The FC theory based on such a model of inhomogeneous barrier relief makes it possible to describe quantitatively all the foregoing facts and consequences. We confine ourselves here to the result of the calculation of the most important FC characteristic, namely the kinetics of its decrease. The FC damping law is given by

$$i_o/i = i(0)/i(t) = (1 + \alpha t)^{\gamma},$$

where i(t) is the FC current at the instant of time t, α is the constant determined by the height of the recombination barrier at t = 0 and by the temperature, and $\gamma < 1$ and depends on the ratio of the recombination and drift barrier heights.

The foregoing formula with $\gamma = 0.26$ describes very well the experimental data of [1, 5] (Fig. 2).

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INFLUENCE OF INHOMOGENEOUS STATES ON THE PARAMAGNETIC-FERROMAGNETIC PHASE TRANSITION

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The experiments of Drabkin et al. [1, 2] on the scattering of polarized neutrons by single crystals of nickel have shown convincingly that there is inhomogeneous magnetization in the vicinity of the Curie temperature. At the same time, in the theoretical investigations of the phase transition from the para- into the ferromagnetic phase it is customary to consider only homogeneous magnetization states [3, 4]. We shall show in this article that allowance for the field of the magnetic dipole interaction causes this transition to proceed from the paramagnetic to the ferromagnetic phase with an inhomogeneous distribution of the magnetization; we calculate the parameters of this distribution.

We start from the following expression for the free energy of a ferromagnetic sample

$$F = \int\left\{\frac{1}{2} x_o^2\left(\frac{\partial M_i}{\partial x_k}\right)^2 - \frac{1}{2}\beta M_z^2 + \frac{1}{4} b(M^2 - M_o^2)^2 + \frac{1}{4}[(\beta^2/b) + 2M_o^2\beta]\right\} dv + \int \frac{H_m^2}{8\pi} dv, \qquad (1) \qquad (1)$$

where the first term is the exchange energy ($x_0^2 \sim (I/\mu^2)a^5$, I is the exchange integral, μ the Bohr magneton, and a is the lattice constant) connected with the inhomogeneities of the magnetization, β is the magnetic-anisotropy constant ($\beta >> 1$), the third term is the usual expansion of the free energy of a

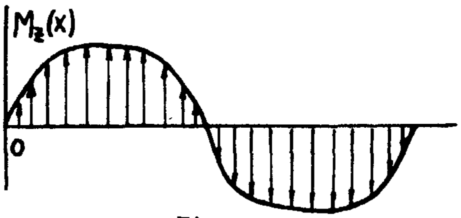

Fig. 1

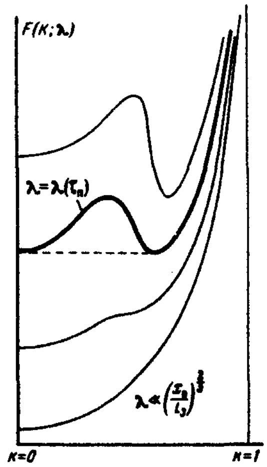

Fig. 2

Fig. 1. Distribution of magnetization in a uniaxial ferromagnet near the Curie point.

Fig. 2. F(k; λ) curves for different temperatures (shown schematically).

ferromagnet in the vicinity of the phase-transition point [5], the fourth constant term has been added for convenience, and the last term is the energy of the magnetic field due to the sample magnetization (the integration in this term is over all of space).

We assume that the body is in the form of a plane-parallel plate of thickness ℓ_3, the surfaces of which are perpendicular to the easy-magnetization axis (the z axis). Assuming that $M = (0, 0\ M_z(x))$ on going from the para- into the ferromagnetic phase, we obtain after varying (1)

$$x_0^2 u'' - u^3 + \lambda u = 0, \tag{2}$$

where $u(x) = \sqrt{b}M_z(x)$ and $\lambda = bM_0^2 + \beta$. As usual, we assume that $\lambda(\tau)$ reverses sign at $\tau = 0$ ($\lambda(0) = 0$), where $\tau = (T_c - T)/T_c$ and T_c is the Curie temperature. It can be shown that $\vec{H}_m \simeq 0$ inside the plate, and therefore $\vec{H}_m$ does not enter in Eq. (2) for the distribution of the magnetization in the interior of the plate.

The solution of (2) is

$$u(x) = \frac{\sqrt{2\lambda}\,k}{\sqrt{1+k^2}}\, sn\left(\frac{\sqrt{\lambda}\,x}{\sqrt{1+k^2}\,x_0}, k\right), \quad D = \frac{4K(k)x_0\sqrt{1+k^2}}{\lambda^{1/2}}, \tag{3}$$

where sn is the elliptic sine with modulus k ($0 \leq k \leq 1$), and k also has the meaning of the integration constant (the second integration constant is chosen such that $u(0) = 0$). The solution (3) describes a magnetization distribution that is periodic with period D (K(k) is a complete elliptic integral of the first kind) (see Fig. 1).

From the distribution (3) we can, solving the corresponding magnetostatic problem, calculate $\vec{H}_m$, after which we find the free energy F per unit volume of the body as a function of k and λ:

$$F = b^{-1}\lambda^2 A(k) + (\lambda^{1/2}x_0/b\ell_3)B(k), \tag{4}$$

where

$$A(k) = \frac{k^2}{3(1+k^2)^2} + \frac{4}{3(1+k^2)} - \frac{3}{4} + \frac{E(k)(3k^2-1)}{3K(k)(k^2+1)};$$

$$B(k) \approx 16\pi \frac{K(k) - E(k)}{\sqrt{1+k^2}}$$

and E(k) is a complete elliptic integral of the second kind.

