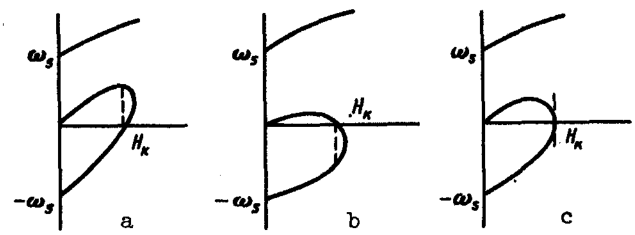
Depending on the value of the parameter ξ, both the "antiferromagnetic" frequency (ω_3) and the "paramagnetic" frequency (ω_1) may vanish. The former case corresponds to $\xi < 2/3$ and the latter to $\xi > 2/3$. The figure shows schematically the dependence of ω on H. Of particular interest is the case when ξ is close to unity ($1 - \xi \ll 1$). In this case the phase transition will take place in fields that are much smaller than the critical field of the dielectric, i.e., even relatively weak magnetic fields will disturb the antiferromagnetic order in the lattice. Thus, the exchange interaction of the s-electrons determines to a considerable degree the magnetic structure of the system.



We note that when $\xi \sim 1$ the formulas in (3) are valid in the entire region of existence of antiferromagnetic order.

As to the possible experimental observation of the considered effects, we note the following. The spectrum of magnetic excitations in nonferromagnetic metals has by now become a realistic subject of experimental investigations. We have in mind magnetic excitations in an electron system - the recent observation of spin waves in paramagnetic metals [4], and also observation of weakly damped electromagnetic waves due to Fermi-liquid interaction near cyclotron resonance [5]. Owing to the existence of magnetic order, an antiferromagnetic metal is, generally speaking, a very convenient object for the study of the role of a Fermi liquid of electrons in the magnetic properties of the metal. However, the conventional model of an antiferromagnetic metal, which we employ at present, is not adequate for a description of d-metals (such as chromium) in which the d-electrons are not strictly localized. Everything said above can apply more readily to rare-earth metals, in which it is possible to separate an ionic subsystem having antiferromagnetic order.

The derivation of the present results, including an analysis of the spectrum of the magnetic excitations when $\vec{k}$ differs from zero, is the subject of a separate publication.

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[1] L. D. Landau, Zh. Eksp. Teor. Fiz. 35, 97 (1958) [Sov. Phys.-JETP 8, 70 (1959)].
[2] P. S. Kondratenko, ibid. 50, 769 (1966) [23, 509 (1966)].
[3] V. P. Silin, ibid. 35, 1243 (1958) [8, 879 (1959)].
[4] S. Schulz and G. Dunifer, Phys. Rev. Lett. 18, 280 (1967).
[5] P. M. Platzman and W. M. Walsh, ibid. 19, 514 (1967).

PHENOMENOLOGICAL THEORY OF K^0 MESONS AND THE NON-EXPONENTIAL CHARACTER OF THE DECAY

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1. In the well-known phenomenological K^0-meson theory (see, e.g., [1-3]), unitarity relations and their various consequences were obtained on the basis of the most general premises of quantum theory, assuming that the decay of the K_L or K_S meson is strictly exponential.

These unitarity relations and their consequences are the basis of the phenomenological analysis of the problem of CP-invariance and different tests of T- and CPT-invariance [1 - 3].

2. It turns out that the unitarity relations and thier consequences are very sensitive to the assumption that the decays are strictly exponential. It can thus be shown that if the mass distributions of the K_L and K_S mesons have poles of order higher than the first, then it follows automatically from the corresponding unitarity relation that

$$\langle K_L(0)|K_S(0)\rangle = 0 \tag{1}$$

regardless of whether CP-invariance is conserved or not. This result is general.

