THE FUNDAMENTAL PARAMETERS OF PHYSICS

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Abstract

The four parameters space, time, mass and charge are shown to possess an exact symmetry as a group of order 4. The explicit properties of the parameters as displayed in this group are then used to propose derivations of the fundamental principles of classical mechanics, electromagnetic theory and particle physics. The derivations suggest that the laws of physics and the fundamental particles have a single origin in the initial process of direct measurement.

The fundamental axioms of physics are not the laws of physics but the physical parameters through which all physical measurements are made and in terms of which the laws of physics are defined. Space, time, mass and charge (where charge refers generally to the sources of electromagnetic, strong and weak interactions) are regarded as elementary components in nearly every physical theory but it is not generally recognised that they may be defined in an explicit way through the discovery of their exact properties and that many laws of physics are consequences of these definitions. This is because the most fundamental physical principles, such as the conservation of laws of mass and charge, are not concerned with *physical phenomena* but with the *process of measurement.*

Now, it is a remarkable fact that, although the laws of physics require *four* fundamental parameters — space, time, mass and charge — only *one* is known by *direct measurement.* Measurement of space (or, at least, of distance) involves an element of enumeration or division into a finite number of discrete components; it is a counting process based on the natural numbers or integers and it is impossible to imagine how any form of direct measurement could be otherwise. It is, of course, possible also to describe the measurement of time as a counting process. Thus we measure time by the number of repetitions of a regular periodic event such as the oscillations of a steel spring or a quartz crystal or the revolution of the earth. However, all these measurements of time are really inferences from direct measurement of *space;* time is only measurable under the special conditions which prevail when a particular force is assumed to cause an object to traverse a certain distance with complete regularity; we measure distances and make assumptions about the forces acting to convert them into fixed time intervals. Masses and charges are, of course, known only through the forces which result from their interactions and these are known only through measurements of space and time.

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Since we believe the explicit properties of parameters to be the fundamental axioms of physics, we may assume that mass and charge are conserved *because* conservation is fundamental to their definition. We also know that all masses and all charges interact mutually to produce the forces which are responsible for all physical processes. At the same time, the other two parameters, space and time, are *not* conserved and do *not* interact. We may assume, therefore, that the property of conservation is linked to the property of interaction. Space and time produce the initial information about a system *because* they are variable or nonconserved and *because* each determination of space and time is separate and independent from any other. If nonconservation is thus linked to noninteraction, it is reasonable to suppose that conservation must be linked to interaction.

While mass and charge are thus so far similar, they are dissimilar in their types of interaction. Masses are always positive and always produce attractive forces; charges can be either positive or negative and can produce either attractive or repulsive forces; in particular, two charges of the same sign produce a force in the opposite direction to two masses. To explain this, we could introduce the mathematical device of making all masses real and all charges imaginary. This would complement the use of real space and imaginary time already established for 4-vector systems. Mass and the three charges (electromagnetic, strong and weak) could be represented as the real and imaginary parts of a quaternion in the same way as space and time are represented as the real and imaginary parts of a 4-vector. Imaginary charge would explain the existence of antistates to all known particles, since equations involving +i and −i are indistinguishable, while the use of a truly imaginary time would explain why this quantity is always measured through the effects of force and acceleration (as t^2) and never through the effects of motion (as t).

