lation given here, is the definition of the mean life time τ of a larmoron. One can as a first approximation use for τ the average time of free flight of the real particle, evaluated without taking the magnetic field into account, but changing the values of the parameters in the logarithmic term (the Larmor radius or the Coulomb screening distance, depending on their relative magnitude). In this way we indeed get from (4) and (5) the well known formulae for transport phenomena in a dilute plasma. It is, however, possible in the "larmoron" theory to give also a more rigorous determination of the quantity τ, in particular, by using to this purpose the method of interpreting the collision terms for larmorons in a way similar to the one used in quantum theories of transfer.

If the magnetic field or the acceleration a are non-uniform and depend on the time, we must change (1) and (2) will as a consequence become more complicated. But the "larmoron" theory will even in that case be appreciably simpler than the usual transport theory of a plasma.

I express my gratitude to A. E. Glauberman for discussing this paper.

[1] L. Spitzer Jr., Physics of Fully Ionized Gases, Interscience, New York, 1956, Russ. Transl. IIL, M., 1957.

[2] S. T. Belyaev, Физика плазмы и проблема управляемых термоядерных реакций (Plasma Physics and the Problem of Controlled Thermonuclear Reactions) U.S.S.R. Acad. Sci. Press, M., 1958, pp. 50-66.

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A DYNAMICAL PRINCIPLE FOR SECOND-ORDER EQUATIONS

A. A. BORGARDT

Dnepropetrovsk State University

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A new method to construct a quantum theory of spinor fields based upon second order equations has recently been suggested.* The results of quantum electrodynamics are not changed in such an approach, but a number of interesting possibilities arise for a more correct description of other processes involving spinor particles. The unusual commutation relations for spinor wave functions are due to a number of peculiarities of the theory.

In this note we show that the application of Schwinger's dynamical principle to systems with a Lagrangian of the second order gives unique commutation rules for fermion and boson fields. It is clear from the derivation that the same result is also valid for fields with higher derivatives: Lagrangians of odd order lead to anticommutativity of spinors and Lagrangians of even order require that they commute.

Taking the Lagrangian in the form (m is the eigen mass, the rest of the notation is the same as in reference 1):

$$\mathcal{L}(x) = (1/2m)\,\partial_\mu\chi(x)\,\alpha_\mu\alpha_\nu\partial_\nu\chi(x) - \mathcal{H}(\chi(x)), \tag{1}$$

we get, after taking the variation, the equation of motion

$$\alpha_\mu\alpha_\nu\partial^2_{\mu\nu}\chi + m\delta_l\mathcal{H}/\delta\chi = \partial^2_{\mu\nu}\chi\alpha_\mu\alpha_\nu + m\delta_r\mathcal{H}/\delta\chi = 0. \tag{2}$$

We first of all determine the commutation rule for χ on the hypersurface σ with $d\sigma_\mu \to d\sigma_0 = d\sigma$, using the shift operator G_χ

$$G_\chi = \frac{1}{2m}\int_\sigma d\sigma_\mu\,(\delta\chi\alpha_\mu\alpha_\nu\partial_\nu\chi + \partial_\nu\chi\alpha_\nu\alpha_\mu\delta\chi)$$

$$= \frac{1}{m}\int_\sigma d\sigma_\mu\delta\chi\alpha_\mu\alpha_\nu\partial_\nu\chi = \frac{1}{m}\int_\sigma d\sigma_\mu\partial_\nu\chi\alpha_\nu\alpha_\mu\delta\chi. \tag{3}$$

As $d\sigma_\mu \to d\sigma_0$ we get

$$G_\chi = \frac{1}{m}\int_\sigma d\sigma\partial_\nu\chi\alpha_\nu\alpha_0\delta\chi = \frac{1}{m}\int_\sigma d\sigma\,(\alpha_0\alpha_\nu)^T\delta\chi\partial_\nu\chi,$$

$$[\alpha_0\chi, G_\chi] = i\alpha_0\delta\chi.$$

The matrices α_μ can be of two kinds: a) $\alpha_\mu^T = -\alpha_\mu$, Dirac algebra; b) $\alpha_\mu^T = +\alpha_\mu$, Kemmer algebra. In both cases $\alpha_\mu\alpha_\nu = (\alpha_\nu\alpha_\mu)^T$ so that always

$$[\delta\chi,\ \partial_\mu\chi] = 0. \tag{4}$$

The commutation relations are the same in both cases:

$$(1/m)\,[\alpha_0\chi(x), \partial'_\nu\chi(x')\,\alpha_\nu\alpha_0] = i\alpha_0\delta_\sigma(x-x'), \tag{5}$$

Using Green's theorem

$$\chi_\alpha(x) = \frac{1}{m}\int_\sigma d\sigma_\mu\,(\Delta(x-x')\ (\alpha_\mu\alpha_\nu\partial'_\nu\chi\ (x'))_\alpha$$

$$-\ \partial'_\nu\Delta(x-x')\,(\alpha_\nu\alpha_\mu\chi(x'))_\alpha) \tag{6}$$

we get for arbitrary points x and x′:

$$[\chi_\alpha(x),\ \chi_\beta(x')] = i\delta_{\alpha\beta}\Delta(x-x'). \tag{7}$$

It is easy to generalize this result to charged fields. In the case of integer spin the right hand side of (7) must be slightly more complicated to take the auxiliary conditions into account.