3. We first postulate the following

Lemma. Let $\omega(m)$ be a non-negative normalized function

$$\int_{-\infty}^{\infty} \omega(m) \quad dm = 1 \tag{2}$$

with a finite first moment (mean value $\overline{m}$):

$$\left| \int_{-\infty}^{\infty} m \, (m) \quad dm \right| = |\,\overline{m}\,| < \infty . \tag{3}$$

Then

$$\frac{d|p(t)|^2}{dt}\Big|_{t=0} = 0, \tag{4}$$

where

$$p(t) = \int_{-\infty}^{\infty} \omega(m) \quad e^{-imt} \quad dm. \tag{5}$$

Proof. On the basis of (2) it is obvious that

$$p(0) = p^*(0) = 1. \tag{6}$$

Further,

$$\frac{d|p(t)|^2}{dt} = p(t)\frac{dp^*(t)}{dt} + p^*(t)\frac{dp(t)}{dt} = i\,p(t)\int_{-\infty}^{\infty} m' \cdot \omega(m')e^{im't}dm' - \\ - i\,p^*(t)\int_{-\infty}^{\infty} m\,\omega(m)e^{-imt}dm \tag{7}$$

and, taking (6) into account, we have

$$\frac{d|p(t)|^2}{dt}\Big|_{t=0} = i\int_{-\infty}^{\infty} m'\omega(m')dm' - i\int_{-\infty}^{\infty} m \;\omega(m)\,dm, \tag{8}$$

whence we obtain on the basis of (3) the sought-for result.

4. If we assume that the energy and momentum conservation law is rigorously satisfied, and take the spectrality principle [8] into account in the reaction of unstable-particle production [4 - 7], then the mass distribution $\omega(m)$ of the unstable particles should be finite finite:

$$\omega(m) = \begin{cases} 0 \text{ if } m < m_{min} \geqslant 0,\ m > m_{max} < \infty \\ \omega(m) \text{ if } m \in [m_{min}, m_{max}] . \end{cases} \tag{9}$$

Recalling the Fock-Krylov theorem [9] and using the proved lemma, we get the following:

Theorem 1. The probability of decay per unit time, $dL(t)/dt$, at $t = 0$, of an unstable particle with finite mass distribution (9) is equal to zero

$$dL(0)/dt = 0 \tag{10}$$

independently of the concrete values of m_{min} and m_{max}.

Corollary 1. The decay of an unstable particle with finite mass distribution (9) is essentially not exponential in the vicinity of $t = 0$.

Corrolary 2. The law of decay $L(t)$ of an unstable particle with finite mass distribution (9) has in the vicinity of $t = 0$ the expansion:

$$L(t) = 1 + \frac{t^2}{2!} \frac{d^2L(0)}{dt^2} + \dots \tag{11}$$

In fact, the finite character (9) of $\omega(m)$ is not necessary for the theorem and its corollaries to be valid - the existence of a finite mean mass $\bar{m}$ is sufficient.

Applying to the state vector

$$|\Psi(t)\rangle = x p_L(t) |K_L(0)\rangle + y p_S(t) |K_S(0)\rangle, \tag{12}$$

where x and y are certain constants, the usual technique of obtaining the unitarity relations [1 - 3], we obtain on the basis of Theorem 1 the following:

Theorem 2. If the K_S and K_L mesons have different finite mean masses and K^0 is a superposition of the K_L and K_S mesons, then

$$\langle K_L(0) | K_S(0) \rangle = 0 \tag{13}$$

independently of whether CP-invariance is conserved or not.

Corollary 3. The usual unitarity relations [1 - 3] do not hold true of the energy and momentum conservation law is assumed to hold rigorously, and consequently allowance is made for the non-exponential character of the decay laws.

Corollary 4. The orthogonality condition (13) is not directly connected with the problem of CP-invariance.

6. If we use the ordinary formulas of the phenomenological theory [1-3, 10], which are derived under the assumption that the decay is strictly exponential, together with(13), then we arrive at contradictions, particularly when it comes to explaining the charge asymmetry in the $K_L \to \pi e \nu$ decays [11, 12]. However, by modifying the formulas of the phenomenological theory, taking (10) and (13) into account from the very outset, we obtain, as can be readily shown, noncontradictory results and, in particular, a correct description of the experiments [11, 12]. We note that the solution of the problem of the $K_L \to 2\pi$ decay, proposed in [5, 13], is compatible with (13). A detailed exposition of all these questions will be published.

