.42781938	3	1026.318	PHI(1020)	(TT)3	1
0 0 -1 1	1.06800000	1.07932591	.48187968	.39071144	.38722905	.33087871	2	793.762	OM(783)	(ST)2	1
0 -1 2 -2	4.08462164	4.16069666	.28263385	.18110508	.17789946	.38144281	2	915.063	K+*(892)	((BS)1(0U)1)2	1
1 -1 2 -2	4.08484245	4.16069666	.28262968	.18109813	.17790193	.38123783	2	914.571	K0*(892)	((BS)1(BD)1)2	1
0 0 2 -2	4.08462164	4.62823597	.25001136	.18269602	.16183558	.84460652	2	2026.171	D0*(2006)	((BI)1(0U)1)2	1
1 0 2 -2	4.08484245	4.62823597	.28003990	.18268736	.16183637	.84482492	2	2026.695	D+*(2009)	((BI)1(BD)1)2	1
1 0 2 -2	4.14984165	4.62823597	.27958717	.18017434	.16206728	.90912732	2	2180.953	F+*(2140)	((BI)1(BT)1)2	1

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Of course the result of splitting an s-quark may not always be
expressible by two-body associations, and the mass-reduction
can in most cases not be calculable by our programs. The substi-
tution of an s-quark with a reduced mass is only a roughly approxi-
mated procedure to get around this difficulty, in order to verify,
for example, whether the configuration proposed for a particle is
consistent with its mass.

Splitting of the c-quark might also have to be considered as a
possible way to interpret the masses of several charmed hadrons.
We have limited our study to the use of a c-quark substitute
$I_1 = ((B_3 T^1) 2L^1) 3$ designated as "intern T" (see table 4), which is
obtained from the normal c-quark $C_1 = ((B_3 S^1) 2L^1) 3$ by substituting
the split s-quark T for its normal version S (see top of table 6A).

T and I are used in stead of S and C respectively in tables 6A and
6B whenever required in order to obtain a better fit between
calculated and observed masses.

The configuration proposed for a particle is considered consistent
with its mass if a fit can be obtained by these means.

11. Interpolated masses for particles involving an independent orbit of angular momentum 1

If the spin 3/2 decaplet baryons are characterized by an (L-5) orbit of angular momentum 1, a question which arises is whether some mesons as well may involve orbits of angular momentum 1. Mesons of spin 1 are possible candidates for this class of particles. For example if the two fermions included in each meson (see section 9) have anti-parallel spin also in the mesons of spin 1, their spin would have to be ascribed to an orbital angular momentum 1.

We have found no clear-cut way to decide whether or not this is the case. If the spins of the two fermions involved are anti-parallel, the angular momentum of the mesons of spin equal to 1 must be ascribed to the orbits of the magnetic monopoles involved. An interpretation, which might be applicable in many cases, is to assume that one of the orbits expressed in the configuration, probably an (L-2) or (L-3) orbit, is not a linear oscillation orbit but an "independent" orbit of angular momentum 1 (this is the same sort of interpretation used in section 9 for the Δ(1232) baryon whose (L-5) orbit was considered an orbit of angular momentum 1). This is not the only possible interpretation and may not apply to all mesons of angular momentum 1, since several not aligned linear oscillation orbits can also give a system with orbital angular momentum different from 0.

Still, if many of these mesons involve an independent orbit of angular momentum 1, we may be able to find it out, since their masses will be intermediate between that calculated for a circular orbit, and that calculated for a linear oscillation orbit. The masses will therefore be lower than expected according to the linear oscillation program.

We find indeed that many mesons of spin 1 as well as baryons of spin 3/2 have masses lower than expected (much more so and much more frequently than is the case for mesons of spin 0 and baryons of spin 1/2). In two earlier presentations of the subject (Barricelli 1978B and 1980) these deviations were interpreted by introducing more split quarks. In this paper we will show that they can nearly as well be interpreted with fewer arbitrary parameters by assuming that several mesons and baryons involve an independent orbit of angular momentum 1.

If we assume a linear relationship between angular momentum and mass for orbits with a common energy level, a prediction of the mass will be possible by interpolation between the mass calculated by the oscillation orbits program and that calculated by the circular orbits program. Let us see how these methods are applied.

In table 6B the masses calculated for an array of spin 3/2 baryons and spin 1 mesons are listed. The same masses are repeated in table 7 for "oscillation orbits", together with the respective masses for "circular orbits" and "interpolated" masses. The interpolated mass for $\Delta^-(1232)$ has already been calculated in section 9 by interpolation between the mass 1244.584 MEV for an (L-5) orbit of angular momentum 0 (linear oscillation) and the mass 1153.280 MEV for a circular (L-5) orbit of angular momentum 5. The result calculated on the assumption of a linear relationship between mass and angular momentum was 1226.326 MEV.

The interpolated masses of the other baryons and mesons of table 7 are calculated by the same procedure. When comparing observed and calculated masses one should pay attention to the fact that the effect of splitting the s-quark is different in different particles. The use of a single split quark T, with a single reduced mass 1.068 M_o can only give an estimate of the average mass reduction one may expect by such splitting in order to evaluate whether the splitting hypothesis is a sensible explanation in each particular case.

Besides the interpretations $K^{o*}(892)=((BS)1(BD)1)2$ and $K^{+*}(892)=((BS)1(BU)1)2$ ascribed to an independent orbit of angular momentum 1 and listed in table 7, the two mesons K^{o*} and K^{+*} have also received an other interpretation $K^{o*}(892)=((BT)1(BD)1)2$ and $K^{+*}(892)=((BT)1(BD)1)2$ listed in table 6A, in which S is replaced by the split s-quark T. Both interpretations give a comparable fit between observed and theoretic masses. For the moment we have no safer method of deciding which interpretation is best.

Other spin 1 mesons whose interpretation, given in table 5, does not involve an independent orbit of angular momentum 1 are $\rho^o(770)=(((BD)1B)1D)2$, $\rho^+(770)=(((BD)1B)1U)2$ and $\psi(3097)=(CC)2$. In these cases we have found no alternative interpretation giving an equally good fit between observed and calculated masses.

Table 7

Particles ascribed an independent orbit of angular momentum 1. Output masses and interpolated masses.

