QUANTUM INDETERMINACY, WAVE-PARTICLE DUALITY AND THE PHYSICAL INTERPRETATION OF RELATIVITY THEORY FROM FIRST PRINCIPLES

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ABSTRACT

Many physical processes can be conveniently united and explained by a more extensive understanding of the concepts of 'conservation' and 'nonconservation', and of 'continuity' and 'discontinuity'. The full power of these concepts is revealed, in particular, by establishing how they link, by symmetry, the fundamental physical parameters, charge, mass, time and space. From this, new mathematical results may be predicted and existing physical laws may be explained. In addition, a more fundamental understanding may be achieved of the concepts of quantum mechanical indeterminacy, of wave-particle duality and of the competing physical interpretations of relativity theory

Introduction

The question of the physical interpretation of relativity theory has an intimate connection with two other major problems in fundamental physics: the nature of quantum uncertainty and the origin of wave-particle duality. It is proposed here that the source of these apparent paradoxes lies in fundamental symmetries between space, time, mass and charge, which determine that conservation and nonconservation, and continuity and discontinuity, remain *exactly opposite* properties. These built-in physical oppositions ensure that indeterminacy is inherent within the formal structure that underlies the whole of physics and that no fundamental choice can be made, on any physical grounds, between wave and particle theories, between quantum mechanics and stochastic electrodynamics, and between competing physical interpretations of the Minkowski formalism for space-time invariance.

We begin with the basic group-structure (set out below) which we have proposed for space, time, mass and charge in earlier publications.[1] Each parameter is seen to have one property in common with each other, and two in opposition. It is suggested here that it is by studying the nature of this opposition, in particular that between the conserved and nonconserved parameters, and that between the continuous and noncontinuous ones, that we may derive fundamental explanations for the paradoxes which underlie quantum theory and relativity.

As we have already described elsewhere, the symmetry between the parameters appears to be describable using a basic D2 group of order 4. Such a grouping requires that each parameter has a direct relationship with every other, and also an inverse relationship; and these relationships require the existence of four independent fundamental constants, of the kind long known from experiment. It is, ultimately, the simultaneous existence of both direct and inverse relationships which is responsible for wave-particle duality (or continuous and noncontinuous descriptions of radiation).

Space	Real	Nonconserved Elements nonunique	Divisible Dimensional
Time	Imaginary	Nonconserved Elements nonunique	Indivisible Nondimensional
Mass	Real	Conserved Elements unique	Indivisible Nondimensional
Charge	Imaginary	Conserved Elements unique	Divisible Dimensional

The group, as we have previously shown, may be structured so that any of the four elements becomes the identity element, and, in all versions, each element becomes its own inverse. Dimensionality is here associated with discontinuity, which is certainly a necessary, if not sufficient, condition for it, continuous quantities being necessarily nondimensional. The existence of charge as a quantity which is both imaginary and dimensional introduces its structure as the imaginary part of a quaternion, whose real part is mass; formal algebraic rules then confine the dimensionality at 3, and determine that the parallel structure for space and time is a 4-vector with three real parts and one imaginary.

We may assume that all fundamental binary operations between group-members are universal, and one such binary operation which must exist is the numerical proportionality between the units of each parameter and every other; this is because the quaternion representation of mass-charge and the 4-vector representation of space-time ensure that a numerical relationship must exist in these cases between the units of space and time, and the units of mass and charge. In addition, because each element is its own inverse, the *inverse* relation must also exist in every case, together with a fundamental scale-fixing set of constants for each of space, time, mass and charge.

In principle, the units of space (r), time (t), mass (m) and charge (q), must be related by a set of equations of the form:

$$r \propto t \propto m \propto q \propto \frac{1}{r} \propto \frac{1}{t} \propto \frac{1}{m} \propto \frac{1}{q}$$

where the charge component represents an idealised value assumed to exist under Grand Unification of the three nongravitational forces. The direct relations require a series of fundamental constants, of which only three will be independent, and the inverse relations follow if one further independent constant can be defined. Such constants have long been known to physics, though they are normally expressed in terms of other constants which have been derived from our historically contingent system of units. Thus, the three independent direct relations introduce the constants c, G and $4\pi\varepsilon_0$ (or Grand Unified equivalent), and the one independent inverse relation introduces the further constant, h. We then obtain:

$$r = ct \qquad (1)$$

$$Gm = c^2 r \qquad (2)$$

$$G^{1/2} m = \frac{q}{(4\pi\varepsilon_0)^{1/2}} \qquad (3)$$

$$mc^2 = \frac{h}{t} \qquad (4)$$

as our four basic equations. Like all physical equations, they are not statements of identity, but only of proportionality relationships between differently-measured units. They also lead to the existence of the fundamental (Planck-type) absolute units for space, time, mass and charge, which, again, have long been known. In combination with the principles of conservation of mass and charge and of *nonconservation* of space and time, they lead to derivations of the laws of classical mechanics and electromagnetic theory; it is significant that these derivations require the explicit use of the relation involving h, suggesting that this constant is fundamental in classical, as well as quantum, physics.

1.1 Conservation and nonconservation

Conservation and nonconservation are the most powerful ideas in physics – all fundamental physical laws are expressed in terms of them; but the full extent of their scope and meaning is not well established. In particular, it has not yet been clearly stated that nonconservation is not only the 'absence' of conservation but its *exact and symmetrical opposite*, with a set of very clearly defined properties which determine much of the character of classical and quantum physics.

Dimensional analysis and the whole pattern of historical development suggest that there are only a few physical parameters which are really fundamental. In addition to space and time, we need only assume the existence of source terms (m, e, s, w) for the four fundamental forces – gravity, electromagnetism, and the strong and weak nuclear interactions. The first of these source terms has been identified with mass and the second with electric charge; it seems reasonable to suppose that a Grand Unified Theory, uniting the three nongravitational interactions, would require source terms for weak and strong interactions of the same kind as electric charge, which we could describe, by analogy, as strong and weak 'charges'. Charge could then be seen, under the idealised conditions represented by Grand Unification, as being a kind of three-'dimensional' parameter in the same manner as space. Since forces are measured in terms of *squared* units of charge, the analogy would even maintain for charge the Pythagorean rule of addition used in vector space.

An even more powerful analogy could be developed by representing mass and the three source terms for the nongravitational interactions as the real and imaginary parts of a quaternion, symmetrically opposite to the standard 4-vector representation of space-time.[2] In this case the squared source terms would have opposite signs, and produce forces in opposite directions for identical particles subjected to gravitational and nongravitational interactions – which, of course, is the case within the accepted model. We could suppose that a quaternion representation of mass-charge within a Grand Unified Theory, opposed to a 4-vector model for a Lorentzian space-time, might suggest the existence of some kind of symmetrical relationship between these parameters, one of whose manifestations would be the fundamental link already observed between continuous symmetries and conservation laws.