The first term in (4) is due to the volume energy of the ferromagnet, and the second is the energy of the magnetic field $\vec{H}_m$. We determine the parameter k from the condition $\partial E/\partial k = 0$. It is easy to verify that B(k) is a monotonically increasing function of k (with minimum at k = 0). This corresponds to the fact that the region of space near the plate surface, in which the magnetic field $\vec{H}_m$ is concentrated increases with increasing period D of the distribution (3). The function A(k) has two minima, at k = 0 and k = 1. It is obvious that F has also a minimum at k = 0 (see Fig. 2). This minimum corresponds to the paramagnetic state of the body, for when k = 0 we have $\vec{M} = \vec{H}_m = 0$ (see (3)). At temperatures such that $\lambda(\tau) \ll (x_0/\ell_3)^{2/3}$, the function $F(k, \lambda)$ has only one minimum, since the first term in (4) is in this case small compared with the second. With increasing λ (i.e., with decreasing temperature) at $\lambda(\tau) \sim (x_0/\ell_3)^{2/3}$, the function $F(k, \lambda)$ acquires one more minimum at $k = k_0(\tau)$, corresponding to the magnetically-ordered state. It is impossible to obtain an analytic expression for k_0 (estimates show that $0 < k_0 \lesssim 1$). Thus, in the temperature region where $\lambda(\tau) \sim (x_0/\ell_3)^{2/3}$ the $F(k, \lambda)$ curve has two minima corresponding to the para- and ferromagnetic states, i.e., a situation typical of first-order transitions arises, with stable and metastable states. The transition from the para- to the ferromagnetic phase thus becomes a first-order transition, and the transition temperature T_t is determined from the condition

$$F(0, \lambda(\tau)) = F(k_0(\tau), \lambda(\tau)).$$

It is easy to estimate the extent to which the temperature T_t differs from T_c. Assuming [5] that $\lambda(\tau) = \xi\tau$ and noting that at $T = T_t$ we have $\lambda \sim (x_0/\ell_3)^{2/3}$, we get

$$(T_c - T_t)/T_c \equiv \tau_t \approx \frac{1}{\xi}\left(\frac{x_0}{\ell_3}\right)^{2/3}; \quad \xi \sim \frac{I}{\mu^2} a^3.$$

The amplitude M of the magnetization produced when $\tau = \tau_t$ is proportional to $M \sim b^{-1/2}(x_0/\ell_3)^{1/3}$, so that we are dealing with a first-order phase transition that is close to a second-order one.

For very thin plates ($\ell_3 \ll x_0$) the inhomogeneous distributions becomes unfavorable energywise [5].

Let us estimate the magnetization period D_2 in the vicinity of T_t. Assuming $x_0 \sim 3 \times 10^{-6}$ cm, $\ell_3 \sim 10^{-1}$ cm, and $\lambda \sim (x_0/\ell_3)^{2/3}$, we obtain from (3) $D \simeq 10^{-3}$ cm. This is much less than the magnetization periods observed in [1, 2], which are of the order of 10^{-1} cm. The difference may be due either to the influence of the magnetic field on the domain dimensions, or to the fact that in [1, 2] they investigated cubic crystals, whereas our analysis pertains to uniaxial crystals.

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SPIN DEPENDENCE OF THE SUSCEPTIBILITY AND CURIE TEMPERATURE OF AMORPHOUS FERROMAGNETS

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Several experimental investigations of amorphous ferromagnets [1 - 4] have established that their magnetizations and the Curie temperatures are lower than those in the crystalline state. The results of theoretical investigations depend essentially on the chosen approximation. As a result of fluctuations of the exchange integrals, both a decrease [5 - 8] and an increase [9] of the Curie temperature and of the susceptibility were obtained. It was noted in [6, 8] that the fluctuations in the account of the short-range magnetic order always lead to a decrease of these quantities.

In this paper, using a high-temperature expansion (HTE), we consider the effect of fluctuations of the exchange integrals on χ and T_c for the Heisenberg and Ising models, as functions of the spin S and of the number of nearest neighbors. A somewhat unexpected "spin anomaly" (change of the influence of the fluctuations on χ and T_c) was established for the Ising model. In analogy with [7], we calculate the first four coefficients in the HTE of the susceptibility

$$\bar{X} = 3kT\chi/\mu_B^2 g^2 NS(S+1) = \sum_{n=0}^{\infty} a_n \theta^n; \quad \theta = \langle I \rangle / kT \tag{1}$$

for the Heisenberg and Ising models at different values of the spin. The structure disorder is taken into account within the framework of the lattice model (see [7]) with the aid of stochastically fluctuating exchange integrals. If the coefficients a_n from (1) are represented in the form

$$a_n = a_n^{\circ}(1 + A_n \Delta^2); \quad \Delta^2/2 = \langle \Delta I_{12}^2 \rangle / \langle I \rangle^2, \tag{2}$$

then calculation yields for n = 1, ..., 4:

	Heisenberg model	Ising model
$S = 1/2$	$A_n \le 0$	$A_n \le 0$
$S \ge 1$ (up to $S = \infty$)	$A_n \le 0$	$A_n \ge 0$

The first coefficients of the HTE (1) determine uniquely the behavior of the susceptibility at $T \gg T_c$. Thus, in the Heisenberg model at high temperatures, we have $\Delta\chi_H = \chi_H - \chi_H^0 \le 0$ for all S (i.e., a decrease of χ as a result of the