B A R Y O N S

Name and observed mass	Configurations	Calculated masses Circular orb.	M.E.V. Oscill. orb.	Interpolated
DLTA(1232)	((BD)1DD)5	1152.828	1244.530	1226
SGMA(1385)	((BD)1DT)5	1310.983	1402.419	1384
XI(1530)	((BD)1TT)5	1469.279	1560.454	1542
OMGA(1672)	((BT)1TT)5	1620.6i0	1711.535	1693

M E S O N S

Name and observed mass	Configurations	Calculated masses Circular orb.	M.E.V. Oscill. orb.	Interpolated
PHI(1020)	(TT)3	996.998	1026.318	1016
OM(783)	(ST)2	763.712	793.762	779
$K^{+x}(892)^{\maltese}$	((BS)1(BU)1)2	878.290	915.063	897
$K^{\circ x}(892)^{\maltese}$	((BS)1(BD)1)2	877.797	914.571	896
$D^{\circ x}(2006)$	((BI)1(BU)1)2	1990.424	2026.171	2008
$D^{+x}(2009)$	((BI)1(BD)1)2	1990.949	2026.695	2009
$F^{+x}(2140)$	((BI)1(BT)1)2	2145.471	2180.953	2163

$\maltese$ An other interpretation of $K^{+x}(892)$ and $K^{\circ x}(892)$, which is presented in table 6A and gives just as good a fit with experimental masses, is to replace S by its split version T, in stead of assuming that the two particles have an independent orbit of angular momentum 1 and calculating their masses by interpolation.

Another borderline case in which both interpretations are
possible is presented by the $\phi(1020)$ meson. Its interpolated
mass calculated in table 7 on the assumption of an independent
(L-3) orbut of angular momentum 1 is 1016 MEV. Its calculated
oscillation oebits mass of 1026 MEV given in tables 7 and 6B
is nearly as good.

12. Summary of configurations

In table 8 the configurations of the elementary particles presen-
ted in table 1 are listed in the same order, so that the reader
can identify each particle and its configuration by comparing the
two tables. Whenever possible the configuration of each meson
has been expressed by using the four quarks U,D,S,C or their split
versions T and I and the barie B, avoiding the use of L and F.
This has been done in order to give a uniform presentation which
stresses the symmetries and the analogies betweem particles within
each family and between related families. The only exception is
the η' meson whose interpretation is uncertain. In the interpre-
tation of the leptons and the quarks the use of the light boson L
was unavoidable. F could everywhere be replaced by (BU)0.

The symmetric properties of the various families revealed by
these configurations make it quite improbable that the agreement
obtained between calculated and observed masses could be accident-
al. If they were, the configurations giving good agreement, if
any could be found at all, could not show the reciprocal rela-
tionship we observe.

Most meson configurations are substantially different from those
one might have expected on the basis of conventional quark models,
which hold that mesons are quark-antiquark associations. Only
three mesons, ETA(543), OM(783) and PHI(1020) follow this pat-
tern and only the last one fits the quark selection usually
ascribed to it.

Rather than defining the mesons as quark-antiquark associations
we shall define them as particles containing two fermions,
whereas the baryons are defined as particles containing three
fermions.

Our model makes also possible the interpretation of the masses

Table 8

Configurations of the elementary particles presented in table 1.

B A R Y O N S

	Octett of spin 1/2			Decaplett of spin 3/2		
Stran-geness	Name and mass	Configurations		Name and mass	Configurations	
-3				Ω(1672)	((BT)1TT)5	
-2	Ξ(1321)	((BS)1DT)4	((BS)1UT)4	Ξ(1530)	((BD)1TT)5	((BU)1TT)5
-1	Σ(1190)	((BD)1DS)4	((BD)1US)4 etc.	Σ(1385)	((BD)1DT)5	((BD)1UT)5 etc
0	n,p(938)	((BUD)4D)1	((BUD)4U)1	Δ(1232)	((BD)1DD)5	((BD)1UD)5 etc
-1	Λ(1115)	((BUD)4S)1				
0	Λ_c(2260)	((BUD)4C)1	Charmed Lambda baryon of spin 1/2			

M E S O N S

	Nonett of spin 0			Nonett of spin 1	
0	η'(958)	((BL)0UT)4 ?		ϕ(1020)	(TT)3
0	η(549)	(ST)1		ω(783)	(ST)2
±1	$K^{\pm}$(494)	((BT)1(BU)0)1		$K'^{\pm}$(886)	((BT)1(BU)1)2
±1	K^0(498)	((BT)1(BD)0)1	((BU)1TL)1	K'^0(892)	((BT)1(BD)1)2
0	$\pi^{\pm}$(140)	((BU)0(BD)0)1		$\rho^{\pm}$(770)	(((BD)1B)1U)2
0	π^0(135)	((BD)0(BD)0)1		ρ^0(770)	(((BD)1B)1D)2

	Charmed triplett of spin 0		Charmed triplett of spin 1	
0	D^0(1863)	((BC)1(BU)1)1	D'^0(2006)	((BI)1(BU)1)2
0	$D^{\pm}$(1868)	((BC)1(BD)1)1	$D'^{\pm}$(2009)	((BI)1(BD)1)2
±1	$F^{\pm}$(2040)	((BC)1(BS)1)1	$F'^{\pm}$(2140)	((BI)1(BT)1)2

	Charm-anticharm of spin 0		Charm-anticharm of spin 1	
0	η_c(2830)	(II)1	ψ(3095)	(CC)2

L E P T O N S

		El.charge	Strangeness	Charm
τ(1807)	(B(BL)0C)3	±1	0	±1
S^0	(B(BL)0S)2	0	±1	0
$\mu^{\pm}$(106)	(B(BL)0U)1 or (BFL)1	±1	0	0
μ^0	(B(BL)0D)1 or (BULL)1	0	0	0
ν_{μ}(0)	(BULL)0	0	0	0
e(0.511)	(UL)0	±1	0	0
ν_e(0)	(DL)0	0	0	0

and other properties of leptons, which are considered as particles containing a single fermion and a variable number of bosons. This makes it possible to build some leptons, such as the electron $e^{\pm}$ and the two neutrinos ν_e and ν_μ, by (L-0) associations without conflicting with exclusion principles and annihilation processes which prevent (L-0) associations involving several fermions.

The difference between the e-neutrino, with the assumed configuration (DL)0, and the Mu-neutrino with the assumed configuration (BULL)0, is not clear, since D=(FL)0=(BUL)0, and the primary monopoles included in the two configurations are therefore the same. The difference must probably depend on the way in which the four monopoles B,U,L, L are put together, in spite of the fact that the energy level is the same (L-0) in both neutrinoes. The two neutrinoes can, however, in some cases replace each other, as indicated for example by the unfrequent cases in which a myon decays directly into an electron and a photon, without producing an e-neutrino and a μ-antineutrino as is usually the case (see table 9A).