1.2 Conservation laws of particle types

Traditionally, space and time are taken as conserved quantities, mass and charge as nonconserved; and the conservation of mass and charge is a local, rather than merely global, phenomenon. This means that the individual elements of mass and charge are unique and retain their identities through all physical processes. Mass and charge are conserved not only in terms of their total quantity, but also in terms of their individual elements. Of course, since charge exists in both positive and negative units, its conservation is algebraic, and individual elements of charge may be created or destroyed by elements with the opposite sign; but, except in this sense, the individual elements of mass and charge may, in principle, be 'labelled' and their identities observed to remain intact whatever interactions may take place.

The elements of space and time do not possess this property; they have no individual identities. This fact is reflected in their properties of translation and rotation symmetry. Both space and time are translation symmetric, because every element of each is indistinguishable from any other. Elements of space and time have no individual identities and are not preserved in physical interactions. Space, in addition, as a dimensional parameter, has no unique set of dimensions, and so has rotation symmetry also. It seems that the effects of nonconservation are always diametrically opposite to those of conservation, and we can, therefore, give a precise description of the conservation properties of mass and charge in terms of translation and rotation *a*symmetries. Thus, mass and charge are locally conserved precisely because one element of mass or charge is not translatable into any other; the property of unique identity is exactly the same thing as the property of translation asymmetry. In addition, charge as a 'dimensional' parameter may be supposed to have the extra property of *rotation* asymmetry. In other words, different *types* of charge are not translatable into each other. The sources of electromagnetic, strong and weak interactions must be subject to independent conservation laws, and cannot replace each other in a physical system, even when they become identical in magnitude and effect at the energy of Grand Unification.

A brief investigation of the probable sources or 'charges' present in the various groups of particles now known to exist shows that the rotation asymmetry of charge, or the separate conservation laws for electromagnetic, strong and weak forces, is almost certainly responsible for the fundamental laws of baryon and lepton conservation. Baryons, very likely, possess both strong and weak charges, whereas leptons have only the weak component. Mesons, though the mediators of the strong interactions between baryons, have global constitutions with zero values for both the strong and the weak source. If only these three types of particle exist, then separate conservation laws for the three types of charge forbid any interconversion between them. In addition, no physical process could be considered which would cause a proton to decay spontaneously into a positron plus pion, which would violate strong charge conservation. Again, since it is very probable that fermions have weak charges, whereas bosons have none, no physical process ought to exist which would spontaneously convert a fermion into a boson.

	electric	strong	weak	
baryons	± e or 0	± s	± w	fermions
leptons	± e or 0	0	± w	fermions
mesons	± e or 0	0	0	bosons

1.3 Continuous symmetries and conservation laws

The seeming exactness of the opposing natures of conservation for mass and charge, and nonconservation for space and time, is reflected also in the relations between symmetries and conservation laws revealed by Noether's theorem. According to this theorem, every continuous symmetry in nature is responsible for a conservation law, and every conservation law is responsible for a continuous symmetry. In particular, the conservation laws of energy and linear momentum may be shown to be identical to the respective translation symmetries of time and space, and the conservation law of angular momentum may be shown to be identical to the additional rotation symmetry of space. The link is apparent in the case of the conservation of energy, which, as we know from relativity, is precisely equivalent to the conservation of mass. In stating that this is the same principle as the translation symmetry of time, we are stating, in effect, that mass is conserved precisely *because time is not.* We may use this example to predict the existence of mathematical theorems not yet discovered, for we may suppose, by analogy, that the conservation of linear momentum (or translation symmetry of space) is precisely the same thing as the conservation of the *value* of charge; and that the conservation of angular momentum (or rotation symmetry of space) is precisely the same thing as the conservation of the *type* of charge.

Further aspects of the now precise and definite property of nonconservation show up in many aspects of the laws of physics. In general, we may describe the most fundamental laws, whether classical or quantum, as being of two types: those defining quantities, such as momentum, force, energy, action, or functions such as the Hamiltonian and Lagrangian, and those which describe how such quantities behave within a 'conservative' system. The defined quantities invariably combine the universal conserved quantity mass with differentials expressing the variation of the nonconserved quantities space and time; the defined quantities, which serve to link the conserved and nonconserved parts of the system, are then observed to be conserved, or zero, or a maximum or a minimum, as the nonconserved quantities are subjected to continuous variation. In principle, the behaviour of the defined quantities expresses the conservation of mass, a quantity which will uniquely define a system, and sometimes also of charge, as the space and time coordinates continuously change. The fundamental laws of physics, of course, are an attempt to define a conservative system, or to isolate for observation a particular section of the unchanging mass of the universe; they become directly useful as physical conditions allow a near approximation to this observation to be made. Quantum physics does not violate the notion of a conservative system; it merely tells us that physical observation is incompatible with its exact definition.

1.4 Gauge invariance

In connection with the laws of physics, nonconservation is manifested in the property of *gauge invariance.* Elements of space and time have no unique identity, and so must be allowed equally to take all possible values which preserve the values of the conserved quantities, whether primary, like mass and charge, or composite, like energy and momentum. In classical electromagnetic theory, electric and magnetic field terms remain invariant under arbitrary changes of scalar and vector potentials brought about essentially by translations or rotations in the space and time coordinates. Scalar and vector potentials, of course, are the products of charge terms and functions of the space and time coordinates; they do not contribute directly to the energy or any other conserved quantity. In this case, the principle of gauge invariance tells us that a system will remain conservative under changes which affect only the space and time coordinates, and which do not involve changes to its energy, momentum or angular momentum.

The changes which are allowed are those which conserve charge and any of the composite parameters related to mass. From standard electromagnetic theory, it is clear that such changes represent changes of *phase* in the electromagnetic wave equations and so 'gauge' invariance is actually a phase invariance. In more formal language, conservation of electric charge is equivalent to invariance of the Lagrangian under arbitrary phase changes of the charged particle wavefunctions to which it applies. Essentially, charge and energy conservation become equated to an invariance under the transformation of electrostatic potential by a constant which represents changes of phase, and phase changes are produced by changes in the coordinate system; once again, the conservation of mass and charge implies, at the same time, the nonconservation of space and time. It is significant that the nonconservation of space and time, expressed in this way, is as local as the conservation of mass and charge, for the arbitrary phase transformations which, in terms of the Yang-Mills principle, are required in all successful gauge theories, are invariably local rather than global.

It is gauge invariance which allows us to see how our predicted direct connection between conservation of charge and conservation of momentum may be realised in a physical system. Conservation of electric charge, as we have seen, proceeds from the invariance of the Lagrangian for a system, under arbitrary phase transformations of the charged particle wavefunctions which it contains. In effect, charge conservation is identified with invariance under transformations of the electric potential by a constant which represents changes of phase: that is, charge conservation is a direct *consequence* of the fact that arbitrary changes in electrostatic potential are allowed. Now, in a conservative system, electrostatic potential varies only with the values of the space coordinates. The principle of charge conservation under gauge invariance is thus a particular case of the general principle which we have derived from symmetry alone: electric charge is conserved *precisely because space is not.* With our previous association of conservation of momentum with nonconservation of space, we now have a direct connection, as predicted, between momentum conservation and the conservation of charge.