There is, however, yet another fundamental distinction between mass and charge. There is only one type of mass, but there are three types of charge, each of which interacts only with its own kind. At the same time, charge, unlike mass, occurs only in discrete units which can be counted; charge is localised in what appear to be point-sources, but mass (which includes energy) is a *continuum* in the sense that it is present in all systems, has an unlimited range of possible values, and is defined only in terms of a spatio-temporal distribution which can never be known exactly because it requires knowledge of the interactions between all masses. Now, space is three-dimensional like charge and is measured by dividing into units which can be counted, but time is one-dimensional like mass and is also a continuum measurable only by relationship to discontinuities in space. (The discontinuities arise *because* space is multi-directional or multi-dimensional; it is impossible to imagine a periodic discontinuity in space without a change in direction.) Space and charge may be described as denumerable quantities, mass and time as non-denumerable, and we may assume that the property of denumerability precedes that of dimensionality. In this context, it is significant that the dimensions of both space (in vectors) and charge (in forces) are added as squares according to the Pythagorean equation. For charges, squaring removes the imaginary quaternion operators and expresses the mutual interaction between one unit charge and any other. The symmetric application of addition by squares to space then actually *introduces* its vector or dimensional properties, for it implies the existence of an alternative combination of distances (via the Pythagorean equation) to the direct addition which is involved in the measurement of an individual distance. Addition by squares also introduces space's property of reflection symmetry, a parallel to charge's introduction of particles and antiparticles. Once the *concept* of dimensionality for space and charge is established, it is easy to see why it has the particular order of 3, for this is the minimum number of independent imaginary numbers for which an algebra can be created.

Our discussion, so far, has revealed the existence of certain symmetries between each pair of parameters. It is instructive to combine these in a single table. Assigning the arbitrary symbols +a, +b, +c to the properties of space, and using the corresponding negative symbols, where appropriate, for the alternative properties, we may set out the primary properties of the four parameters as follows:

space	real	nonconserved	denumerable	+a +b +c
time	imaginary	nonconserved	nondenumerable	-a +b -c
mass	real	conserved	nondenumerable	+a -b -c
charge	imaginary	conserved	denumerable	-a -b +c

It may now be apparent that space, time, mass and charge form a noncyclic group of order 4 (D2), with the multiplication table as set out below:

*	space	time	mass	charge
space	space	time	mass	charge
time	time	space	charge	mass
mass	mass	charge	space	time
charge	charge	mass	time	space

The multiplication rule for this group would be:

$$+a * +a = -a * -a = +a$$
$$+a * -a = -a * +a = -a$$

and similarly for b and c.

This remarkable and unexpected symmetry cannot be accidental and we may suspect that it is related to the fact that space is the only parameter used in direct physical measurement. We may assume that the symmetry between the four fundamental parameters is exact and is, indeed, the *source* of the properties of time, mass and charge. In that case, we need only define space to have the properties required for use in direct measurement and the definitions of the other three parameters will automatically follow.

The parameters are, in addition, the *sole* means by which the raw data of physical measurement is channelled into usable physical information. Thus information derived through the members of the parameter group is not only subject to its absolute symmetry but is also *absolutely exclusive.* Though a more rigorous derivation would, perhaps, make explicit use of the group properties, it is possible to see, even without elaborate mathematics, how the elementary principles of classical physics become a matter of organising the exclusive information about the physical parameters — of equating information available with information required.

In general, the variable, nonconserved parameters, space and time, are used to derive information about the invariant, conserved parameters, mass and charge; the former represent information available, the latter information required. A "system" (by which we mean nothing but a method of organising measurements) may be defined as a set of interrelated values of space, time, mass and charge, its permanent feature being the invariant value of the two latter quantities. There is no limit to the combination or division of systems, with the corresponding combinations or divisions of mass and charge, except that charge exists only in discrete units. These units may be negative or positive, and so it is possible to have a system with zero charge. Mass, however, is a continuum and so cannot be excluded from a system. This means that mass cannot take both positive and negative values, for systems with zero mass would otherwise be possible. A remarkable corollary of this property of mass is the unidirectionality of time, for time is the other parameter which is a continuum; this is a striking confirmation of the exact symmetry between the parameters. Time, however, is imaginary and has positive and negative mathematical representations which are physically indistinguishable. Thus, even though it is not possible to reverse time, it is possible to discuss the symmetry of physical laws under an *imagined* reversal of time. Since we can never specify the actual sign of time, we are unable to ensure that the laws of physics maintain the same form following a sign reversal in any individual parameter; we can only guarantee symmetry under sign reversal for the group as a whole (the CPT theorem).