Besides the three (L-0)leptons, table 8 presents a few leptons with higher energy levels, namely two charged leptons (MU(106) and Tau(1807)) and two electrically neutral, S_o(450?) and an electrically neutral version of MU(106). The electrically neutral leptons of higher energy have not been identified yet. They represent a theoretic prediction of our model. A so called Tau neutrino has been observed, but its mass is not well determined. The mass of 450 MEV for the S_o lepton is theoretically calculated by assuming the configuration (B(BL)0S)2. Its decay mode and the ways in which it can be formed by Tau(1807) decay are suggested in an earlier preprint (Barricelli 1979).

13. Decays and the B,U,L conservation law

Besides the calculation of the masses of elementary particles, an other way of testing the validity of the configurations proposed is by using them in the interpretation of decay processes.

The B,U,L conservation law. An important conservation law which apply in all decay processes is the conservation of the three basic monopoles B,U,L, which are used in the definitions of all particles. According to this law the three basic monopoles are conserved in every decay process and every interaction process between elementary particles. That means that none of these monopoles can be created or destroyed except in the form of a "monopole-antimonopole pair", namely a $B^3 B_3$-pair, $U^1 U_1$-pair or $L^1 L_1$-pair. Decay processes not following this conservation law are appearantly impossible in nature.

An array of decay processes interpreted on the basis of the B,U,L conservation law are listed in the tables 9 A, B,C. The interpretation is made as follows. One compares the B,U,L composition of the decaying particle (for example $\mu^+ = (B_3 D^1 L^1 L^1)1$ which is composed by the basic monopoles $B_3 B^3 U_1 L_1 L^1 L^1$, see table 4) with the composition of the decay products (for example $\nu_e = (D^1 L_1)0$, $\nu^\mu = (B_3 U^1 L^1 L^1)0$, $e^+ = (U_1 L^1)0$ which all together contain the basic monopoles $B^3 U_1 L_1 L_1 B_3 U^1 L^1 L^1 U_1 L^1)$. If there is a difference between the two sets of basic monopoles one may introduce the necessary number of pair formations and/or annihilations in order to bring agreement (if possible) between the two sets (in the above example the two pairs $L^1 L_1$ and $U^1 U_1$ are missing in the decaying particle in order to complete the list of basic monopoles appearing in the decay products. These two pairs are recorded in the table as pair formations). A simple way to make sure that the two sets can be converted to one another by pair formations and/or annihilations is to remove in both sets every pair which can be found. If the two sets become identic after the removal they will obviously be reducible into each other by simple pair formations and/or

Table 9A

Decay of elementary particles

Particle and Configuration	Mean life (sec)	Pairs formed	New associations	Annihilations	Decay products	% of decais
			LEPTONS			
$\mu^+ = (B_3D^1L^1L^1)1$	2×10^{-6}	LL,UU	$(D^1L_1)0$, $(B_3U^1L^1L^1)0$, $(U_1L^1)0$	--	$\nu_e=(DL)0$, $\bar{\nu}_\mu=(BULL)0$, $e^+=(UL)0$, (γ)	100^*
		--	$(B_3D^1L^1L^1)0$	BB,LL	$e^+=(UL)0$, γ, (γ)	10^{-3}
		UU	$(B_3B^3U_1L^1)0$, $(U_1L^1)0$, $(U^1L_1)0$	BB	$e^+=(UL)0$, $e^+=(UL)0$, $e^-=(UL)0$	10^{-7}
$\tau^+ = (B^3(B_3L^1)OC_1)3$	?	DD	$(B^3(B_3L^1)OD_1)0$, $(B_3F^1L^1)1$, $(D^1L_1)0$	BB	$\bar{\nu}_e=(DL)0$, $\mu^+=(BFL)1$, $\nu_e=(DL)0$	18
meaning $= (B^3(B_3L^1)0((B_3S^1)2L^1)3)3$		LL,UU	$(B_3(B^3L_1)0D^1)0$, $(U_1L^1)0$, $(B_3U^1L^1L^1)0$	BB	$\nu_e=(DL)0$, $e^+=(UL)0$, $\bar{\nu}_\mu=(BULL)0$	18
		UU	$(F^2U_1L_1)1$, $(B_3U^1L^1L^1)0$, $(B^3B_3)0$	BB	$\pi^+=(FUL)1$, $\bar{\nu}_\mu=(BULL)0$	10 ?
		UU	$(((B_3D^1)1B^3)1U_1)2$, $(B_3U^1L^1L^1)0$	--	$\rho^+=(((BD)1B)1U)2$, $\bar{\nu}_\mu=(BULL)0$	20 ?
		UU,(nFF)	$((B_3T^1)1(B^3U_1)0)1$, $(B_3U^1L^1L^1)0$, $n(F^2F_2)1$	--	$K^+=((BT)1(BU)0)1$, $\bar{\nu}_\mu=(BULL)0$, $n\pi^\circ$	?
		UU,(nFF)	$(F^2U_1L_1)1$, $(B_3U^1L^1L^1)0$, $(B^3B_3)0$, $n(F^2F_2)1$	BB	$\pi^+=(FUL)1$, $\bar{\nu}_\mu=(BULL)0$, $n\pi^\circ$	?
			etc.			

* The identity of the two neutrinos is given only as an example, which applies in less Than 25% of the cases (cfr. Tables of Particle Properties. April 1978).

