The starting point of the theory is the idea that particles with spin produce a gravitational field whose potential is a real *nonsymmetric* second-rank tensor. The reasons for introducing this idea have been described elsewhere[1]; here we shall examine its implications for the mathematical representation of elementary particles or fields. In particular, we wish to introduce spinors into a space determined by a nonsymmetric metric. The resulting formalism then leads to the consequences mentioned above.

A considerable amount of work has been done on the problem of introducing spinors into Riemannian space. The most convenient method to generalize consists of introducing a local Lorentz frame of reference (vierbein or tetrad) at each point of space.[2] Spinors can then be defined in terms of Lorentz transformations of these tetrads.

In order to generalize the tetrad, it is convenient to represent the nonsymmetric metric g_{ij} by a complex Hermitian tensor,[3] whose real and imaginary parts correspond to the symmetric and skew parts of g_{ij}. We can now introduce a *complex* tetrad $e_i(\alpha)$ at each point of space, such that

$$g_{ij}=e_i(\alpha)e_j{}^*(\alpha),$$

where the star means complex conjugate. This is the analog of the corresponding equation in Riemannian space.

These complex tetrads are subject to a unitary transformation which can vary arbitrarily (but continuously) from point to point. Elementary particles or fields can then be described by quantities which transform irreducibly under unitary transformations. In addition the space will be endowed with a skew-Hermitian affine connection $\mu_p(\alpha\beta)$, which generalizes the skew-symmetric connection $O_p(\alpha\beta)$ of Weyl.[2]

For simplicity let us first consider the analog of the scalar field. This will be[4] a scalar density ψ of weight α, where α is any complex constant:

$$\varphi\rightarrow\Delta^\alpha\varphi,$$

where Δ is the determinant of the transformation. The factor Δ^α gives a contribution to the covariant derivative of φ:

$$\varphi_{;p}=\varphi_{,p}+\alpha\mu_p(\beta\beta)\varphi.$$

This suggests that we interpret $\mu_p(\beta\beta)$ as the electromagnetic potential. This suggestion is supported by the fact that

$$\mu_p(\beta\beta)=i\,\mathrm{Im}\left(\frac{\partial e_q(\beta)}{\partial x^p}e^q(\beta)\right),$$

so that the transformation

$$e_p(\beta)\rightarrow e^{\frac{1}{4}i\theta}e_p(\beta),$$
$$\varphi\rightarrow e^{i\alpha\theta}\varphi,$$

leads to

$$\mu_p(\beta\beta)\rightarrow\mu_p(\beta\beta)+i(\partial\theta/\partial x^p),$$

which is just a gauge transformation.

On this interpretation of $\mu_p(\beta\beta)$, α is the coupling constant for the φ and electromagnetic fields. Now since φ is a boson field, it is measurable, and so it must correspond to a single-valued representation of the unitary group. This requirement restricts α to being a positive or negative integer or zero.[4] Hence, when the field is quantized, the charge of the resulting particles will be an integer (α) times a basic unit e_0.

Similar considerations apply to vector, tensor, etc., representations, so that we arrive at result 1 for bosons. Fermions need special consideration as there is no spinor representation of the whole unitary group. However, gauge transformations of spinors can be made to correspond to gauge transformations of the tetrads, and then result 1 applies also to fermions.

In order to derive result 2, we note that the unitary group differs from the Lorentz group in that reflections are continuous with the identity.[5] Hence we should expect that the interaction between bosons and the electromagnetic field is invariant under a space or time inversion. Again fermions need special consideration, and it turns out that (as far as this theory goes) their electromagnetic interaction must be invariant under a combined space-time inversion (and hence charge-conjugation). By contrast, particles which do not interact (directly or indirectly) with the electromagnetic field are described by real field variables which are transformed only by the (real) Lorentz subgroup of the unitary group. For these transformations, reflections are discontinuous with the identity, so that reflection symmetry may be lost.

Result 3 follows from the fact that all singly charged bosons are densities of weight ±1.

A detailed account of this work is being prepared. I am grateful to Professor P. A. M. Dirac, Dr. D. Finkelstein, Dr. O. Penrose, Dr. R. Penrose, Professor A. Salam, and Dr. J. C. Taylor for helpful discussions.