We have, of course, also predicted a second relation, this time between the conservation of angular momentum and the *type* of charge. An instance of this is almost certainly to be found in the connection observed in fundamental particles between spin and statistics. Fermions, as we have already stated, probably have weak units of charge, where bosons have none, and these two classes of particles are associated, respectively, with half-integral and integral values of spin. The respective symmetric and antisymmetric wavefunctions which are responsible for these spin values are undoubtedly connected with the absence or presence of the weak unit of charge and its parity-violating properties; they are certainly not related to the presence or absence of electromagnetic or strong charge units. It is, therefore, the presence or absence of a *particular type* of charge which determines the spin component of the angular momentum of the particle. Now, the parity or space-reflection operator reverses momentum, but not angular momentum; it is significant, therefore, that the weak interaction, in violating parity, shows itself indifferent to the sign of weak charge, but not to its type. Charges, we may say, which are subject to parity operations, which preserve angular momentum, may change their signs, but not their type.

1.5 Quantum mechanics

The mysteries of quantum mechanics become significantly less mysterious if we accept the principle that nonconservation is a fundamental and exact property. It is then *inherent* in the nature of space and time that they do not possess fixed values and that they should be arbitrary over a range limited only by the restrictions imposed by conservation laws related to mass and charge. States distinguishable *only* by arbitrary changes in space and time coordinates – in effect, changes of phase – have equal probability of occurring, and the laws of physics must be constructed so as not to make physical distinctions between them.

With space and time as inherently nonconserved quantities, the absolute measurement of particle coordinates becomes an intrinsic impossibility, which needs to be reflected in the structure of fundamental physical laws. Heisenberg's uncertainty principle tells us, in effect, that a *physical* conservative system cannot be realised in practice because a 'measurement' fixes the values of space and time, quantities that, in principle, ought not to be fixed. In other words, an ideal system requires that $\Delta p = 0$, $\Delta E = 0$, $\Delta x = \infty$, $\Delta t = \infty$; changes of energy and momentum should never happen, changes of space and time should always happen. The consequence is that the system, so fixed, ceases to be conservative.

Ideally, in a conservative system, variations in momentum and energy should be zero and variations in space and time infinite, but, if we elect to make the system nonconservative, we can reduce the relationship to finite variations in each; the extremely small value, in classical terms, of the constant relating the units of energy and inverse time, or momentum and inverse displacement, means that the nonconservative aspects of fixing particle coordinates become relatively insignificant on the large scale, and close approximations to conservative systems may be found.

Space and time, however, cannot really be fixed, even by making a 'measurement'. If, at some instant, we assume a classically precise state in space and time for a system with an infinite number of equally probable alternative states, the effect will be a degree of purely random variation from this state – that is, a random variation of the space and time coordinates – to allow an equal representation of the alternative states, although always in such a way as to preserve energy and momentum within a conservative system. The random variation of space with time will take place with respect to the three symmetries of space which yield equally probable states (translation, rotation and reflection) and the single corresponding symmetry of time (translation), to produce the translational, rotational and vibrational modes of motion which are characteristically associated with the internal energy function of classical thermodynamics.

In the case of thermodynamics, classical and quantum approaches merge almost imperceptibly; classical thermodynamics is not really 'classical' because the fundamental thermodynamic quantity, 'heat', is not classical. Although it is often stated that the indeterminacy of classical thermodynamics is different in kind from the indeterminacy of quantum mechanics because in classical systems indeterminacy is not intrinsic while in quantum systems it is, heat is undoubtedly quantum mechanical in origin and cannot be treated as though it is not. The concepts of indeterminacy in classical electrodynamics, and probability in quantum mechanics stem from precisely the same source: gauge invariance, or the translation-rotation symmetry of space-time, and, ultimately, from space-time nonconservation. The random modes of motion of, say, molecules in gases with respect to an assumed 'fixed' position, have precisely the same meaning as the probability densities of quantum mechanics with respect to a 'measured' position determined by the collapse of a wavefunction onto a particular eigenstate.

Gauge invariance in both quantum and classical physics requires that interactions have no absolute phase and the mass, energy and momentum associated with the exchange particles in these interactions have no specified positions at any given time instant. The same is likely to be true even of the 'fixed' masses associated with particles of 'real' matter, for these undoubtedly stem in some way from the action of gauge-invariant 4-vector fields. As a result of gauge invariance, all equally probable states occur, as it were, at once. To make a measurement, one state must be selected arbitrarily at a particular instant and given classically 'precise' coordinates. (The classical or quantum nature of this process is purely a matter of the degree to which an expectation value can be regarded as a 'fixed' position.) The result is a random variation from this state to allow equal representation of all the alternative states. In a measurement we choose one phase in an infinite series of equally probable states and then observe the system progress through the rest of the series. That is, as time varies monotonically, a variation occurs in all the states of space which are symmetric by translation, rotation or reflection, but which retain fixed values of mass, energy and momentum.

It is for this very reason that it has been possible to develop a 'stochastic electrodynamics', based on a combination of classical physics and a fluctuating electromagnetic zero-point field, which is equivalent in all respects to the standard versions of quantum mechanics, and which can account for the black body spectrum, zitterbewegung, spontaneous emission, and other basic quantum phenomena, in addition to leading to a relatively straightforward derivation of the Schrödinger and Dirac equations.[3] Stochastic electrodynamics is in no way a 'hidden variables' theory; the random fluctuations of the zero-point field are just as intrinsic as those of quantum mechanics, and this is because they stem from exactly the same source. The two theories are merely alternative expressions for the same physical information, and both derive from the fact that random variation is an inherent component of the nonconserved parameters, space and time.

A true understanding of the idea of nonconservation reveals that there is nothing whatever mysterious about the intrinsically random nature of quantum mechanics or "God playing dice" with the universe. It is simply a result of the absolutely symmetrical nature of the opposition of nonconservation, as manifested by space and time, to conservation, as manifested by charge and mass. Symmetry alone constrains space and time to be translation and rotation symmetric, for their units to have no fixed identity, and for their values to be indeterminate within limits set only by the necessity of conserving mass and charge. Quantum mechanics is, therefore, not something of a different, probabilistic, nature imposed on a 'deterministic' system of classical physics; it is the logical culmination of a system in which the parameters space and time are *intrinsically* indeterminate.

In addition to being 'quantum' (that is, incorporating the quantity h), then, all physics is also probabilistic. This probabilistic nature of physics stems from the fact that space and time are nonconserved quantities, while mass and charge are conserved. In principle, these are absolute requirements, so space and time should vary infinitely while mass and charge vary not at all. This is the fact reflected in the phenomenon of gauge invariance, which applies alike to both classical and quantum systems, and is the ultimate source of quantum mechanical uncertainty and of its macroscopic manifestations in areas like molecular theory.

conserved quantities	**nonconserved quantities**
translation asymmetry	translation symmetry
rotation asymmetry	rotation symmetry
elements unique	elements nonunique
local identity	local nonidentity
noninvariance	gauge invariance
fixed in system	differentiable
fixed units	variable grain size

The concepts of conservation and nonconservation have long been used in physics, but the full range of their possibilities has never been completely exploited. For this to be accomplished, it needs to be established that they apply specifically to the fundamental parameters, mass, charge, space and time, and that in this context they are exactly opposite properties, many of whose aspects may be discovered by applying precise rules of symmetry. They are, in fact, one aspect of the group of symmetries which seem to relate, in different ways, to these four parameters, the study of which can be expected to reveal many results of consequence for establishing the fundamental principles of physics. It is now time to consider the effects of another aspect: the opposition between continuity and discontinuity.