Table 9B

Decay of elementary particles

Particle and Configuration	Mean life (sec)	Pairs formed	New associations	Annihilations	Decay products	% of decais
			MESONS			
$\Pi^+ = (F^2 U_1 L_1)1$	3×10^{-8}	LL	$(B_3 F^2 L^1)1, (F^2 L_1 L_1)0$	--	$\mu^+ = (BFL)1, \nu_e = (FLL)0, (\gamma)$	100
$= ((B_3 D^1)0(B^3 U_1)0)1$		LL	$(U_1 L^1)0, (D^1 L_1)0$	BB	$e^+ = (UL)0, \nu_e = (DL)0, (\gamma)$	10^{-2}
		LL,UU	$(U_1 L^1)0, (D^1 L_1)0, ((B_3 U^1)0(B^3 U_1)0)1$	--	$e^+ = (UL)0, \nu_e = (DL)0, \Pi^\circ = (FF)1$	10^{-6}
		LL,e^+e^-	$(U_1 L^1)0, (D^1 L_1)0, e^+ e^-$	BB	e^+, e^+, e^-, ν_e	10^{-6}
$\Pi^\circ = (F^2 F_2)1$	10^{-16}	--	$(F_2 F^2)0$	FF	$\gamma, \gamma, (\gamma \dots)$	99
		LL	$(U_1 L^1)0, (U^1 L_1)0, (B^3 B_3)0$	BB	$e^+ = (UL)0, e^- = (UL)0, (\gamma)$	1
$K^+ = ((B_3 T^1)1F^2)1$	10^{-8}	LL	$(B_3 F^2 L^1)1, (B^3 U_1 L_1 L_1)0$	--	$\mu^+ = (BFL)1, \nu_\mu = (BULL)0, (\gamma)$	64
$= ((B_3 T^1)1(B^3 U_1)0)1$		FF	$((B_3 D^1)0(B^3 U_1)0)1, (F_2 F^2)1$	--	$\Pi^+ = ((BD)0(BU)0)1, \Pi^\circ = (FF)1, (\gamma)$	21
		FF,UU,LL	$(F^2(B_3 F^2)0 L_1)1, (F^2 U_1 L_1)1, (F_2 U^1 L^1)1$	BB	$2\Pi^+ = 2(FUL)1, \Pi^- = (FUL)1, (\gamma)$	6
		2FF	$(F^2(B_3 F^2)0 L_1)1, (F^2 F_2)1, (F^2 F_2)1$	BB	$\Pi^+ = (FUL)1, 2\Pi^\circ = 2(FF)1$	2
		FF,LL	$(F^2 F_2)1, (B_3 F^2 L^1)1, (F^2 L_1 L_1)0$	--	$\Pi^\circ = (FF)0, \mu^+ = (BFL)1, \nu_e = (FLL)0, (\gamma)$	3
		UU,LL	$((B^3 U_1)0(B_3 U^1)0)1, (F^2 L_1 L_1)0, (U_1 L^1)0$	--	$\Pi^\circ = (FF)0, \nu_e = (FLL)0, e^+ = (UL)0, (\gamma)$	5
$K^\circ_S = ((B_3 U^1)1T^1 L^1)1$	10^{-10}	UU	$((B_3 U^1)0U^1 L^1)1, (F^2 U_1 L_1)1$	--	$\Pi^- = (FUL)1, \Pi^+ = (FUL)1, (\gamma)$	69
		FF	$((B_3 U^1)0F^2)1, (F^2 F_2)1, (L^1 L_1)0$	LL	$2\Pi^\circ = 2(FF)1$	31
$K^\circ_L = ((B_3 T^1)1U^1 L^1)1$	5×10^{-8}	FF,UU	$((B_3 U^1)0(B^3 U_1)0)1, 2(F^2 F_2)1, (L^1 L_1)0$	LL	$3\Pi^\circ = 3(FF)1$	21
$= ((B_3 T^1)1(B^3 D_1)0)1$		2UU	$((B_3 U^1)0F^2)1, ((B^3 U_1)0U_1 L^1)1, (F_2 U^1 L^1)1$	--	$\Pi^\circ = (FF)1, \Pi^+ = (FUL)1, \Pi^- = (FUL)1$	12
		UU,LL	$((B_3 U^1)0U^1 L^1)1, (B_3 F^2 L^1)1, ((B^3 U_1)0 L_1 L_1)0$	--	$\Pi^- = (FUL)1, \mu^+ = (BFL)1, \nu_e = (FLL)0$	27
		UU,LL	$(F^2 U_1 L_1)1, (U^1 L_1)0, (B_3 U^1 L^1 L^1)0, (B^3 B_3)0$	BB	$\Pi^+ = (FUL)1, e^- = (UL)0, \bar{\nu}_\mu = (BULL)0, (\gamma)$	40
Reversible transition	--	--	$((B_3 D^1)0(B^3 T_1)1)1$	--	K°_L with opposit strangeness	~100

Particle and Configuration	Mean life (sec)	Paies formed	New associations	Annihilations	Decay products	% of decays
$\eta = (S^1T_1)1$	10^{-18}	--	$(L^1L_1)0, (F^2F_2)0$ or $(F^2F_2)1$	LL,(FF)	$\gamma, \gamma, (\Pi^\circ)$	41
		2FF	$3(F^2F_2)1, (L^1L_1)0$	LL	$3\Pi^\circ=3(FF)1$	30
		UU,FF	$(F^2U_1L_1)1, (F_2U^1L^1)1, (F^2F_2)1$	--	$\Pi^+=(FUL)1, \Pi^-=(FUL)1, \Pi^\circ=(FF)1,(\gamma)$	24
		UU	$(F^2U_1L_1)1, (F_2U^1L^1)1$	--	$\Pi^+=(FUL)1, \Pi^-=(FUL)1$	5
$\eta' = ((B^3L_1)0U_1T_1)4$?	$>10^{-21}$	2FF	$(((B^3U_1)0L_1)1T_1)1, 2(F^2F_2)1$	--	$\eta=(ST)1, 2\Pi^\circ=2(FF)1$	66
		BB	$(((B^3D_1)1B_1)1(B^3U_1L_1)0)2$	--	$\rho^\circ=(((BD)1B)1D)2, \gamma$	30
		--	$(((B^3U_1)0L_1)1T_1)2$	--	$\omega=(ST)2, \gamma$	2
		--	$((B^3U_1)0F_2)0, (L^1L_1)0$	FF,LL	γ, γ	2
$\rho^+ = (((B^3U_1)1B_3)1D^1)2$	10^{-23}	UU	$((B^3U_1)0(B_3U^1)0)1, (F^2U_1L_1)1$	--	$\Pi^\circ=(FF)1, \Pi^+=(FUL)1$	100
$K^X = ((B^3T_1)1(B_3D^1)1)2$	10^{-23}	FF	$((B^3T_1)1(B_3D^1)0)1, (F^2F_2)1$	--	$K^\circ=((BT)1(BD)0)1, \Pi^\circ=(FF)1$	100
$\omega = (S^1T_1)2$	10^{-22}	UU,FF	$(F^2U_1L_1)1, (F_2U^1L^1)1, (F\ F)1$	--	$\Pi^+=(FUL)1, \Pi^-=(FUL)1, \Pi^\circ(FF)1$	90
		UU	$(F^3U_1L_1)1, (F_2U^1L^1)1$	--	$\Pi^+=(FUL)1, \Pi^-=(FUL)1$	1
		--	$(F^2F_2)1, (L^1L_1)0$	LL	$\Pi^\circ=(FF)1, \gamma$	9
$\phi = (T^1T_1)3$	10^{-22}	BB,FF	$((B^3T_1)1F_2)1, ((B_3T^1)1F^2)1$	--	$K^-=((BT)1F)1, K^+=((BT)1F)1$	48
		BB,LL,UU	$((B^3T_1)1U_1L_1)1, ((B_3U^1)1T^1L^1)1$	--	$K^\circ_L=((BT)1UL)1, K^\circ_S=((BU)1TL)1$	35
		UU,FF	$(F^2U_1L_1)1, (F_2U^1L^1)1, (F^2F_2)1$	--	$\Pi^+=(FUL)1, \Pi^-=(FUL)1, \Pi^\circ=(FF)1$	15
		--	$(S^1T_1)1$	--	$\eta=(ST)1, \gamma$	2
$D^+ = ((B^3I_1)1(B_3D^1)1)2$	10^{-21}	UU	$((B^3C_1)1(B_3U^1)1)1, (F^2U_1L_1)1$	--	$D^\circ=((BC)1(BU)1)1, \Pi^+=(FUL)1$	68
		(FF)	$((B^3C_1)1(B_3D^1)1)1, (\ (F^2F_2)1\ )$	--	$D^+=((BC)1(BD)1)1, (\Pi^\circ=(FF)1), (\gamma)$	32
$F^+ = ((B^3I_1)1(B_3Q^1)1)2$?		--	$((B^3C_1)1(B_3S^1)1)1$	--	$F^+=((BC)1(BS)1)1, \gamma$	100