In classical mechanics, we begin by assuming a system with a mass but no charge. The mass (m) must interact with all others but we cannot know this without a source of available information. The only information which is available is the variation of the nonconserved parameters space and time. Individually, the variations of space (dx) and time (dt) are arbitrary whereas the interaction between masses is not, so we define a new vector, velocity, which is their ratio (dx/dt). But velocity, again, is imaginary whereas the interaction of masses is not, so we introduce a new *real* vector quantity, acceleration (d^2x/dt^2), to express the available information on this interaction.

Acceleration is thus the quantity which we use to describe the effect of the interaction of other masses, or *gravitational field*, on the mass m, but we cannot consider the acceleration of the system independently of the conserved mass which defines it, and so we arrive finally at the definition of *force* as md^2x/dt^2 (Newton's second law of motion). The force vector is in the opposite direction to the space vector because the t^2 term introduces a negative sign into the definition. This means that the interaction between masses must be *attractive.*

In principle, force cannot be a direct source of information because we do not have direct information on the mass m, but we ought, nevertheless, to know of the interaction of masses. The problem may be resolved by assuming that the total sum of the force vectors in any system is *known to be zero*, or that to every action there is an equal and opposite reaction (Newton's third law of motion). This accords, in particular, with the principle that the interactions between masses are mutual.

For a distribution of masses in space we need to know the interaction between each individual mass and all the others in the system and so we are also interested in the distribution or variation of the gravitational field. (Here we will be concerned only with the restricted or limiting case in which curl-terms and effects of the 4-vector representation of space-time are assumed to be insignificant.) Because of our definition of force, the gravitational field at any point does not depend on the mass on which it acts. In fact, the gravitational field due to each mass (g_n) and its distributtion or variation through space ($\nabla . g_n$ in the limiting case represented by classical mechanics) do not depend on the presence of any other masses in space; in terms of the available information represented by the field variation, each mass behaves as though isolated. Yet the field variation cannot be detected for an isolated mass, because if any such variation could be discovered, we could detect the presence of mass independently of other masses. Assuming that necessary information, which cannot be made available, can be equated to zero would be compatible with setting up equations of the form

$$\nabla . g_n = 0$$

from which (assuming classical conditions) we could derive Newton's inverse square law of gravitation.

Since mass is a universal component of physical systems, a system containing charges must also contain masses. The addition of charges to a system adds no new direct information but it does add a new requirement: we must know how the charges in any system interact with all others, and we can only know of this effect through the concepts of force and acceleration. The interaction of charges must, therefore, be analogous to that of masses and must be so defined as to include the effects of the mass of the system. By defining an electric field E (the force on a unit charge) by analogy with the gravitational term g, we obtain Coulomb's law for a system of localised stationary charges:

$$\nabla . E = 0$$

(This is valid for the same restricted or limiting conditions as Newton's law of gravitation.) Through the concept of force, masses and charges become related by a numerical ratio, which is exactly what we would expect from the representation of mass as the real part of the quaternion involving the three charges. By applying the principle of exact symmetry, we may suppose that there must be a corresponding numerical relationship between space and time in all systems containing both mass and charge. By defining the constant of proportionality as the velocity of light, we obtain the familiar 4-vector representation of space-time. Coulomb's law and 4-vector space-time are all the principles we need to set up Maxwell's equations, the Lorentz transformations, the equivalence of mass and energy, and the other principles of electromagnetic theory, and it is particularly significant that we can thus derive all the relevant equations (which lead, in particular, to the 4-vector dynamics of particle physics) without any of the phenomenological assumptions of special relativity.

We are, of course, aware that there are three types of charge and that electromagnetic theory alone will not suffice to explain the properties of strong and weak interactions. For this we need also a comprehensive theory of particles. However, the properties of the fundamental particles are as much a consequence of the symmetrical arrangement of the physical parameters as are the laws of physics. In this case they arise from the application of the quaternion system to the parameter charge. This is because there is a problem in relating the imaginary quaternions i, j, k to the physical manifestations of the electromagnetic, strong and weak charges (e, s, w). Mathematical imaginary quaternions are not physically distinguishable, unlike spatial dimensions, but the three *charges* ought to be identifiable because, by analogy with space and mass, unit charges ought to have unit interactions with other charges of the same kind and we must know how one system of charge interacts with any other.