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Spin of 27-Hour Arsenic 76*

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THE Princeton focusing atomic beam apparatus[1] has been used to measure the angular momentum of the odd-odd nucleus As^{76}. We find $I=2$, confirming the result obtained by Pipkin and Culvahouse[2] by a double-resonance method in an arsenic-doped silicon crystal. This represents the start of a series of atomic beam measurements of ground state hyperfine structure in elements which normally vaporize as molecules and which are hence inaccessible to the high-intensity atomic beam methods needed for measurements on radioactive nuclei. In this case, approximately 20% dissociation of the As_4 vapor is effected by means of a microwave discharge at the end of a coaxial line, similar to the technique described by King and Zacharias.[3] The 27-hour isotope is produced by neutron irradiation in the Brookhaven reactor.

Owing to instability in the discharge, the beam apparatus has been converted to operate in a "flop-out" manner. Because the unflopped beam is focused into an area of $\frac{1}{8}$-inch radius around the axis of the apparatus, the deposition detector disk has been divided into eight sectors and is rotated about an axis eccentric to that of the machine. Each sector has associated with it a particular rf transition frequency. The disk is rotated, exposing successively each sector to the beam for a short period while applying the appropriate frequency to the transition-inducing loop. Many revolutions are made, thereby averaging the beam fluctuations over all the sectors and providing a total exposure of about five minutes for each sector. It is necessary to cool the copper disks to about $-120°C$ or lower in order to insure a high, reproducible sticking probability for the arsenic atoms. The beam intensity is measured by removing the disk from the vacuum system, separating the sectors, and counting the activity on each one in a 2π scintillation counter.

By means of these techniques, resonances have been observed at the three transition frequencies 0.75, 1.48, and 5.60 Mc/sec, at values of the dc magnetic field measured by using as calibration the resonances observed with an atomic beam of K^{39}. A typical As^{76} resonance is shown in Fig. 1. The observed As^{76} resonances are consistent only with ($\Delta F=0$) transitions within the state $J=\frac{3}{2}$ (the known J for the atomic ground state), $I=2$, $F=\frac{7}{2}$. A resonance at 0.65 Mc/sec

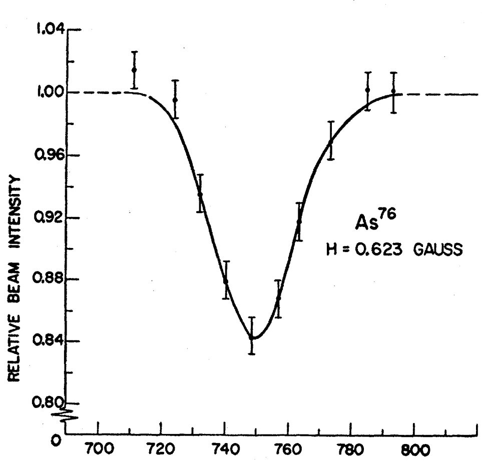

FIG. 1. A typical As^{76} resonance in the Zeeman region. Beam intensity without rf applied is about 2000 counts/min for a 5-minute exposure.

within the state $J=\frac{3}{2}$, $I=2$, $F=\frac{5}{2}$ has also been observed. The spin of the 27-hour As^{76} is thus uniquely determined as two.

The spin of two is in agreement with the beta decay systematics[4] and the reasonable shell-model expectation of an $f_{5/2}-g_{9/2}$ odd-proton, odd-neutron configuration.

A splitting of the observed resonances which results from the various multiplicities of multiple quantum transitions[5] has also been observed. This splitting and the field dependence of the resolved components are now being measured to obtain values for the hyperfine intervals of the ground state of the As^{76} atom.

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Some Experimental Tests of the Lüders Theorem*

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THE recently observed violations of the principle of symmetry under space and space-time inversions may easily be accommodated in the existing theoretical framework by the readmission of various interaction terms or by the suppression of certain states. The violations of these symmetry principles may, however, signify a more fundamental defect in the current form of physical theory. In view of the conclusions of Landau and Pomeranchuk[1] and of the prevailing sentiment that the renormalization procedures are fundamentally unsatisfactory, the failure of the spatial symmetries casts an additional suspicion upon the current treatment of the space-time point.[2]

A recent theorem of Lüders shows that for the usual types of field theory the product of time reversal (T), charge conjugation (C), and space inversion (P) must be a valid symmetry operation. As the validity of the usual treatment of the space-time point is assumed in the proof of this theorem, an inadequacy of the treatment may be reflected in a failure of the theorem. Regardless of the validity of the present treatment of space and time, a demonstrated violation of the Lüders theorem would be of considerable theoretical importance, as it would imply the nonvalidity of at least one of the fundamental precepts of current physical theory.