Decay of elementary particles

Particle and Configuration	Mean life (sec)	Pairs formed	New associations	Annihilations	Decay products	% of decais
			BARYONS			
$n = ((B^3 U_1 D_1)4 D_1)1$	918	UU,LL	$((B^3 U_1 D_1)4 U_1)1, (U^1 L_1)1, (D_1 L^1)1$	--	$p = ((BUD)4U)1, e^- = (UL)0, \bar{\nu}_e = (DL)0$	100
$\Lambda = ((B^3 U_1 D_1)4 S_1)1$	3×10^{-10}	UU	$((B^3 U_1 D_1)4 U_1)1, (F_2 U^1 L^1)1$	--	$p = ((BUD)4U)1, \Pi^- = (FUL)1, (\gamma)$	64
		FF	$((B^3 U_1 D_1)4 D_1)1, (F_2 F^2)1$	--	$n = ((BUD)4D)1, \Pi^0 = (FF)1$	36
$\Sigma^+ = ((B^3 U_1)1 U_1 S_1)4$	10^{-10}	FF	$((B^3 U_1 D_1)4 U_1)1, (F_2 F^2)1$	--	$p = ((BUD)4U)1, \Pi^0 = (FF)1$	52
		FF,LL	$((B^3 U_1 D_1)4(F_2 L^1)0)1, (F^2 U_1 L_1)1$	--	$n = ((BUD)4D)1, \Pi^+ = (FUL)1, (\gamma)$	48
$\Sigma^\circ = ((B^3 D_1)1 U_1 S_1)4$	6×10^{-20}	$(e^+ e^-)$	$((B^3 U_1 D_1)4 S_1)1, (e^+ e^-)$	--	$\Lambda = ((BUL)4S)1, \gamma, (e^+ e^-)$	100
$\Sigma^- = ((B^3 D_1)1 D_1 S_1)4$	10^{-10}	UU	$((B^3 U_1 D_1)4 D_1)1, (F_2 U^1 L^1)1$	--	$n = ((BUD)4D)1, \Pi^- = (FUL)1, (\gamma)$	100
$\Xi^\circ = ((B^3 S_1)1 U_1 T_1)4$	3×10^{-10}	FF	$((B^3 U_1 D_1)4 S_1)1, (F^2 F_2)1$	--	$\Lambda = ((BUD)4S)1, \Pi^0 = (FF)1$	100
$\Xi^- = ((B^3 S_1)1 D_1 T_1)4$	2×10^{-10}	UU	$((B^3 U_1 D_1)4 S_1)1, (F_2 U^1 L^1)1$	--	$\Lambda = ((BUD)4S)1, \Pi^- = (FUL)1$	100
$\Lambda_c = ((B^3 U_1 D_1)4 C_1)1$	?	FF,2UU,LL	$((B^3 U_1 D_1)4 S_1)1, 2(F^2 U_1 L_1)1, (F_2 U^1 L^1)1$	--	$\Lambda = ((BUD)4S)1, 2\Pi^+ = 2(FUL)1, \Pi^- = (FUL)1$	?
$\Delta^- = ((B^3 D_1)1 D_1 D_1)5$	10^{-23}	UU	$((B^3 U_1 D_1)4 D_1)1, (F_2 U^1 L^1)1$	--	$n = ((BUD)4D)1, \Pi^- = (FUL)1$	100
$\Sigma^- = ((B^3 D_1)1 D_1 T_1)5$	3×10^{-23}	UU	$((B^3 U_1 D_1)4 S_1)1, (F_2 U^1 L^1)1$	--	$\Lambda = ((BUD)4S)1, \Pi^- = (FUL)1$	88
		FF	$((B^3 D_1)1 D_1 S_1)4, (F_2 F^2)1$	--	$\Sigma^- = ((BD)1DS)4, \Pi^0 = (FF)1$	12
$\Xi^- = ((B^3 D_1)1 T_1 T_1)5$	10^{-22}	FF	$((B^3 S_1)1 D_1 T_1)4, (F_2 F^2)1$	--	$\Xi^- = ((BS)1DT)4, \Pi^0 = (FF)1$	100
$\Omega^- = ((B^3 T_1)1 T_1 T_1)5$	10^{-11}	FF	$((B^3 S_1)1 D_1 T_1)4, (F_2 F^2)1$	--	$\Xi^- = ((BS)1DT)4, \Pi^0 = (FF)1$	?
		FF	$((B^3 U_1 D_1)4 S_1)1, ((B^3 T_1)1 F_2)1$	--	$\Lambda = ((BUD)4S)1, K^- = ((BT)1F)1$	?

annihilations (in the above example both of the two sets are reduced to the same set U_1L^1 after such pair removal).

In many cases the notation FF is used in the tables 9 A,B,C in stead of BB,UU in a pair formation or annihilation. Likewise can a pair (L-0) associations such as e^+e^- be used in stead of the corresponding pairs of basic monopoles. Also pairs which involve higher energy associations ($\mu^+\mu^-,p^+p^-$ etc.) are possible when a sufficient amount of energy is available.