The solution to the problem involves the creation of the system of "coloured" quarks. Quarks combine only in threes and are often assumed to possess fractional charges, but it is more likely that, as in the model of Han and Nambu[1], they possess either unit or zero charge. (In either case, the *average* charges would be fractional and, for permanently confined quarks, the models would be phenomenologically indistinguishable.) Quarks may be considered as particles which would, ideally, contain one unit, either positive or negative, of each of e, s and w. There are eight such combinations, to which we may assign the labels of the u, d, c, s quarks and the $\bar{u}$, $\bar{d}$, $\bar{c}$, $\bar{s}$ antiquarks:

$$(\pm e + s + w)\ u, d \quad (\pm e + s - w)\ c, s$$
$$(\mp e - s - w)\ \bar{u}, \bar{d} \quad (\mp e - s + w)\ \bar{c}, \bar{s}$$

Now, we cannot simply assign quaternion value to e, s, w in these combinations because i, j, k would then be physically identifiable, but if each were, at any one time, one of *three* representations, arbitrarily defined by "colours" — say blue (ie, js, kw), green (ie, ks, jw), red (je, is kw) — then we would not be specifying a unique quaternion value for any particular charge. Nevertheless, the system would be inconsistent if charges of the same type could be associated with different quaternion values. Thus, if we assigned a unit value to ie in the blue quark, then we could not also assign a unit value to je in the red quark. It would, therefore, be necessary to find a system combining quarks and and antiquarks of each type or flavour in three-colour or colour-anticolour combinations in which a blue quark with unit ie would be indistinguishable from a red quark of the same flavour with *zero* je.

We can show that such a system does exist, but this depends on two conditions: the first is that the division between quarks and antiquarks must be made by assigning a positive unit of one type of charge (s) to all quarks and a negative unit to all antiquarks; the second is that at least one other type of charge (w) must be allowed to change sign, when appropriate, by assuming a simultaneous sign reversal in other parameters such as space and time. These conditions are ultimately responsible for all the differences between the three nongravitational interactions. Typical arrangements of the quarks in this system are given in the following tables (see Tables 1 and 2 below). There are also arrangements which allow the possibility of further quarks (t,b) (see Tables 3 and 4 below). This system of coloured quarks and their respective antiquarks presents us with a unique way of combining the charge components of different systems without specifying their quaternion values. The terms "quark" and "colour" now take on their conventional meanings in particle theory. The quarks are almost identical to those of the Han-Nambu theory, with the s component directly related to the baryon number. Here, however, there is an additional term in w, and in some cases this requires a sign reversal to preserve the invariance of quarks to colour transformations within "colourless" combinations. The laws of physics are so defined that the sign reversal in charge requires a simultaneous reversal in the sign of either the space coordinate or the time operator.

Table 1

		Blue	Green	Red
u	+e	li	li	Oj
	+s	lj	Ok	Oi
	+w	lk	Oj	Ok
d	-e	Oi	Ok	li
	+s	lj	Oj	Ok
	+w	lk	Oi	Oj
c	+e	li	li	Oj
	+s	lj	Ok	Oi
	-w	lk	Oj	Ok
s	-e	Oi	Ok	l_i
	+s	lj	Oj	Ok
	-w	lk	Oi	Oj

Table 2

		Blue	Green	Red
u	+e	li	li	Ok
	+s	Ok	Oj	lj
	+w	Oj	lk	Oi
d	-e	Oi	Oj	li
	+s	Ok	Oi	lj
	+w	Oj	lk	Ok
c	+e	li	li	Ok
	+s	Ok	Oj	lj
	-w	Oj	lk	Oi
s	-e	Oi	Oj	li
	+s	Ok	Oi	lj
	-w	Oj	lk	Ok