*V. Vanyashin's paper "Second-Order Wave Equations for Spinor Wave Functions" at the Conference on the Theory of Elementary Particles, Uzhgorod, October 1958.

[1] J. Schwinger, Phys. Rev. **91**, 713 (1953).

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COMPARISON OF THE MACROSCOPIC THEORY OF SUPERCONDUCTIVITY WITH EXPERIMENTAL DATA

V. L. GINZBURG

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

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GOR' KOV[1] has recently shown that the macroscopic equations for superconductors, established earlier by Landau and the author[2] (see also references 3 and 4) follow from the current microscopic theory of superconductivity. He obtained then an essentially new result, namely a confirmation that the charge e_{eff} which occurs in these equations is equal to twice the electronic charge, 2e. This result has an obvious physical meaning since the charge of a Cooper pair is just equal to 2e. Meanwhile, the charge e_{eff} was previously usually put equal to e. It is in that connection advisable to consider a comparison of the macroscopic theory with experiments, putting $e_{eff} = 2e$. The parameter κ entering into the theory is then equal to

$$\varkappa = \frac{\sqrt{2}\,|e_{eff}|}{\hbar c} H_{cM}\delta_L^2 = 4.32\cdot 10^7 H_{cM}\delta_L^2, \qquad (1)$$

where H_{cM} is the critical magnetic field and δ_L the depth of the penetration of the field in a bulk metal at the given temperature T. It is now essential that the theory of reference 2 in a weak field goes over into the theory of F. and H. London and that δ_L in (1) is thus the London penetration depth. Near the critical temperature (this will be the only region with which we shall be concerned) the measured penetration depth δ is for all metals equal to δ_L. If, however, for tin $\delta \approx \delta_L$ for $\Delta T = T_c - T \lesssim 0.1°$ with an accuracy of 10 to 15%, then for aluminum, for instance, $\delta \approx \delta_L$ only when $\Delta T \lesssim 10^{-3}°$. As a result one can for tin, lead, and some other superconductors (in contradistinction to aluminum) determine the value of κ near T_c directly from the experimental data for H_{cM} and δ. Such a method is very suitable since Eq. (1) is practically independent of any assumption when $\delta = \delta_L$ and $T \to T_c$ (the result $e_{eff} = 2e$ was obtained for an isotropic model[5] but is most probably much more generally true).

If we use the empirical law

$$\delta = \delta_{00}\,[1 - (T/T_c)^4]^{-1/2},$$

we have near T_c

$$\delta = \frac{1}{2}\delta_{00}\sqrt{\frac{T_c}{\Delta T}} \qquad H_{cM} = \left|\frac{dH_{cM}}{dT}\right|_c \Delta T,$$

$$\varkappa = 1.08\cdot 10^7 \left|\frac{dH_{cM}}{dT}\right|_c T_c\delta_{00}^2.$$

For tin

$$\left(T_c = 3.73°,\ \left|\frac{dH_{cM}}{dT}\right|_c = 151, \qquad \delta_{00} = 5.1\cdot 10^{-6}\,\mathrm{cm}\right)$$

we have thus $\kappa = 0.158$. The limiting field for supercooling H_{ci} is for such a value of κ equal to $H_{c1}/H_{cM} = \sqrt{2\kappa} = 0.224$. Experimentally[6] $H_{c1}/H_{cM} = 0.232$. For the surface energy $\sigma_{ns} = H_{cM}^2\Delta/8\pi$ we have[7] for $\kappa = 0.158$

$$\Delta = 6.5\delta_L \approx 1.66\cdot 10^{-5}\sqrt{T_c/(T_c - T)}$$

while we have experimentally, instead of 1.66, according to Sharvin's data[8] 2.5 and according to Faber's data[9] 1.88. Since in both cases $T_c - T > 0.1°$ and we are dealing with a limiting law as $T \to T_c$ we can as yet scarcely consider the discrepancy obtained here to be real (if we determine κ from Faber's data for Δ we get $\kappa = 0.15$ and $H_{c1}/H_{cM} = 0.212$). In the isotropic model[5] near T_c

$$\delta_L(T) = \delta_L(0)\sqrt{T_c/2\Delta T}, \qquad \delta_L^2(0) = mc^2/4\pi e^2 n \qquad (2)$$

(n is the concentration of "free electrons"). If we use this expression, Eq. (1) takes the form

$$\varkappa = 2.16\cdot 10^7\,|dH_{cM}/dT|_c\,T_c\,\delta_L^2(0). \qquad (3)$$

For tin $\delta_L(0) = 3.5\times 10^{-6}$, according to references 10 and 6, whence $\kappa = 0.149$. The value $\kappa = 0.15$ to 0.16 for tin agrees thus with sufficient accuracy both with experiments and with the requirements of the macroscopic as well as of the microscopic theory.

A further check must, in particular, consist in the measurement of a third effect: the change of δ with field.[2,7] The increase of δ in tin near T_c