If a decay process is possibele, the B,U,L conservation law requires that the set of basic monopoles in the decaying particle can be converted into the set of basic monopoles in the decay products by a few pair formations and/or annihilations. But this does not have to be the case if the considered decay process is faulty or impossible. For example one of two faulty decay processes we have found in the literature (Barricelli 1978B) is the process $K^+ \rightarrow \Pi^- e^+ e^+$, conflicting with the rule that two positively charged leptons can not be produced by a meson decay without producing an equal number of neutrinos or negatively charged leptons

If we compare the B,U,L composition of the decaying particle $K^+ = ((B_3T^1)1(B^3U_1)0)1$, which is $B_3B^3U_1L_1B^3U_1$, with that of the decay products, $\Pi^- = (F_2U^1L^1)1$, $e^+ = (U_1L^1)0$, $e^+(U_1L^1)0$, namely $B_3U^1U^1L^1U_1L^1U_1L^1$, we find that they are not reducible into one another by pair formations and/or annihilations. In fact, after removing all pairs, the first set becomes $B^3U_1U_1L_1$ and the second one becomes a quite different set namely $B_3L^1L^1L^1$.

Similar inconsistensies could be found if the decaying particle or one of the decay products had been assigned a faulty configuration. The B,U,L test is a powerful tool as a means to detect errors in the assigned configurations as well as in decay and interaction processes.

14. Other rules and conservation laws

We may mention a few more conservation rules and/or implications
of already known rules and experimental observations.

The forbidden annihilation rule. This rule applies only for
baryons. If we look at the baryon decays in table 9C, we do not
find a single annihilation. The same apply to all baryon decay
processes we have analysed so far. This is a very surprising
property of baryons which, we will see, may have important impli-
cations.

One may notice, however, that several baryon decay processes in
table 8 lead to the formation of a particle (such as Π^o) or a pair
of particles (such as e^+e^-) which will or might be annihilated
later on (by the process $\Pi^o \to \gamma\gamma$ or $e^+e^- \to \gamma\gamma$). One may be tempted to
consider this as a sort of "postponed" or "delayed" annihilation.
In a sense it is. But look at what kind of monopoles are annihi-
lated in this delayed process. The formation of $\Pi^o = (FF)1$ is always
preceeded by an FF-pair formation. Likewise e^+e^- appears only
as the result of a pair formation. The net result of these delayed
annihilations is never the elimination of monopoles included in the
decaying baryon configuration. Only the excess monopoles created
by pair-formation during the decay process can be included in a
particle where they may be subject to subsequent annihilation.

In short: The net result of a baryon decay can not be the annihila-
tion of monopoles included in the baryon, without creating the same
monopoles by pair formation.

The implications of this rule seems to be strictly relate to the
conservation of baryon number, because if no decay can eliminate
any monopole belonging to a baryon by (either immediate or delayed)
annihilation, there will always be left a set of monopoles adequate
for the formation of a baryon.

The forbidden magnetic charge rule. An other rule which seems to
apply to all elementary particles is that no elementary particle
carrying a magnetic monopole charge can be formed by any decay or
interaction process known today. All elementary particles formed

in any known process carry an equal number of positive and negative magnetic monopole charges and are magnetically neutral.

Other rules are the exclusion principles presented in section 8. We shall not enumerate all the well known conservation laws which apply in elementary particle processes. But there must be other laws and rules which are still unidentified, because many configurations and many decaying processes which would not seem impossible or prohibited by any law which is presently known have never been observed. In some cases this might be due to experimental difficulties such as the difficulty to identify neutral leptons like the μ^O=(BULL)1 and

S^O=(B(BL)0U)2 leptons (see table 8) predicted by our theory. In other cases the unfrequent occurance of a predicted decay or a predicted particle may be the explanation. But this will hardly explain all the cases.

15. Conclusion

A question many readers may have asked is: Why did we have to re-
sort to the Bohr and Sommerfeld quantization method in stead of
using wave mechanics in the calculation of the energy levels and
the masses of elementary particles?

The problem is mainly a question of selecting the most practical
method in order to calculate the energy levels to begin with, and
it has hardly any theoretical implications concerning the question
which one of the two methods (semi-classical or wave mechanical)
is more precise, since we were satisfied with a rough approximation
(errors not substantially greater than 1%).

The reason for our selection is that in semi-classic theory there
is no more than one correct method of dealing with the energy level
problem for charges the size of magnetic monopoles, and that method
leads without difficulty to the calculation of energy levels, as
we have shown in section 5. The same can not be said about the wave
mechanical approaches applied so far. The general belief that magne-
tic monopoles must be treated as point charges requiring renormali-
zation and the habit of ignoring their classical radius seems to
have led to the consistent failures in every attempt to calculate
the energy levels in a system of magnetic monopoles (see section 4).

These are, however, only practical considerations about the best
way to start the investigation. Now after the way is found we
are planning to use a wave mechanical approach in order to calculate
the energy levels using the same kind of potencials we have used
in the semi-classical approach. That will hardly change many of
the particle configurations we have identified, but may still avoid
the infinity and renormalization problems and, it is hoped, will
give just as good or better results as those obtained by the semi-
classical approach.

Attempts might also be made to obtain estimates of various decay
probabilities once wave mechanical methods are introduced.

Unnecessary to say that much work remains to be done in order to
improve the interpretations of the various particles and find the
configurations of new particles.

Appendix 1.

The impossibility of observing orbits of two elementary charges (electric or magnetic) with an expected error smaller than $\hbar$ for the orbital angular momentum (see section 3) also poses severere restrictions to the possibility of finding an experimental meaning and a precise measure of the radius of such charges. Let us for example attempt the following approach:

The existence of a finite radius r_o presumes, as a matter of definition, that the attraction force between two equal and opposite magnetic charges g and -g (or electric charges e and -e) becomes lower than the coulombian value $\frac{g^2}{r^2}$ (or $\frac{e^2}{r^2}$) when r decreases to a value lower than or comparable to r_o. The very radius r_o of the two particles can be defined as the distance in which the attraction force between the two particles is below its coulombian value by a certain proportion $P < 1$ (for example P=80%). The basic point in this argument is however given by the question: what is the meaning of, and how do we measure the exact attraction force between the two particles at a given distance r?

Since the force is intended to be used for the calculation of orbits, the most direct method for measuring or defining the force is to put the two particles in a circular orbit at a reciprocal distance equal to the distance r in which we want to measure the force (any other orbit allowing the distance to vary, including scattering experiments, would be subject to interpretations and criticism, as a method of measuring and defining the exact force at the exact distance r). The force can now be calculated by measuring for example the orbital angular momentum of one of the particles, which can be done by hitting it twice with a photon or some other object.

By this method, according to Heisemberg's well known argument, we can measure the angular momentum with an error never smaller than $\hbar$.

Let us now find out what will be the error in the determination of the radius r^* in the case of two elementary charges electrical or magnetic. We are calling this radius r^* rather than r_o because by the new definition r^* is not only subject to a measuring error but is also dependent on the arbitrarely selected proportions P between the attraction force F and its coulombian value at the distance r^*. On the other hand r_o is defined as a precise quantity proportional or equal to the classical radius of the charge (electron or magnetic

monopole), irrespective of the question whether or not this radius can be subject to a direct measurement by the method indicated above.

