

electrooptics

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The concept of the photon

In this special report, reprinted from PHYSICS TODAY, March 1972, distinguished experts Emmet Leith and Juris Upatnieks, Robert Kingston and Robert Keyes, Marlan O. Scully and Murray Sargent III review major areas of their disciplines within the field of Electro-Optics. In addition, nine of the world's leading laser specialists discuss their views on the future of fundamental and applied laser physics. This report covers a wide range of subjects and offers you a concise, comprehensive look at what many consider one of the fastest-growing research areas in Physics.

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continued from page 15

methods considered should be the establishment and promotion of permanent part-time faculty positions. I urge also that the AIP and the most prestigious departments of physics formulate a program that will unify and strengthen the efforts of individual physics departments, and which will encourage, in as strong terms as possible, that everyone in the physics academic community address himself to solving this problem.

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Scale symmetry

In his recent article on scale symmetry (January, page 23) Roman Jackiw suggested that dilatation symmetry must be inexact for massive particles. His proof of this assertion applies, however, only in the framework of the Lorentz group, $O(3, 1)$. If one goes to the larger group $O(4, 2)$ (the conformal group), which contains $O(3, 1)$ as a subgroup, it is quite possible to construct an explicit acceptable scale-invariant wave equation for massive spin-1/2 composite particle system, and we shall do this specifically for the quark triplet $(\Phi, \mathfrak{N}, \lambda)$ system.

We begin with the most general minimal linear parity-conserving currents in the $O(4, 2)$ algebra of Dirac matrices¹

$$J_\mu =$$

$$\bar{q}\gamma_\mu q - i\left\{\bar{q}M^{-1}(\partial_\mu q) - (\partial_\mu \bar{q})M^{-1}q\right\} \quad (1)$$

where

$$M = \begin{bmatrix} m_\Phi & 0 & 0 \\ 0 & m_{\mathfrak{N}} & 0 \\ 0 & 0 & m_\lambda \end{bmatrix} \quad (2)$$

defines the quark masses (m_Φ , $m_{\mathfrak{N}}$, m_λ) assumed to be nonzero. (We adopt the natural units $\hbar = c = 1$). The simplest wave equation that conserves this current is the $O(4, 2)$ wave equation

$$i\gamma^\mu \partial_\mu q + M^{-1}\partial^\mu \partial_\mu q = 0 \quad (3)$$

The Lagrangian density may be written $L = \theta_{\mu\nu}$, where $\theta_{\mu\nu}$ is the energy-momentum tensor

$$\begin{aligned} \theta_{\mu\nu} = i\frac{1}{4}\left\{\left[\bar{q}\gamma_\mu(\partial_\nu q) - (\partial_\nu \bar{q})\gamma_\mu q\right] \right. \\ \left. + [\mu \leftrightarrow \nu]\right\} - \frac{1}{2}\left\{(\partial_\mu \bar{q})M^{-1}(\partial_\nu q) \right. \\ \left. + [\mu \leftrightarrow \nu]\right\} \quad (4) \end{aligned}$$

(Where $[\mu \leftrightarrow \nu]$ means that the term is repeated with μ and ν interchanged.)

But $L = 0$ by virtue of the field equation (3); that is, $\theta_\mu^\mu = 0$. Thus, the dilatation current and conformal current defined respectively by

$$D_\mu = x^\nu \theta_{\mu\nu}; \quad K_{\mu\nu} = (2x_\mu x_\nu - g_{\mu\nu} x^2) \theta_\lambda^\lambda \quad (5)$$

are exactly conserved in the forms $\partial^\mu D_\mu = \theta_\mu^\mu = 0$; $\partial^\mu K_{\mu\nu} = 2x_\mu \theta_\lambda^\lambda = 0$

Thus, the model has dilatation symmetry.

The $O(4, 2)$ mass equation for equation (3) is simply

$$m - m^2/M = 0 \quad (6)$$

which has two eigenvalues, $m = 0$ and $m = M$. We may associate $m = 0$ with strictly massless Goldstone's bosons, and $m = M$ with the real world of strongly interacting particles with non-zero rest masses in the quark model. Indeed, if $m_\phi = m_\pi$, then chiral $SU_3 \times SU_3$ symmetry is broken in the manner proposed by Gell-Mann, Oakes and Renner.² We are thus able to obtain a nontrivial scale-invariant wave equation that fulfills Lorentz-covariance, gauge-invariance, $O(4, 2)$ invariance, and SU_3 -invariance in the appropriate limit. Equations of type (3) include *convective currents* (the second-order derivative structure) and were first considered in connection with radiation reaction theories.³

References

1. A. O. Barut, Phys. Rev. Lett. 20, 893 (1968).
2. M. Gell-Mann, R. J. Oakes, B. Renner, Phys. Rev. 175, 2195 (1968).
3. G. Rosen, Nuovo Cimento 32, 1037 (1964).

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Waste management

It is with great interest that I read "Physics Looks at Waste Management" in the February issue (page 32). I would like to make the simple point that if people were less wasteful, there would be less junk around to contend with. For example on the cover of this same issue, which represents a pile of junk cars, one can plainly see that the green one, on the top of the pile, only needs a new clutch.

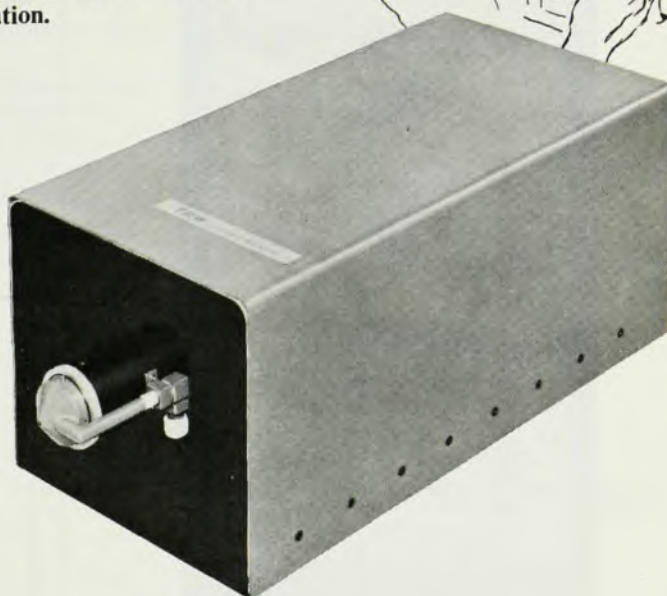
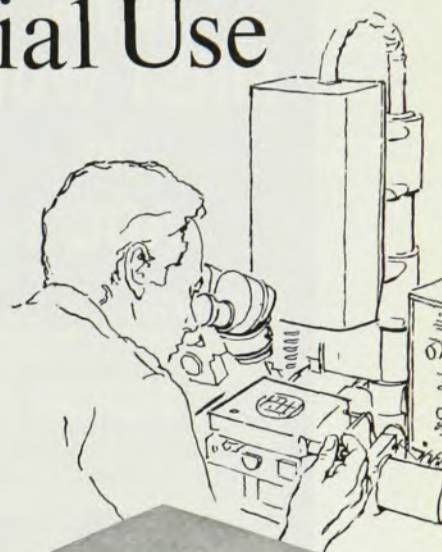
DANIEL R. PARIGNAULT
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Correction

February, page 73—The figure given in the table for gas-main explosions should read 3×10^{-12} instead of 3×10^{-1} . □

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