I am grateful to L. I. Lapidus for an interesting discussion of the unitarity relations in the conventional phenomenological theory of K^0 mesons.

[1] J. S. Bell and J. Steinberger, Lectures at Oxford Intern. Conf. on Elementary Particles, 1965.
[2] M. Gourdin, Lectures at the III Tokyo Summer Institute, 1967.
[3] L. I. Lapidus, JINR Preprint, 1968.
[4] L. A. Khalfin, Dokl. Akad. Nauk SSSR 165, 541 (1965) [Sov. Phys.-Dokl. 10, 1091 (1966)].
[4] L. A. Khalfin, Dynamic Mass Filter and the Problem of $K_L \to 2\pi$ Decay. Lecture at Session of Nucl. Phys. Division, USSR Acad. Sci., January 1967.
[6] L. A. Khalfin, Dokl. Akad.Nauk SSSR 181, No. 3, 1968.
[7] L. A. Khalfin, ZhETF Pis. Red. 7, 341 (1968) [JETP Lett. 7, 267 (1968)].
[8] L. A. Khalfin, Quantum Theory of the Decay of Physical Systems, Dissertation, Phys. Inst. Acad. Sci. 1960.
[9] N. S. Krylov and V. A. Fock, Zh. Eksp. Teor. Fiz. 17, 93 (1947).
[10] L. B. Okun', Usp. Fiz. Nauk 89, 603 (1966) [Sov. Phys.-Usp. 9, 574 (1967)]
[11] D. Dorfan et al. Phys. Rev. Lett. 19, 987 (1967).
[12] S. Bennett et al., ibid. 19, 993 (1967).
[13] L. A. Khalfin, ZhETF Pis. Red. 3, 129 (1966) [JETP Lett. 3, 81 (1966)].

ON THE POSSIBILITY OF VERIFYING THE EQUIVALENCE PRINCIPLE (FOR THE ELECTROMAGNETIC FIELD) IN SECOND ORDER IN THE NEWTONIAN GRAVITATIONAL CONSTANT

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1. We have shown in [1] that violation of the equivalence principle for atomic phenomena could lead to a specific observable effect in strong gravitational fields. It turns out that violation of the equivalence principle (in second order in the Newtonian gravitational constant G) for electromagnetic phenomena could also lead to an observable effect, namely birefringence of light by a gravitational field. In the simplest case of violation of the equivalence principle, which we shall consider in Sec. 4, the gravitational birefringence would be appreciable even in so weak a gravitational field as the sun's. The optical path difference that this field produces between the polarization components of a light wave (from a nebula or a star) would have an appreciable magnitude, about 6×10^{-3} cm, i.e., 100 - 150 wavelengths in the visible band. An observer on earth could then discern seasonal fluctuations in the corresponding polarization planes, with amplitude up to 45°. Thus, an analysis of the results of systematic polarization measurements of light from nebulas and stars would greatly help in distinghishing between general relativity theory (GRT) and other relativistic gravitation theories that yield values for the three classical tests that agree with experiment; the proposed method supplements the one suggested by us in [1], and is simpler for observations.

2. We consider the equivalence principle in this paper in the same sense as in [1]. It follows from this principle, in particular, that no gravitational field should produce birefringence of electromagnetic waves, since the presence or absence of birefringence is invariant to the choice of the reference frame. Thus, in any theory that includes the equivalence principle for the electromagnetic field, the equations of this field (in the presence of gravitation) should have some singularity capable of excluding the appearance of gravitational birefringence, regardless of any anisotropy of the gravitational field, for example, nonequivalence of the radial and tangential directions in a spherically-symmetrical field. In the case of the equations of electrodynamics in GRT, such a singularity consists of the fact