2.1 Duality and indeterminacy

Heisenberg uncertainty or indeterminacy is not the explanation of wave-particle duality, although it is frequently advanced as an *application*. In conventional accounts of quantum mechanics, the fundamental duality condition, $p = h/\lambda$, is applied to the Heisenberg uncertainty relation between momentum and displacement in order to investigate indeterminacy within a dualistic context, but the use of the Heisenberg relation does not contribute to the understanding of the origin of the duality condition itself. Indeterminacy results from the distinction between conserved and nonconserved quantities, but duality comes from a separate distinction: that between quantities which are continuous or discontinuous, or, as we have previously called them, indivisible or divisible.

According to the Copenhagen interpretation of quantum mechanics, measurement takes place at the interface between the "world" and the "measuring apparatus". We have *measurement*, which requires fixed space and time; and a *system*, which requires nonfixed space and time. Now, physical laws are constructed in terms of conservative systems; physical measurements are not. Fixing space and time breaks continuity and variability; irreversibility of time shows up when we break its continuity. Coarse-graining processes, for example, produce irreversibility, because every process that interrupts smoothness does, not because they are its intrinsic source. Irreversibility cannot be manifested until we interrupt time, but becomes immediately apparent as soon as we do so. Measurement "breaks the rules": continuous or indivisible time becomes countable, so its direction becomes manifest.

Now, the whole of "measurement" arises from the quaternion, and ultimately algebraic, link-up between mass and charge and the corresponding 4-vector link-up between space and time, which are incorporated into what we describe as "Lorentz-invariance". (It is the *further* link-up, between the conserved quaternion mass-charge and the nonconserved 4-vector space-time, which is responsible, as we have seen, for "uncertainty".) Lorentz invariance is at the interface between the continuous and discontinuous, and the real and imaginary. With space and time we have two parameters, one of which is discontinuous and the other continuous; and, because of the imaginary system of numbers which we have used, we must combine them in a single mathematical structure. Lorentz invariance makes space continuous or it makes time discontinuous. Either way is possible; the choice provides the origin of duality. The combination introduces measurement, which manifests itself clearly in the discontinuous option; but the fundamental sharing of properties occurs in "measurement" only, and not in ultimate "reality". The same options occur in the case of mass and charge.

It is, therefore, the Lorentz invariance between space and time, and the parallel connection between mass and charge – the ultimate source of the process and units of 'measurement' as independent of the laws of physics – which forces us to link one quantity which is continuous (that is, time or mass) with one which is discrete (that is, space or charge). Lorentz invariance arises solely from the mathematical description of the parameters in terms of real or imaginary numbers (quaternions requiring an added real part, and 4-vectors an added imaginary) but the result of this forced union is that, *for the purpose of measurement*, either a quantity which is continuous must become discrete, or a quantity which is discrete must become continuous. The first is the particle option (time and mass become discrete), while the second leaves us with waves and wavefunctions (space and charge become continuous). Neither solution is characteristic of what may be called ultimate 'reality', the idealised state in which no parameters exchange properties; each is simply introduced as an artefact of measurement. Lorentz invariance, of course, leads us to what is usually called the "wave" equation, but this is just as much a particle equation, as quantum theory has shown, and the formal expression cannot predict the physical nature of its individual solutions.

As is well known, of course, Heisenberg's quantum mechanics and Schrödinger's wave mechanics are quite different theories physically, though their mathematical formulations are interchangeable, as Schrödinger and others have demonstrated. While the Heisenberg theory is discrete and directly based on observables, the Schrödinger formalism is based on a continuous, and therefore unmeasurable, interpretation of space and time, in the concept of the wavefunction; particles such as electrons are delocalised and spread throughout space and time. Time, in this formalism, has no status as an observable quantity; information is derived from the wavefunction only by the application of momentum and position operators.

2.2 Indeterminacy and conservation laws

Now the uncertainty relations of the Heisenberg formalism are directly connected with conservation laws involving the fundamental parameters mass and charge. Thus

$$\Delta E \, \Delta t \geq \hbar/2$$

is associated with conservation of mass,

$$\Delta p \, \Delta x \geq \hbar/2$$

with conservation of charge, and

$$\Delta J \, \Delta \theta \geq \hbar/2$$

with conservation of charge type. The spin term $\hbar/2$ suggests a minimum discrete value for angular momentum. The fact that electron spin has constant magnitude in any given direction is an extreme example of the uncertainty relations; zero variation of spin is associated with infinite variation of angle.

To make physical *measurements*, as we have seen, it is necessary to fix, to some degree, the nonconserved quantities, space and time, at the expense of unfixing the conserved quantities, mass and charge. Of course, as we have also observed, this does not mean that classical conservation laws are violated, only that the physical measurements are not made within systems defined as conservative. This is why pairs of variables exist that, in the Heisenberg formulation, do not commute, and their noncommutation is expressed in terms of the constant which relates their *reciprocal* units. Energy (which corresponds with mass as a conserved quantity) does not commute with time; and momentum (which corresponds with charge) does not commute with space. The reason for these particular pairings is that energy, mass and time are one-dimensional; while momentum, charge and space are three-dimensional. The third anticommuting relation exists to cover the rotational aspects of the latter – angular momentum (corresponding with type of charge) does not commute with angle.

In addition, the parameters in the first pairing are fundamentally continuous, while those in the second pairing are fundamentally discrete; and, in their combination, we have the ultimate reason for wave-particle duality. The quantity h links pairings of continuous *and* of discontinuous quantities, which are separately linked by Lorentz-invariance, or its quaternion equivalent: space-time, momentum-energy, charge-mass. It is because discrete charge is linked with the microscopic aspects of matter that we have hitherto assumed that 'quantization' (meaning discontinuity) is particularly characteristic of this aspect of physics. But the continuity of the parameter mass makes it possible to reconstruct physics at the most fundamental level on the basis of a continuous vacuum field (or 'aether').

2.3 Irreversibility and relativity

Time is essentially irreversible because it is absolutely continuous, in the same way as mass is unipolar because it is an absolutely continuous scalar field. The continuity of time is opposed to the essential discontinuity of space used in the process of measurement.[4] Measurement is not an absolute process because it involves changing some of the conditions required for absolute truth.

According to the laws of physics, whether relativistic, quantum or classical, time has two indistinguishable directions of mathematical symmetry; this is characteristic of quantities determined by imaginary numbers. Physical irreversibility allows only one time direction, but, because of the mathematical indistinguishability of imaginary numbers, this can never be known in absolute terms. According to standard mathematical arguments, imaginary numbers of one sign cannot be privileged in any way with respect to those of the other; so, the laws of physics, in being constructed always for quantities involving the second power of time, prevent a mathematical realisation of time's direction.

