though relativistically invariant, is not Larmor invariant. Such a formulation is possible only in the framework of a Larmor invariant theory which includes magnetic charges (Kottler's formulas).[1]

Recently Ohmura[2] has shown that magnetic charges must be considered to achieve stability for the classical electron.

The wave equations for a boson field, invariant under the Larmor transformation, can be written as follows[3,4]

$$\gamma_\lambda \partial\psi / \partial x_\lambda + k_0\psi = q, \quad -\partial\psi^+\gamma_\lambda / \partial x_\lambda + k_0\psi^+ = q^+, \tag{1}$$

$$1/2\,\{\gamma_\mu\gamma_\nu\} - \delta_{\mu\nu} I = 0, \qquad \psi^+ = \psi^* R_4, \tag{2}$$

(in the general case $\psi^+ = -i\psi^* R_n$, where $R_n = n_\lambda R_\lambda$, $n_\lambda^2 = I$).

In this theory Larmor conjugation is accomplished by means of the matrix $\overline{\gamma_5} = R_5\gamma_5$:

$$\psi^L = \overline{\gamma}_5\psi, \quad q^L = \overline{\gamma}_5 q, \quad \psi^{+L} = \psi^+\overline{\gamma}_5, \quad q^{+L} = q^+\overline{\gamma}_5. \tag{3}$$

Equations (1) are Larmor invariant because $[\overline{\gamma_5}\ \gamma_\mu] = 0$ and $\overline{\gamma_5} = I$. This is not the case in Kemmer's theory where the kinematic matrices are the β_μ — the "halves" of the γ_μ:

$$\beta_\mu = 1/2\,(\gamma_\mu + \overline{\gamma}_\mu), \qquad [\overline{\gamma}_5\beta_\mu] = \overline{\gamma}_5\overline{\gamma}_\mu. \tag{4}$$

Invariance of the (1) — (2) system under the transformation (3) leads to the interesting fact, pointed out in Ref. 4, that the wave equations can be deduced from two different Larmor invariant Lagrangians, a scalar L and a pseudoscalar $\widetilde{L}$,

$$L = 1/2\,(\varphi^+ R_5\psi + \psi^+ R_5\varphi), \ \widetilde{L} = 1/2\,(\varphi^+\gamma_5\psi + \psi^+\gamma_5\varphi) \quad (\varphi = \psi - q). \tag{5}$$

In actuality one apparently has to form a linear combination of the two and choose the action in the form

$$S = 1/4 \int (\varphi^+ R_5 (I \pm \gamma_5)\,\psi + \psi^+ R_5 (I \pm \gamma_5)\,\varphi)\,(dx). \tag{6}$$

The invariance under transformation (3) is connected with the intrinsically five-dimensional character of our space (γ_μ and γ_5 form a five dimensional representation of the Dirac algebra). Therefore it is logically unavoidable to require that both classical and quantum field theory be Larmor invariant.

The extension of these conclusions to the theory of spinor fields does not present any difficulties and requires merely a slight development of existing methods similar, for example, to those employed in Ref. 5.

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THEORY OF ELECTRON PARAMAGNETIC RESONANCE IN SUPERCONDUCTORS

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ELECTRON spin paramagnetic resonance has recently been observed in various metals.[1] The theory of the resonance has also been published.[2,3] The theory indicates that diffusion of conduction electrons into the depth of the metal plays an important part in the effect. The diffusion causes the attenuation of electromagnetic fields in the metal to be much less at resonance than it is away from resonance. Thin films are thus selectively transparent.

The question arises, whether paramagnetic resonance and selective transparency are possible in superconductors. Since the superconducting electrons do not diffuse, one must presumably consider only the normal electrons. Then the difference in behavior of a metal in the superconducting state will arise only from the fact that the constant magnetic field is attenuated with depth ($H = H_0 e^{-z/\delta_0}$). The electrons are consequently polarized by the constant field only for a time $(\delta_0/v) \sim 10^{-13}$ sec (v is the electron velocity), much shorter than one period of the high-frequency field. Paramagnetic resonance in bulk superconductors thus appears to be impossible. To observe resonance in a superconductor, we must make the thickness d smaller than δ_0. An experimental observation of paramagnetic resonance in a bulk superconductor would imply that the resonance is produced by the superconducting electrons.

