events and frames but it cannot be defined in terms of a special kind of law, among other reasons because a single concept of time is needed in various branches of physics both for overall coherence and for the interrelation of experimental results.

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Modalities and the Quantum Theory

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After many years of consideration the wave/particle duality problem in the quantum theory is still of interest. This letter seeks to sketch out this dual nature in terms of formal logic, and shows that one is drawn to the use of the modality operator to sort out the dilemma, which appears as a real mathematical problem in a system with two truth values.

Consider two experimental situations, C_1 and C_2, either of which imply the existence, E, of some entity, an electron for instance. Using '$\rightarrow$' as the usual implication connective in a two-valued logic, '$\vee$' and '$\wedge$' being 'and' and 'or' respectively, one has,

$$C_1 \rightarrow E \qquad C_2 \rightarrow E \qquad C_1 \vee C_2 \rightarrow E \qquad C_1 \wedge C_2 \rightarrow E \tag{1}$$

Suppose that in situation C_1 the entity has a significance best described by the existence P of a set of properties which one would associate closely with the idea of a classical particle, and that in situation C_2 the existence of a wave description, W, is best. Then

$$C_1 \rightarrow P \qquad C_2 \rightarrow W \tag{2}$$

Also, if the aforesaid set of particle properties occur, C_1 can occur.

$$P \rightarrow C_1 \qquad W \rightarrow C_2 \tag{3}$$

Thus, if one has a two-valued interpretation

$$W = C_1 \qquad P = C_2 \tag{4}$$

But

$$E \rightarrow P \vee W \qquad E \rightarrow P \wedge W \tag{5}$$

Using (1) to (5) one easily obtains

$$C_1 \vee C_2 = C_1 \wedge C_2$$
$$P \vee W = P \wedge W \tag{6}$$

But this implies equivalence of particle and wave concepts using the two-valued interpretation, an undesirable result, since one knows particles and waves are not the same. While the calculus is still quite valid, it does elucidate in mathematical terms the fact that a dilemma is likely to arise if two physical concepts are associated with a single entity.

The problem now looks generally similar to the specific one posed by Carnap (1958) in a mathematical context, and Carnap's solution can be used. That is, one introduces modality operators. If $\Box$ is the modal necessity operator in a revised version of the calculus, and (1) to (5) are appropriately modified, one has, for instance, $\Box(C_1 \rightarrow E)$ but not $\Box(E \rightarrow C_1)$.

Thus one never arrives at $\Box(P = W)$, so there is not strict equivalence between particle and wave in the new calculus. The result suggests, though in no way proves, that the use of modalities and strict implication could be appropriate and have a direct significance in a precise axiomatisation of physics.

Reference

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Mechanism for Yielding Particles of Non-integral Charge

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Recently, McCusker & Cairns (1969) and Cairns *et al.* (1969) have reported the observation of charged particles with charges less than that of the electron. The particles were produced in cosmic-ray interactions above 10^{14} eV. The purpose of this Letter is to point out that this observation is consistent with the existence of fundamental particles with masses of only a few GeV, and with charges much greater than, but not integral multiples of, the electronic charge.

The starting point of the discussion is the unified six-quark field theory that has recently been proposed by one of us (Yock, 1969). In this theory the observed particles are assumed to be the 'nearly neutral' bound states of a set of six fundamental particles [we refer to them as 'quarks' for a reason stated previously (Yock, 1969)] whose (bare) charges are g_0, $2g_0$, $3g_0$, $4g_0$ and $g_0 + e_0$ and $4g_0 + e_0$

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