Now, "relativity" is a term with a complex meaning. The expression "relativity" is used variously to cover more than one aspect of the theories of that name, and to locate the ultimate sources for the theories, it is necessary to separate out these aspects according to their particular origins. Thus, space and time are "relative", in one sense, because they are nonconserved and have no absolute meaning; but uniform motion is, additionally, "relative" because it is dependent on the first power of time, and is, therefore, an imaginary quantity. Accelerated motion is privileged, unlike uniform motion, because it is no longer concerned with space and time only, but, by relation, with conserved quantities, such as mass, and this is because it is also concerned with a real quantity of motion, with time taken to the second power.

This aspect of "relativity", of course, is also apparent in nonrelativistic Newtonian physics, but, in *relativistic* theories, there is the additional element of the mathematical combination of space and time, which extends the aspect of nonconservation or "relativity" known as space rotation invariance to a combined space-time rotation, or Lorentz, invariance. The theories which incorporate Lorentz invariance as a fundamental component necessarily involve a mathematical combination of unlike physical quantities – space and time are only similar in their shared property of nonconservation. The combination is not, in fact, a true physical process; the consequence is that the mathematical procedure of Lorentz-invariance has no completely recoverable physical meaning.

Lorentz invariance involves squaring of quantities; space and time are only linked when they are squared for Pythagorean addition. Squaring in the parallel case of mass and charge represents an "interaction", and it is interaction which produces irreversibility. It is, indeed, the process of interaction, which is unique for any set of elements of mass and charge, which leads to irreversibility in physical terms. Interactions are responsible for wavefunction collapse in quantum mechanics; variously "charged" particles, or sources of "interactions", provide the so-called "apparatus" required for quantum mechanical "measurements"; there is no need for "conscious" observers. Lorentz invariance is not therefore directly responsible for interaction and for irreversibility, but it is responsible for them, indirectly, by symmetry.

2.4 Irreversibility and causality

Measurement requires the fixing of space and time. That fixing has two aspects: it changes the space-time properties of nonconservation, and it violates time's additional property of continuity. In the former case, we give space-time the characteristics of mass-charge. In the latter case, we give time the characteristics of space. Stop time at any point to make a measurement and it is no longer continuous; so irreversibility manifests itself. Measurement therefore requires us to determine the arrow of time, to specify the extra thing we need to know, in addition to the fixed mass, charge, etc., within the system. The identical mass-charge link-up gives us fixed values of mass.

Time is absolute in one sense, relative in another. Classical and relativistic theories, contrary to popular opinion, use *both* absolute and relative time. The absolute order of causally-connected events cannot be reversed. This is what Newton meant by absolute time: events cannot precede their causes.[5] But causality is only known relatively, that is when we interrupt the flow of time. The scale of time is also arbitrary, and therefore relative, like that of space. But the unidirectionality of time makes it unlike space in this respect. Hence, "relativity" of time is not the same as "relativity" of space. Relativity of space includes nonconservation of magnitude, direction, components, grain size, element identity, zero position, discontinuity, but relativity of time does not include direction.

Causality requires discontinuity, as in the Einstein approach to relativity. As soon as we make time discontinuous at all, we directly introduce causality or time's specific direction. Before this, we don't know what its direction is, and we have no direct knowledge of causality – in quantum mechanics, we don't need causality before we make a measurement.[6] Causality also requires mass to be discontinuous, as in Einstein's theory, where relativity is linked with the lightquantum and signalling at the speed of light.[7] The alternative, wave, picture (with its built-in gauge invariance) is not based on an identifiable sequence of causally related discrete events.

The second law of thermodynamics is the physical expression of irreversibility and causality. It is only half a conservation law[8] – entropy can be created but not destroyed – because time is irreversible and we choose only one of two options when we make a measurement. The actual direction of time is that which corresponds to the single allowed sign of mass-energy (arbitrarily described as "positive") to which it is symmetrical. Roger Penrose has speculated that gravity will solve the irreversibility paradox;[9] this is true in the sense that positive mass means positive time. If we like, we can say that the negative form of mass is virtual; so is the negative form of time.[10]

2.5 The mass frame and zero-point energy

What is known as absolute space, or aether, or vacuum, is the mass frame. This frame is unobservable by definition, although we can conceive of it theoretically, for, just as we can transfer the discontinuous properties of space to mass, so we can transfer the continuous properties of mass to space. Observation, of course, requires discontinuity. The frame is also not subject to variation, and is nonLorentzian, but it may be the frame in which gravity operates. It is only in the Lorentzian frame that we have variation, and that we have concentrations of mass brought about by charged particles, etc. In the absolute frame, mass would be unchanged from place to place. The rest frame of the photon is of this kind, photons experiencing zero time and zero space, and so transferring their energy immediately and without change of location.[11]

Vacuum, as we know, is not empty space, but contains an apparently infinite amount of zero-point energy. Zero-point energy, according to exponents such as T. H. Boyer, can be interpreted as a classical phenomenon, arising from electromagnetic radiation, with an energy spectrum of $\hbar\omega/2$ per normal mode of vibration, derived from Lorentz invariance; and leading to classical explanations of the Planck black body spectrum and Bose-Einstein statistics. (The zero-point energy is, of course, seen from within a Lorentzian frame in the context of measurement.) The Schrödinger equation has been reduced to Newtonian mechanics combined with this extra component, while the third law of thermodynamics has been shown to be derivable classically if the zero-point energy component is taken into account. Classical thermodynamics, including the theory of specific heats, certainly becomes completely consistent when it is included, and equipartition leads directly to the Planck law for black body radiation and not to the Rayleigh-Jeans version. At the same time, quantum field theory becomes, in effect, classical field theory with zero-point fluctuations. The whole development of stochastic electrodynamics, as it is called, has shown, more or less conclusively, that quantum results can be duplicated by classical theories which take full account of the existence of zero-point radiation.[3] In principle, continuous 'aether' theories work if the effects of aether are taken as equivalent to discontinuous quanta.

The term $\hbar/2$ which appears in the zero-point energy expression is significant because it is identical to the minimum value of action in the Heisenberg uncertainty relations, and is also the spin angular momentum unit for a fermion. Spin is not, as is often thought, a relativistic or a quantum concept, though it found its first explanation in Dirac's relativistic quantum equation for the electron. It is actually an expression of pure space rotation invariance, and can be found in classical, as well as in quantum, contexts. It can also be derived from the nonrelativistic Schrödinger equation, as well as the relativistic one of Dirac, given a more extensive understanding of the vector properties of space.[12]

The factor 1/2 in the spin term $\hbar/2$ derived from the Schrödinger equation comes from the kinetic energy expression $p^2/2m$. From the same origin is derived the zero-point energy ($\hbar\omega/2$) in the Schrödinger expression for the harmonic oscillator. But the total energy of an electromagnetic oscillator also contains an equal component from electromagnetic field modes (which is why the spontaneous emission coefficient is twice that for stimulated emission). The $\hbar/2$ term in the Heisenberg uncertainty relations, being identical to that derived from the electromagnetic zero-point harmonic oscillator, also has the same ultimate origin in the classical kinetic energy term. The relativistic spin $\hbar/2$ equation also predicts a zitterbewegung or additional random motion, with frequency $2mc^2/\hbar$, superimposed on the normal directed motion, which represents an interference between the positive and negative virtual energy components (which both exist where, as here, causality and a unique time-direction are not specified).