To determine the attenuation of the high-frequency and constant fields with depth, we solve Eq. (12a) of Ref. 3. An elementary examination of the terms in Eq. (12a) shows that Eq. (15) of Ref. 3 always holds for the normal electrons. We suppose that the constant field $H_0 e^{-z/\delta_0}$ is not too strong, so that even at the surface the Larmor frequency $\Omega_0 = (2\mu H_0/h)$ is small compared with the collision frequency $(1/t_0)$ of the electrons; this condition is always fulfilled in practice. Then taking the constant field along the x-axis, we obtain as in Ref. 3

$$M = -i\chi\bar{w}e^{i\omega t}; \quad M_z = \chi(B_z - \bar{w}_z); \quad \bar{\Phi} = \frac{1}{2}\int_0^\pi \Phi \sin\theta \, d\theta; \quad v\cos\theta\frac{\partial w_z}{\partial z} + \frac{w_z}{t_0^*} = \frac{\bar{w}_z}{t_0^*} + \mathrm{Re}(w\Omega_1^*);$$

$$v\cos\theta\frac{\partial w}{\partial z} + \frac{w}{t_0} + i(\omega - \Omega_0 e^{-z/\delta_0})w = \frac{\bar{w}}{t_0} + \omega B_1; \quad w(0; v_z) = 0; \quad w(0; -v_z) = 0 \quad (v_z > 0); \tag{1}$$

$$M = M_x + iM_y; \quad 1/t_0^* = 1/t_0 + 1/T_{\mathrm{sp}}.$$

Here **M** is the electron spin magnetization, T_{sp} is the relaxation time for an electron spin to be flipped in a collision, v is the electron velocity, and ω the applied frequency. We find then an equation for $\bar{w}$,

$$\bar{w}(z) = \int_0^\infty K(z;\mu)\left(\frac{\bar{w}(\mu)}{t_0} + \omega H_1(\mu)\right)d\mu, \quad K(z;\mu) = \frac{1}{2v}\int_1^\infty \frac{du}{u}\exp\left\{-\frac{|z-\mu|u}{v}\left(\frac{1}{t_0^*} + i\omega\right) + \frac{i\omega\delta_0}{v}\left|e^{-z/\delta_0} - e^{-\mu/\delta_0}\right|u\right\}. \tag{2}$$

But $\omega\delta_0/v \ll 1$ for $\omega \ll 10^{13}\ \mathrm{sec}^{-1}$. Therefore

$$K(z;\mu) \approx K(|z-\mu|) = \frac{1}{2v}\int_1^\infty \frac{du}{u}\exp\left\{-\frac{|z-\mu|}{v}\left(\frac{1}{t_0^*} + i\omega\right)u\right\}. \tag{3}$$

From Eq. (2) and (3) it appears that in superconductors with $\omega\delta_0/v \ll 1$ there is never any paramagnetic resonance from the normal electrons. But even in superconductors, the spin diffusion of the normal electrons gives rise to a small deeply penetrating term in the expressions for both high-frequency and constant fields.

Using the methods which we have explained elsewhere,[3,4] we find for the constant field the expression

$$H(z) \approx H_0 e^{-z/\delta_0} + A\cdot 4\pi\chi\left(\frac{c^2|Z|}{2\pi v}\right)^2 |H_{\mathrm{Inc}}|^2 \frac{2\mu}{h\omega}\frac{3T_{\mathrm{sp}}}{t_0}\frac{e^{-z/\delta_{\mathrm{eff}}}}{\sqrt{1+\omega T_{\mathrm{sp}}}}; \quad A \sim 1, \quad \delta_{\mathrm{eff}} = v\sqrt{t_0 T_{\mathrm{sp}}/3},$$

Here we assume $\omega t_0 \ll 1$, $t_0 \ll T_{sp}$. Z is the surface impedance of the metal,[5] and H_{Inc} is the strength of the incident component of the high-frequency magnetic field. Thus when $z \gg \delta_0$ the magnetic field in a superconductor is attenuated much more slowly than the usual London theory predicts.