Table 3

		Blue	Green	Red
u	+e	li	li	Ok
	+s	Oj	lj	Oi
	+w	lk	Ok	Oj
d	-e	Oi	Ok	li
	+s	Oj	lj	Ok
	+w	lk	Oi	Oj
c	+e	li	li	Ok
	+s	Oj	lj	Oi
	-w	lk	Ok	Oj
s	-e	Oj	Ok	li
	+s	Oi	lj	Oj
	-w	lk	Oi	Ok
t	+e	li	li	Oj
	+s	Ok	lj	Oi
	±w	Oj	lk	lk
b	-e	Oj	Oi	li
	+s	Ok	lj	Oj
	±w	Oi	lk	lk

Table 4

		Blue	Green	Red
u	+e	li	li	Oj
	+s	Ok	lj	Oi
	+w	Oj	Ok	lk
d	-e	Oj	Ok	li
	+s	Oi	lj	Oj
	+w	Ok	Oi	lk
c	+e	li	li	Oj
	+s	Ok	lj	Oi
	-w	Oj	Ok	lk
s	-e	Oj	Ok	li
	+s	Oi	lj	Oj
	-w	Ok	Oi	lk
t	+e	li	li	Ok
	+s	Oj	lj	Oi
	±w	lk	lk	Oj
b	-e	Oj	Oi	li
	+s	Oi	lj	Ok
	±w	lk	lk	Oj

Mesons and baryons may now be constructed from the u, d, s quarks and $\bar{u}$, $\bar{d}$, $\bar{s}$ antiquarks in the conventional way. The strong and weak charge structure of these particles may be given as follows:

Mesons (spin 0) : π, η (0); K^+, K° (0 or 2); K^-, $\bar{K}^\circ$ (0 or −2w)

Baryons (spin ½) : N (s+w); Λ, Σ, Ξ (s±w)

(spin 3/2) : Δ (s + w); Σ^*, Ξ^* (s±w); Ω^- (s-w)

These structures explain many significant facts. Thus it is obvious that π°, which has zero charge structure, must be its own antiparticle, whereas K° or $\bar{K}^\circ$ which may have a charge structure ± 2w, is not. Also, it is clear why Ω^- is the only member of the spin 3/2 baryon decuplet which can decay only by a weak interaction, for it is the only member of the series which always has a negative weak unit of charge. From the decays of mesons and baryons we may also derive the charge structures of leptons: ν_e (w), e^- (-e+w), ν_μ(-w), μ^-(-e-w); the transition τ^- u → d (p → n) and the continued failure of experimental attempts at detecting ν_τ may also suggest τ^- (-e) and ν_τ (o). These structures immediately explain why ν_e and ν_μ are not antiparticles of each other and why muons do not decay into electrons by the emission of photons. Also, baryon number is conserved because baryons are the only particles with s component, while lepton number is conserved because leptons are the only particles with ±w component but no s component.

The charge structures of particles suggest the origin of particle masses, for there is evidence that these masses provide the missing energy due to the zero charges in their component quarks. In general, the rest masses of fundamental particles can be expressed as close approximations to multiples or half-multiples of the term m_e/α, where m_e is the mass of the electron and α is the fine-structure constant. The masses of baryons can be predicted from the expression $(n_o M_o/M)\, m_e/\alpha$, where n_o is the total number of zero charges in the components of a multiplet of multiplicity M, and M_o is the highest multiplicity in the relevant octet or decuplet. For the spin 3/2 baryon decuplet, where M = 4 and the Σ^*, Ξ^* and Ω multiplets represent the excited states of the four Δ particles, the minimum values for n_o give the theoretical masses of Δ, Σ^*, Ξ^* and Ω as 20, 20, 22 and 24 m_e/α. These may be compared to the experimental values 18, 20, 22 and 24. In fact, differences of $2m_e/\alpha$ can be expected at each level in the decuplet because the excitation from Δ to Σ^* to Ξ^* to Ω occurs due to the successive transitions of one d quark to one s quark with the net loss of two w charges, and this might suggest a theoretical Δ mass of 18 m_e/α. The difference between the two possible masses of the Δ particle is then accounted for by a high kinetic energy of order $2m_e/\alpha$, which explains the particle's rapid decay. Similar predictions may be made for the masses of the spin 1/2 baryons and spin 0 mesons.