Now, the Klein-Gordon equation for the photon is based on $E = mc^2$, with twice the mass applied compared to that in the Dirac equation, and this is, essentially, because it is derived from a potential energy term (mc^2), rather than from the classical kinetic energy, $mv^2/2$. Hence, the spin in this case is derived by dividing the momentum operator by m, rather than by 2m. Consequently, the spin is a unit of $\hbar$, and the energy of emission or absorption of photons is $\hbar\omega$, rather than $\hbar\omega/2$. This is why transformations between states in the Heisenberg formalism are in integer units of $\hbar\omega$. In principle, the term $\hbar\omega$ is connected with an exchange particle and hence represents potential energy (the mass of the particle); while $\hbar\omega/2$ is associated with intrinsic rotational energy (and wave-type motions) and hence represents kinetic energy. The distinction is essentially that of the classical virial theorem from which the relationship between kinetic and potential energies ultimately derives.

The two major physical interpretations of relativity theory offer choices between discontinuous and continuous formalisms, just like the two major representations of quantum mechanics. In quantum mechanics, Heisenberg's representation is a discontinuous theory, with integral spin $\hbar$ boson exchange (equivalent to fixed potential energy) as the mechanism for interaction, and unit values of $\hbar$ in the commutators; while Schrödinger's formulation is continuous, with gradualistic energy exchange, just as the classical kinetic energy $mv^2/2$ or $p^2/2m$ represents integration over a continuous range of energy values. In the same way, Einstein's special relativity is a discontinuous theory, with events caused by a localised exchange of particles with unit $\hbar$; while the Lorentz-Poincaré aether provides an alternative model in which the emphasis is on continuity provided by the delocalised energy provided by a continuous vacuum field.

In principle, the choice seems to be between potential or kinetic energy mechanisms, via spin $\hbar$ or spin $\hbar/2$ exchanges, boson or fermion carriers, abrupt or gradualistic transitions, using localised or nonlocalised energies. It is interesting to note that the delocalised energy assumed in the continuous theories has the characteristics of both the classical aether and the quantum mechanical vacuum, and need not be finite in value. Rather than finding the infinite energy density of the vacuum a problem to be avoided by some arbitrary cut-off, we should rather expect it to be true, and suggestive of a medium along the lines of Dirac's infinite number of filled negative energy states, and related to the exclusion of the negative direction of time. Vacuum energy in this form would certainly remain undetectable by direct means.[13]

2.6 Are photons necessary?

The photon is probably never absolutely necessary; to look for places where it is an absolute requirement is a futile exercise. The existence of the constant h, and its undoubted universal validity, does not by itself make any comment on the discontinuity of the radiation field; just as the discontinuous theory uses integral multiples of this constant to define its energies, so the continuous theory uses half-integral values. It is almost certainly always possible to use either method, in each physical instance where the question arises. Duality is very probably completely absolute across the whole range of physics.

According to our analysis, it stems from fundamental symmetries involving the irreducible parameters space, time, mass and charge, in particular, the existence of both direct and inverse relationships between the basic units of each, and the pairing off of parameters as real or imaginary, conserved or nonconserved, discrete or continuous, in addition to the fact that the act of measurement effectively requires a violation of the fundamental conditions determining these relationships. The idea that the 'photon' or 'quantisation' must become 'absolutely' necessary at some point is a carry-over from the 'Correspondence Principle' approach to quantum mechanics, when 'classical' theory required continuous waves and 'quantum' theory introduced discontinuity at a more microscopic level; but this is not at all what wave-particle duality is about. There is no fundamental dividing line between classical and quantum physics; all physics is quantum in requiring the constant h. Fundamental derivations of the equations of classical mechanics and electromagnetic theory require it, just like those of quantum mechanics and quantum electrodynamics. But we can use h either in a continuous sense ($\hbar\omega/2$, zero-point energy) or in a discontinuous sense ($\hbar\omega$, quantum energy), just as we can use kinetic or potential energy, related by the same factor, in understanding the behaviour of material gases. There seems to be no general rule for deciding on the issue, and the most convenient method at any given time seems largely to be determined by the contingent processes by which we acquire scientific knowledge.

2.7 Versions of relativity

The problem of determining the relationship and relative status of, say, the Einstein-Minkowski version of special relativity and the aether-based theories associated with Poincaré and Lorentz has been one of the most contentious in recent scientific history, but we can now see that the relationship between the two relativity theories is very clearly related to the problem of duality in the physical nature of radiation. And, in fact, there are many sets of alternatives in fundamental physics which are merely different ways of making the same basic choice.[14] For example:

particles	waves
relativity	aether
quantum mechanics	wave mechanics
QED	SED
$\hbar$	$\hbar/2$
potential energy	kinetic energy
charge-like	mass-like
space-like	time-like
momentum-related	energy-related
spin 1 exchange	spin 1/2 exchange
boson exchange	fermion exchange

Special relativity is at one extreme of a range of options open to us as a result of Lorentz invariance. The derivation of expressions like that for the relativistic Doppler shift of light in vacuum does not require the explicit exclusion of a medium; *any* inertial frame can be used in the derivation, and a privileged one is by no means excluded. The possibility of such a privileged frame is even suggested by the existence, in addition to the zero-point energy, of an isotropic microwave background radiation relative to which the Earth's 'absolute' motion can be detected. Again, tests of Lorentz invariance are not identical to absolute tests of the assumptions of special relativity; a perfectly uniform aether would show no deviations either. Because the zero-point energy is virtual *in the Heisenberg formulation, based on discrete energy exchange* – a result of Heisenberg uncertainty – there is a degree of option in our employment of the concept, even where we are using the related discrete energy exchange mechanism of Einsteinian relativity. The fact that we have the option of excluding it in kinematic considerations does not mean that we must necessarily do so.

Of course, as Heisenberg's quantum mechanics is based on a discrete model of radiation, it is an equally valid (though non-Heisenberg) option to treat the zero-point energy as real. This is the basis of stochastic electrodynamics, the Lorentz-Poincaré version of relativity, and even the Schrödinger formulation of quantum mechanics. Neither option gives an entirely true picture of reality, as each is limited by the processes of measurement. There is undoubtedly a truly continuous real distribution of energy or mass in the vacuum, but matter, on the other hand (representing "charged" particles), is discrete. Einstein, Minkowski, Heisenberg and QED, taken to their logical conclusions, would deny the existence of real continuous mass; Lorentz, Poincaré, Schrödinger and SED, taken to their logical conclusions, would deny the existence of real discontinuous charged matter; each, of course, has to accommodate the alternative possibilities in a virtual form. Essentially, to maintain Lorentz-invariance for the purpose of measurement, we have to assume, either that continuous mass is discrete, or that discontinuous charge is continuous; either way, the choice represents a deviation from fundamental "reality".