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ON THE THEORY OF THE NEUTRINO WITH ORIENTED SPIN

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LEE and Yang[1] have advanced the hypothesis of the nonconservation of parity under spatial inversion in the weak interactions. Developing this idea, Lee and Yang,[2] Salam,[3] and Landau[4] have suggested that this violation of the parity rule can in particular cases be related to special properties of the neutrino, by requiring that it satisfy an equation with the two-rowed Pauli matrices. According to this theory the spin of the neutrino is always parallel to the direction of its momentum, and the spin of the antineutrino is always antiparallel to its momentum. As has been shown by Landau and by Lee and Yang, this theory is invariant with respect to combined inversion. Combined inversion means interchange of particle and antiparticle with simultaneous spatial inversion.

We wish to show that the new theory of the neutrino can be obtained from the Dirac theory, if in the latter one carries out an explicit resolution of the functions in terms of spin states.[5] Then it is not necessary to separate the interaction energy into a sum of main quantities and their pseudo-values (for example, scalar plus pseudoscalar).

The Dirac equation for a free particle has the form

$$(\hat{E} \mp m_0 c^2)\begin{pmatrix}\psi_{1,3}\\ \psi_{2,4}\end{pmatrix} = c\,(\sigma'\hat{\mathbf{p}})\begin{pmatrix}\psi_{3,1}\\ \psi_{4,2}\end{pmatrix}, \tag{1}$$

where $\hat{E}$ and $\hat{\mathbf{p}}$ are the operators for energy and momentum, respectively, and σ' is the two-rowed Pauli matrices. Since the mass of the neutrino is zero ($m_0 = 0$), we get a linear relation between the functions,

$$\begin{pmatrix}\psi_1\\ \psi_2\end{pmatrix} = \varepsilon\begin{pmatrix}\psi_3\\ \psi_4\end{pmatrix}, \tag{2}$$

where $\epsilon = \pm 1$.

We can choose four values for ϵ: (a) $\epsilon = 1$ (states with $E > 0$ and $E < 0$ describe the neutrino), (b) $\epsilon = -1$ (states with $E > 0$ and $E < 0$ describe the antineutrino), (c) $\epsilon = E/|E|$ (states with $E > 0$ correspond to neutrinos and states with $E < 0$ to antineutrinos), and (d) $\epsilon = -E/|E|$ (states with $E > 0$ correspond to antineutrinos, and those with $E < 0$ to neutrinos).

We consider first of all the case $\epsilon = E/|E|$, in which the neutrino is a particle with positive energy and the antineutrino is a hole in the background of negative levels. Equation (1) takes the form

$$(\hat{E} - \varepsilon c\,(\sigma'\hat{\mathbf{p}}))\begin{pmatrix}\psi_{1,3}\\ \psi_{2,4}\end{pmatrix} = 0. \tag{3}$$

The solution of Eq. (1) is of the form (see Ref. 5)

$$\begin{pmatrix}\psi_{1,3}\\ \psi_{2,4}\end{pmatrix} = L^{-3/2}\sum_{\mathbf{k}}\frac{1}{\sqrt{2}}\begin{pmatrix}\cos\frac{\theta}{2}\\ \sin\frac{\theta}{2}\,e^{i\varphi}\end{pmatrix} e^{i\mathbf{kr}}\,[C(\mathbf{k})\,e^{-ickt} \pm \tilde{C}^{+}(-\mathbf{k})\,e^{ickt}], \tag{4}$$