The proportion P_r between attraction force F and its coulombian value $\frac{g^2}{r^2}$ for two magnetic monopoles of opposite equal charges g and -g is defined by the formula

(A)
$$P_r = \frac{r^2 F}{g^2}$$

We want to find the r value r^* where this proportion reaches a certain value $P < 1$ used in order to define the particle radius r^*.

F must be equal to the centrifugal force:

(B)
$$F = \frac{mv^2}{r}$$

m being the mass and v the velocity of each particle.

By eliminating F between (A) and (B) we obtain:

(C)
$$P_r = \frac{mv^2 r}{g^2}$$

or

(D)
$$v = g \sqrt{\frac{P_r}{mr}}$$

We define the angular momentum A by the formula

(E)
$$A = mvr$$

or according to (D)

(F)
$$A = g \sqrt{mrP_r}$$

or after solving with respect to r:

(G)
$$r = \frac{A^2}{mP_r g^2}$$

We now remember that the angular momentum A can be measured only with one error not smaller than $\hbar$, which we may express by the formula

(H)
$$A = A^* \overset{+}{\underset{-}{}} \hbar$$

A^* being a measured value and $\hbar$ its minimum error.
Formula (G) becomes then:

(I)
$$\sqrt{r} = \frac{A^* \overset{+}{\underset{-}{}} \hbar}{g\sqrt{mP_r}}$$

If P_r happens to be equal to our selected proportions P for the definition of r^*, then r^* will be related to A^* by the following formula which is a version of formula (F) for this particular case:

(L)
$$A^* = g\sqrt{mr^* P}$$

Putting this value into formula (I) we obtain for $P_r = P$:

(M)
$$\sqrt{r} = \sqrt{r^*} \overset{+}{\underset{-}{}} \frac{\hbar}{g\sqrt{mP}}$$

which gives the error in our measurement of the squareroot of the particle radius.

If m is the mass of a magnetic monopole given by formula (11) in section 5:

$$m = \frac{g^2}{2r_o c^2}$$

then formula (M) becomes

(N)

$$\sqrt{r} = \sqrt{r^*} \pm \frac{\hbar c}{g^2} \sqrt{\frac{2r_o}{P}}$$

If g is a Dirac monopole given by formula 2 section 2, $g^2 = \frac{137}{4} \hbar c$ and the above formula becomes:

$$\sqrt{r} = \sqrt{r^*} \pm \frac{4}{137} \sqrt{\frac{2r_o}{P}}$$

Since r_o is supposed to be comparable to r^* and P is comparable to 1, the error would be slightly lower than $\frac{10}{137} \sqrt{r^*}$ or less than 10 %.

This is a rather conspicuous error but not so large as to make the radius of a magnetic monopole a meaningless concept.

A diametrally opposite result would be obtained if in stead of calculating the error for a Dirac monopole-radius we had calculated the error for an electron-radius. In that case g would have to be replaced by e in formula (N) and since $e^2 = \frac{\hbar c}{137}$, formula (N) would become

$$\sqrt{r} = \sqrt{r^*} \pm 137 \sqrt{\frac{r_e}{P}}$$

The error would be more than two orders of magnitude greater than the quantity $\sqrt{r^*}$ we want to measure (since $P \approx 1$).

The radius of the electron, as defined above, is not a measurable quantity according to Heisemberg's indetermination principle. This would seem to put a question mark behind every statement to the effect that the electron has a specific radius finite or zero.

Appendix 2.

We shall now present the relativistic semi-classical theory for linear oscillation in a two-body system.

The bindings energy between the two particles will be a constant E defined by:

(A) $\quad E = U(r) + (M_1 + M_2)c^2 - (M_{10} + M_{20})c^2$

where $U(r)$ is the potential energy, M_1 and M_2 are the masses of the two particles, while M_{10} and M_{20} are their rest masses related to M_1 and M_2 by the formulae

(B) $\quad M_1 = \dfrac{M_{10}}{\sqrt{1 - v_1^2/c^2}} \qquad ; \qquad M_2 = \dfrac{M_{20}}{\sqrt{1 - v_2^2/c^2}}$

v_1 and v_2 being their respective absolute velocities relative to the center of gravity.

The laws of movement (impuls $= 0$, barycenter at rest) are expressed by:

(C) $\quad M_1 v_1 = M_2 v_2$

and

(D) $\quad M_1 r_1 = M_2 r_2$

(E) $\quad r_1 + r_2 = r$

r being the distance between the two particles (centers), r_1 and r_2 their respective distances from center of gravity.

Sommerfeld's condition for quantitation can now be expressed by:

(F) $\quad \oint M_1 v_1 dr_1 + \oint M_2 v_2 dr_2 = nh$

or according to (C) and (E)

(G) $\quad \oint M_1 v_1 dr = nh$

If we call r_x the maximum distance periodically achieved by the two particles (maximum r-value), this formula becomes:

(H) $$4 \int_0^{r_x} M_1 v_1\, dr = nh$$

The maximum distance r_x is characterived by the condition $v_1 = v_2 = 0$, which according to formulas (A) and (B) gives:

(I) $$E = U(r_x)$$

which is a way of defining r_x in terms of the bindings energy E.

In equation (C) we may now replace M_1 and M_2 by their values obtained from formula (B) and then solve the equation with respect to v_2 or v_1:

(L) $$v_2^2 = \frac{v_1^2}{v_1^2/c^2 + (1-v_1^2/c^2)M_{20}^2/M_{10}^2} \qquad , \qquad v_1^2 = \frac{v_2^2}{v_2^2/c^2 + (1-v_2^2/c^2)M_{10}^2/M_{20}^2}$$

which according to (C) and (B) gives:

(M) $$M_2 = M_1 v_1/v_2 = M_{10}\sqrt{\frac{v_1^2}{c^2 - v_1^2} + M_{20}^2/M_{10}^2} \qquad ; \qquad M_1 = M_{20}\sqrt{\frac{v_2^2}{c^2 - v_2^2} + M_{10}^2/M_{20}^2}$$

If we put

(N) $$M(r_x, r) = \frac{U(r_x) - U(r)}{c^2} + M_{10} + M_{20}$$

formula (A) becomes according to (I):

(O) $$M(r_x, r) = M_1 + M_2$$

In this formula we may replace M_2 by (M) and then eliminate v_1 by the following formula derives from (B)

(P) $$v_1 = c\sqrt{1 - M_{10}^2/M_1^2}$$

By solving the result with respect to M_1 we obtain:

(Q) $\quad M_1 = \dfrac{M_{10}^2 - M_{20}^2 + M^2(r_x, r)}{2M(r_x, r)}$

This way M_1 is expressed as a function of r_x and r only. According to formula (P) also the product $M_1 v_1$ can therefore be expressed as a function of r_x and r only, which will be designated as $P(r_x, r)$:

(R) $\quad P(r_x, r) = M_1 v_1$

and (H) becomes

(S) $\quad 4\displaystyle\int_0^{r_x} P(r_x, r)dr = nh$

Using these formulae our machine program can calculate $M(r_x, r)$ for any given r_x and r values by formula (N) then by formula (Q) it obtains M_1 and by formula (P) it obtains v_1, and $P(r_x, r)$ is then given by formula (R). An r_x value fulfilling formula (S) can then be obtained by successive approximations. Once r_x is determined, formula (I) gives the bindings energy E, and the mass M of the two-body system is then given by

$$M = M_1 + M_2 + \frac{E}{c^2}$$

This way all of the parameters: maximum distance r_x, velocities v_1 and v_2, mass of the system M are obtained.

The asyptotic coulombian potential $U_g(r)$ we are going to use in order to calculate the masses of elementary particles is given by the following formula fulfilling the requirements presented in section 5, provided the substitution indicated in the footnote below ^{x} is applied:

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^{x}This formula gives the potential $U_g(r)$ only for $r < r_0\sqrt{2}$. The general asymptotic coulombian formula valid for all r values is obtained by substituting the infinite series $\dfrac{1}{SR^2}(1 + \tfrac{1}{2}R^2 + (\tfrac{1}{2}R^2)^2 + (\tfrac{1}{2}R^2)^3 + \ldots)$ for the expression $1/SR^2(1 - \tfrac{1}{2}R^2)$ in formula (T).

$$(T) \qquad U_g(r) = \frac{g_1 g_2 + e_1 e_2}{r_0 \sqrt{1/(1+R^2) + R^2 \mathrm{Exp}(1/(1+1/SR^2(1-\tfrac{1}{2}R^2)))}}$$

g_1, g_2 are the magnetic charges, e_1, e_2 the electric charges of two interacting magnetic monopoles, $R = \frac{r}{r_0}$, r being the distance between their centers and r_0 their standard radius.

S is a free parameter whose best value (giving the best predictions for the masses of elementary particles including the electron) is found to be $S = 5{,}853 \approx \frac{1}{2}\sqrt{137}$. This value of S is suspiciously close the Dirac monopole expressed in units of $\sqrt{\hbar c}$, namely $\frac{g}{\sqrt{\hbar c}} = \frac{1}{2}\sqrt{137}$ and might not be an accident, even though we do not know what this coincidence means.

The above potential $U_g(r)$ and the force field generated by it are shown in fig. 3.
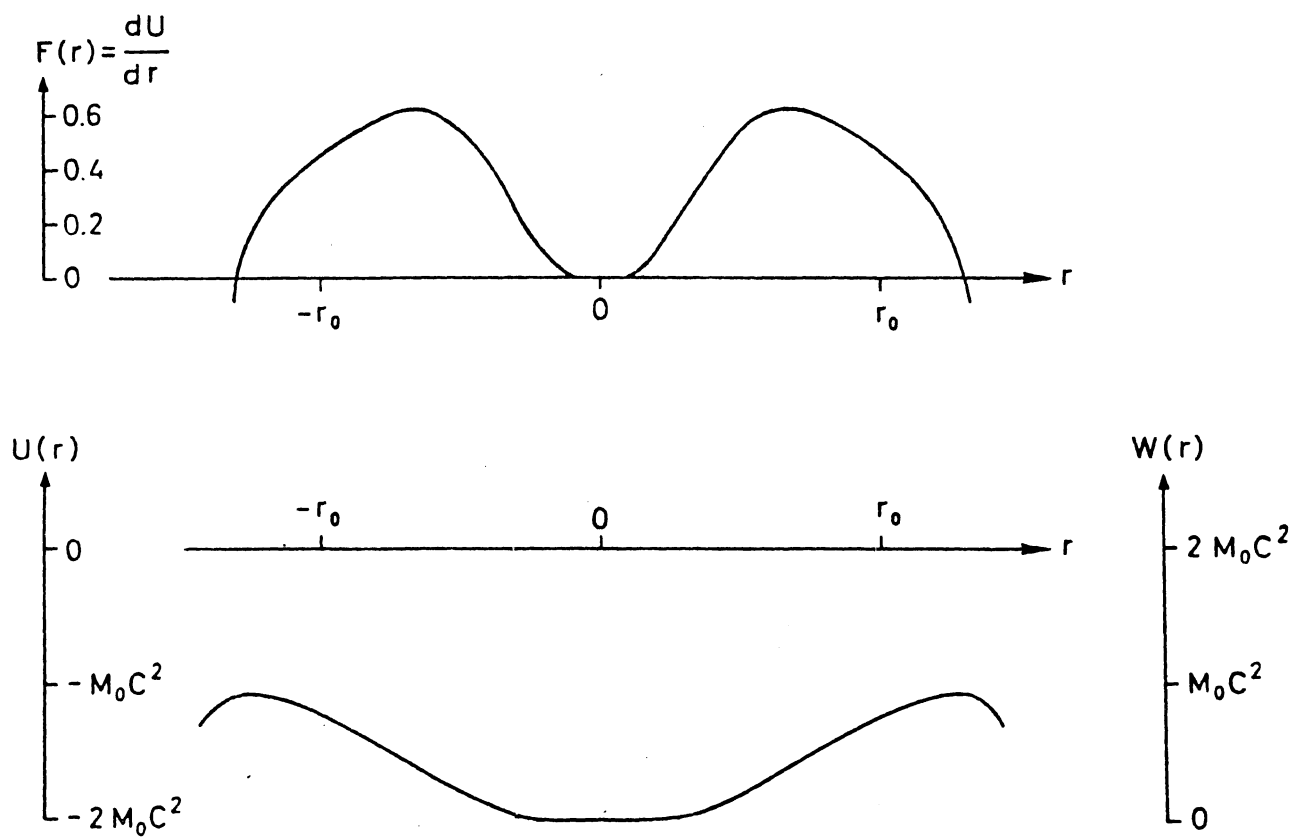
Fig. 3
Potential field $U = U_g$

Fig. 3
Potential field $U = U_g(r)$ defined in appendix 2, formula (T), and its derivative F identifying the force field generated by it, for two Dirac monopoles of opposit magnetic charge.

R E F E R E N C E S

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