The charge structures of mesons and baryons also emphasize the fundamental differences between the three nongravitational forces, which were introduced with the restrictions on s and w necessary to complete the quark system. Thus e, which is unrestricted and which differs from s and w in being neither required to be present in a baryon state nor absent in a meson state, appears as an independent term, not bound to the particle in the same way as the other two charges. The two consequences of this are that the electromagnetic interaction is infinite in range and that the strong interaction has the property of isospin conservation or charge independence. As the strong interaction is characterized also by its confinement of the strong charge within colourless hadrons, so the weak force is distinguished by its violations of parity conservation or time-reversal symmetry, brought about by exchanges in charges between particles.

The fundamental equivalence of the three nongravitational forces is now a generally accepted principle, and it is believed that their apparent differences are due to a spontaneous symmetry breaking which results from the particles involved in the interactions assuming various masses. (Such a process may be expected to occur if the masses of particles result from the absence of charges whose presence would otherwise *maintain* symmetry.) With the identifying properties of these forces established without the use of phenomenological assumptions, there is sufficient evidence to suggest that the original source for both the laws of physics and the fundamental particles is to be found in the exact properties of the fundamental parameters and, hence, in the actual process of measurement.

References

1. Han, M.Y. and Nambu, Y., *Phys. Rev.*, 139B, 1006 (1965).

First Report by Reviewer on P. Rowlands' Paper

This paper is based on the author's misunderstanding of the use of an imaginary time co-ordinate in special relativity. Some authors like to use the co-ordinate ict since it makes the equations appear more symmetric in space and time and simplifies some of the mathematics. It is only a mathematical trick, not at all necessary to relativity theory. Although the co-ordinate ict is imaginary, the time t is real and any measured time remains real. The author has let the use of an imaginary time *co-ordinate* mislead him into thinking that time itself is imaginary.

Another basis of the paper — the argument that, although time is a continuum, space is countable — is very weak.

The author claims to derive the law of gravitation using, "No phenomenological assumptions about gravitation". But in fact such assumptions are there although not stated. For example, he implicitly *assumes* gravitation to be a curl-free vector field, and his equations agree with the usual ones only because of the implicit assumption that the field is an acceleration field — this, then, just amounts to assuming, as usual, the principle of equivalence. Furthermore, his equations ignore sources of the gravitational field.

R. Burman

Second Report by Reviewer

The author has made some improvements to his paper and has gone some way towards answering my criticisms. However, a number of problems remain.

(1) How does the author propose to make his use of an imaginary time (as distinct from an imaginary time coordinate) compatible with macroscopic equations of motion involving frictional forces proportional to velocity?

(2) How does the author's statement that "mass and charge are conserved *because* conservation is fundamental to their definition" relate to Noether's theorem?

(3) The author seems to be claiming that, because space is measured by counting units of distance, space is, like charge, countable. But the point about charge is that it is quantised: it comes in units that we cannot subdivide by refining our measurements, and hence is countable. So far as we know, that does not apply to space; a particular set of units of measurement may themselves be countable but we can always introduce another, finer-grained set; thus space itself is not — to our knowledge — countable.

(4) Although the paper deals with space-time and fundamental particles, and so is presumable meant to be relativistic, the author defines force as mass × acceleration instead of as rate of change of momentum.