Much confusion has been generated by mixing philosophically incompatible quantum formulations, none of which gives a complete description of reality, and each of which requires completion with an ad hoc process of measurement.

		The system		Measurement	
Schrödinger	**continuous**	**space**	**virtual**	restores	introduces
		charge	**particles**	discreteness	localised
		momentum		of these	particles
		ang. mom.			
		time	real	not changed	
		mass	vacuum	by measurement	
		energy			
Heisenberg	discrete	space	real	not changed	
		charge	particles	by measurement	
		momentum			
		ang. mom.			
		time	**virtual**	restores	introduces
		mass	**vacuum**	continuity	nonlocalised
		energy		of these	vacuum

As the diagram shows, the two main versions of quantum theory represent opposite extremes in both their definitions of the system and of measurement. The expressions in bold type represent the violations of fundamental conditions within each system, which must be corrected by the respective processes of measurement. The introduction in these measurement processes of a virtual version of what each theory excludes in the system effectively links uncertainty to duality. The Schrödinger measurement process, for example (wavefunction collapse) allows us to restore particles in discrete space (not contained within the system), but only at the expense of knowledge of the wavelengths of the system. The price of Heisenberg measurement, on the other hand, is the loss of the causality, which the system had retained; measurement brings in nonlocality and the vacuum.

Wavefunction collapse is outside of the Schrödinger *equation*, because the equation itself doesn't give the true full information, as it makes space continuous. Neither, of course, does the Heisenberg formalism, because this makes time discrete! In principle, the Schrödinger wavefunction is continuous, allowing no direct knowledge of time or position, and so denying causality of the discrete Einsteinian kind, until a virtual causality is introduced by measurement. Thus the Born *interpretation* explains the squared wavefunction (squared, of course, because it links space with time in a process of measurement) as a probability amplitude when *we* introduce a particle-like discontinuity in the ad hoc process of "measurement", or collapse of the wavefunction. But the unobservable status of time in Schrödinger's theory (which remains even when position becomes observable with wavefunction collapse) does not carry over into the *alternative* Heisenberg formulation, where time is assumed to have a discrete structure, like space, and so can be brought into a meaningful uncertainty relation with energy.

Conclusion

Thus, there is no information on which we can decide that either the continuous or the discontinuous option is superior or closer to physical 'reality' than the other. It is like the Heisenberg formulation itself with its arbitrary choices between momentum and position, or energy and time. It is not Lorentz-invariance itself that introduces the wave aspect into physics. The so-called "wave equation" has both wave and particle solutions. Einstein's version of relativity is a discontinuous particle theory, and we have both continuous (Schrödinger) and discontinuous (Heisenberg) versions of wave or quantum mechanics.

And, indeed, it is a crucial point in setting up such alternative theories that the differences between them are *beyond the scope of measurement*, because measurement violates the conditions required for absolute knowledge. Thus, while the Lorentz-Poincaré theory requires an aether which cannot be detected (by electromagnetic signals), a velocity of light change that cannot be observed, the Einstein-Minkowski version requires a *relativity* which cannot be observed either, for the lesson of the whole clock paradox argument is that, under no conceivable physical circumstances, can we conceive of a situation in which the two clocks are perfectly symmetric. In other words, there is no such thing in the physical world as *relativity*, or, very probably, simultaneity, either;[15] we can use the idea of 'relativity' precisely because it is an absolute or extreme position which can never be realised physically. The special theory of relativity, contrary to the views expressed by many of its exponents, uses absolute time in the true Newtonian sense, that is, in the sense of an irreversible absolute order of events. The impossibility of transmitting energy faster than c means that there can be no reversal of causality; events cannot precede their causes.

Again, the whole point of quantum mechanics, and the Heisenberg uncertainty principle in particular, is that the act of measurement violates the principles on which a 'system' is built, namely, the conservation principles of mass, energy, momentum, angular momentum and charge, and the *nonconservation* principles of space and time (translation and translation-rotation symmetries, gauge invariance, and so forth). To the extent where we allow fixing of space and time, we must have simultaneous 'nonfixing' of the conserved quantities; it is the extent to which we can reduce this latter to a minimum which determines our success in using a classical formalism.[16] It is significant, of course, that the 'aether' of Heisenberg's version of quantum mechanics is a *virtual* aether, unattainable in the normal sense, and a product of the uncertainty of fixing absolute position in space.

In no sense does this lead to a position of complete relativity of knowledge; overall absolute positions are certainly still possible, and even required. The relationship between the components of the overall theory is a precise one – varying assumptions are made within *fixed* areas of indeterminacy. The fundamental axioms may be contradictory, but this is always allowed within the general theory. Special relativity and the alternative aether theories are such options; and these in effect presuppose the quantum and classical theories of radiation. We can have an idealised absolute motion if we like, or we can specify an idealised absence of absolute motion. This is a choice available to us, like a gauge condition in electrodynamics.

It so happens that the fundamental structure of physics requires the incorporation of the opposing concepts of continuity and discontinuity on an equal basis; in principle, one basic parameter, mass, is continuous while another, charge, is discrete; these two fundamental quantities correspond, in the older style of physics, to the categories of aether and matter. Radiation is the connecting link between mass and charge, or as late nineteenth century physicists described it, aether and matter, and we can look on it either as discrete, like charge, or continuous, like mass; the position is indeterminate, and indeterminacy of this kind is fundamental within physics.

Notes

1 P. Rowlands, *The Fundamental Parameters of Physics: An Approach towards a Unified Theory* (PD Publications, Liverpool, 1991) and "A new formal structure for deriving a physical interpretation of relativity", *Proceedings of Conference on Physical Interpretations of Relativity Theory*, British Society for Philosophy of Science, London, September 1990, 264-8. There is an earlier version in P. Rowlands, "The Fundamental Parameters of Physics", *Spec. Sci. Tech.*, 6, 1983, 69-80.

2 The application of quaternion methods to quantum mechanics has been advocated by many authors – for example, J. D. Edmonds, "Quaternion quantum theory: new physics or number mysticism?", *Am. J. Phys.*, 42, 220-3 (1974), W. Gough, "Quaternions and spherical harmonics", *Eur. J. Phys.*, 5, 163-171 (1974), "The analysis of spin and spin-orbit coupling in quantum and classical physics by quaternions", *ibid.*, 7, 35-42 (1986), and "A quaternion expression for the quantum mechanical probability and current densities", *ibid.*, 10, 188-93 (1989) – but these authors have not used quaternions to describe the sources of the four interactions.

3 See, for example, E. Nelson, "Derivation of the Schrödinger equation from Newtonian mechanics", *Phys. Rev.*, 150, 1079-85 (1966), T. H. Boyer, "Derivation of the blackbody spectrum without quantum assumptions", *ibid.*, 182, 1374-83 (1970), "Third law of thermodynamics and electromagnetic zero-point radiation", *ibid.* D, 1, 1526-30 (1970), "Concerning zero-point energy of a continuum", *Am. J. Phys.*, 42, 518-9 (1974), H. E. Puthoff, "Ground state of hydrogen as a zero-point-fluctuation-determined state", *Phys. Rev.* D, 35, 3266-9 (1987) and "Sources of vacuum electromagnetic zero-point energy", *ibid.* A, 40, 4857-62 (1989). See also the papers in *Proceedings of Conference on Physical Interpretations of Relativity Theory*, British Society for Philosophy of Science, London, September 1988, by N. Shanks (vol. I) and G. Cavalleri (vol. II, 1-13); and in *Proceedings of Conference on Physical Interpretations of Relativity Theory*, British Society for Philosophy of Science, London, September 1990, by G. Cavalleri (41-59) and M. Surdin (279-89 and 538-43).

4 Continuous time, linked to discontinuous space, yields a ready explanation of Zeno's paradox of the flying arrow. See G. J. Whitrow, *The Natural Philosophy of Time* (Oxford 1989), pp. 196 ff.

5 In what is probably one of the most often quoted, and most misunderstood, passages in the *Principia*, Newton writes: "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time ... ." (*Isaac Newton's Mathematical Principles of Natural Philosophy*, translated by A. Motte, revised by F. Cajori, Cambridge

1934, p. 6) But, as he also writes: "It may be, that there is no such thing as an equable motion, whereby time may be accurately measured. All motions may be accelerated and retarded, but the flowing of absolute time is not liable to any change. The duration of perseverance of the existence of things remains the same, whether the motions are swift or slow, or none at all: and therefore this duration ought to be distinguished from what are only sensible measures thereof ... ." Absolute time, to Newton, is an order of events, not a "sensible" measure: "As the order of the parts of time is immutable, so also is the order of the parts of space. ... All things are placed in time as to order of succession; and in place as to order of situation. ... in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them." In principle, this is no different from the Einsteinian order determined by causality. Of course, a complete causal sequence can never be established, because we never have complete information about a physical situation through measurement, but such would certainly exist on a cosmic scale, and Einstein's general theory also presupposes it. W. L. Craig has argued, in a different context, that Newton's absolute time is not eliminated by either general or special relativity. ("The elimination of Newton's absolute time by relativity theory", *Proceedings of Conference on Physical Interpretations of Relativity Theory*, British Society for Philosophy of Science, London, September 1990, 73-132.) I think that M. Wegener is right in saying that order is absolute, while duration (taken as a "measured" quantity) is relative. ("Arguments for the existence of a privileged time", *Proceedings*, op. cit., 317-28, p. 318.) It seems to me that this fact is the basis of both Newtonian and Einsteinian positions. Absolute order, of course, stems from the irreversibility or continuity of time, while the "relativity" of the measurement of duration is a result of its nonconservation.

6 This is why quantum mechanical "information" appears to be transferred faster than light, when concerned with virtual processes, as in the experimentally-observed correlations between the angular momentum states of once-connected photons. "Interactions", in this sense, are immediate. As a result of gauge invariance, we have no absolute knowledge of the phase of an interaction, and so we cannot specify it as beginning at one point in time and ending at another. It is only when there is an actual transfer of energy, a localisation or "collapse of the wavefunction" in an irreversible event, a "measurement" or interaction with a "measuring apparatus", that we can specify the velocity of light as a limiting speed.

7 R. M. Nugayev has discussed the connection in Einstein's work between the lightquantum hypothesis and special relativity, in several publications. See, for example, "Special relativity as a stage in the development of quantum theory", *Historia Scientiarum*, 34, 57-79 (1988), and "Why did Einstein-Lewis programme force out Lorentz-Poincaré", *Proceedings of Conference on Physical Interpretations of Relativity Theory*, British Society for Philosophy of Science, London, September 1990, 203-6 and 419-36.

8 The idea of the Second Law of Thermodynamics as "half" a conservation law is discussed in G. Falk, "Entropy, a resurrection of caloric – a look at the history of thermodynamics", *Eur. J. Phys.*, 6, 108-15 (1985).

9 R. Penrose, *The Emperor's New Mind* (Oxford 1989), chapters 7 and 8.

10 There may be an even subtler manifestation of the connection between irreversibility of time and unipolarity of mass. Irreversibility of time may mean that there is no such thing as an isolated system, that is, that there is no such thing as a system which, after a sufficient time, must return to its original state in a Poincaré recurrence. The absence of isolated systems would mean that *every* system is connected to every other, because anything which could become separated would be an isolated system. This suggests, both an ultimate condition of energy and mass nonlocality, and an absolute, irreversible time sequence determined by causal connections between all parts of the universe; it would also suggest that the universe itself is not isolated and must be infinite in extent – an infinitely many body system. The one candidate for a universal connecting mechanism is gravity, which is universal because mass is universal or continuous, and mass is universal or continuous because it is unipolar (or vice versa). To be truly universal, gravity would be required to be instantaneous in the universal mass frame.

11 In the mass frame, all events are instantaneous because no "measurement" can be made to determine the direction of time.

12 See, for example, A. Heslot, "Classical mechanics and the electron spin", *Am. J. Phys.*, 51, 1096-1102 (1983) and W. Gough, "Mixing scalars and vectors – an elegant view of physics", *Eur. J. Phys.*, 11, 326-33 (1990). Gough derives spin from the Schrödinger equation for an electron in a vector potential **A**, by defining the full product for a vector as symmetrical with the corresponding product defined by the three imaginary parts of a quaternion.

13 The $\hbar\omega/2$ energy involved in the continuous processes is suggestive of a fermionic or fermionic-antifermionic exchange mechanism, via particles with spin $\hbar/2$. There is a sense in which we could regard the vacuum as a virtual neutrino vacuum or a bosonic neutrino-antineutrino vacuum. Neutrinos are fermions with charge structure $+w$ or $-w$ only, and, perhaps also, zero rest mass. If, like photons, they travel at the speed of light, the rest frame of a virtual neutrino would be the same as that of a virtual photon, and its energy would be delocalised like that of the zero-point energy virtual photon. It is significant that it is the weak charge which, in fundamental particle theory, is supposed to supply mass to charged particles, by coupling to a universal Higgs field extending throughout space and representing the lowest available state for vacuum energy. The nonzero value for the Higgs energy is held to be responsible for the broken symmetry represented by the spectrum of particle masses.

14 Perhaps the choice also extends to areas of pure mathematics; for example, to that between Leibnizian differentials (based on space) and Newtonian fluxions (based on time), or to that between real numbers, representing space, which are ultimately based on a countable number of algorithmic processes, and the uncountable set of real numbers defined by Cantor, representing time.

15 That is, in measurable terms, at least, any measurement requiring a causal sequencing of the events involved. Simultaneity between measurable events can only be assumed where causal connections are not known.

16 Macro-conditions are the only ones in which we have both measurement and conservation. The macro-state emphasizes the irreversibility of time (measurement) within reversible equations (representing conservation). In principle, conservation is only true within isolated systems, a condition which measurement (dependent, as it is, on "interaction") must violate at the quantum level. Macro-conditions, however, allow a near approximation to be made to the separation of measurement and interaction.