(5) The author has by no means fully answered my criticism of his discussion of gravitation. In referring to the variation through space of the gravitational field he mentions $\nabla.g$; but the spatial variation of a vector field involves both its div and its curl. In fact, without discussion, he assumes $\underset{\sim}{g}$ to be curl-free by subsequently writing $\underset{\sim}{g}$ as $-\nabla\phi$. Furthermore he states "the field variation cannot be detected for an isolated mass, because if any such variation could be discovered, we could detect the presence of mass independently of other masses", and claims this to imply that $\nabla.\underset{\sim}{g}$ must vanish. This cannot be accepted as an argument for the equation $\nabla.\underset{\sim}{g} = 0$; in fact, it appears to be meaningless. How could the author rule out an equation of the form $\nabla.\underset{\sim}{g} = -\mu^2 \phi$ where μ is a constant?

If the author can overcome these criticisms — particularly (3) above, which strikes at the basis of his argument — then it is possible that he could have the elements of a paper that might be of interest to SST. At present he is spoiling his case by claiming to have derived laws — such as Newton's law of gravitation — when he has done no such thing. He should consider presenting his work as a framework for treating known laws rather than as a means of offering spurious derivations of them.

R. Burman

Third Report by Reviewer

In response to my comments, the author has made some significant further improvements to his paper. I do not believe that these improvements, or his reply, fully meet my objections. (For example, the equation $\nabla.\underset{\sim}{g} = -\mu^2 \phi$ could, in principle, describe gravitation under *classical* conditions.) In fact, I am not at all sure of what he is getting at in several places in his reply. In spite of these remarks, I feel that what the author has to say may be of interest to readers of SST, and that he has improved his paper sufficiently for it to be published there, along with critical comment.

The author's willingness to interact with the reviewer might be a useful lesson to other SST authors and would-be authors, who often seem unwilling to adjust their manuscripts in response to the referee's comments.

R. Burman

Final Response to Rowlands' Reply

Rowlands misrepresents my position on the equations $\nabla.\underset{\sim}{g} = 0$ and $\nabla.\underset{\sim}{g} = -\mu^2\phi$. I did not suggest that there is any evidence that an equation other than $\nabla.\underset{\sim}{g} = 0$ is necessary to describe gravitation under classical conditions. Rowlands was trying to claim a derviation of $\nabla.\underset{\sim}{g} = 0$; my point was that his argument (which actually appeared to be meaningless) did not distinguish between the equations $\nabla.\underset{\sim}{g} = 0$ and $\nabla.\underset{\sim}{g} = -\mu^2\phi$. I note that he seems to have tacitly recognised this by modifying his claim in his revised paper, now claiming only compatibility of $\nabla.\underset{\sim}{g} = 0$ with his argument.

The equation $\nabla.\underset{\sim}{g} = -\mu^2\phi$ would imply gravitational potential ϕ varying as $-r^{-1}e^{-\mu r}$: for distances small compared with μ^{-1}, the usual newtonian 1/r behaviour would obtain, but the potential and the field would fall exponentially at distances greater than about μ^{-1}.

So far as observations are concerned, F. Zwicky (*Publ. Astron. Soc., Pacific,* 73, 314 (1961)) has comment on this area.

R. Burman

Author's Final Reply

Full replies to all the reviewer's points are contained in an extended version of this paper available in photocopy or microfiche from ASIS/NAPS, Microfiche Publications, P.O. Box 3513, Grand Central Station, New York, N.Y. 10163, U.S.A. (All orders must be prepaid.)

This sixty-page document contains an alternative, more analytic derivation of the laws of classical mechanics and electromagnetic theory, based more directly on the group representation combined with the quaternion and 4-vector systems, in addition to sections detailing extensive applications of the theory to particle physics and cosmology. At this stage, I would like to make three particular points: that the imaginary nature of time is not introduced in this paper solely to accommodate the imaginary time-coordinate of special relativity, but is also used to explain such fundamental physical effects as inertia and the attractive nature of gravitational forces; that space, though countable, does not occur in fixed units because, unlike charge, it is also *non*-conserved; and that Noether's theorem relates the conservation of mass-energy to the translation symmetry (that is, nonconservation) of time, because, according to the group symmetry, the property of conservation in one parameter is the necessary complement to the property of nonconservation in the other.