whereas the chief P term is linear and therefore does not readily lend itself to a potential description. Our phenomenological calculations seem to lend some support to the Drell-Henley treatment of pion-nucleon scattering.

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[1] Anderson, Fermi, Nagle, and Yodh, Phys. Rev. **86**, 793 (1952).
[2] The sign of δ is left undetermined by the analysis of reference 1; moreover, the S phase shift associated with the $\frac{1}{2}$ isotopic spin state of the pion-nucleon system appears to be much smaller than δ and is therefore neglected for the purposes of our discussion.
[3] E. Fermi, private communication. In a very recent communication, Professor Fermi has listed the δ's as: $\pm 21°$ at 135 Mev, $\pm 13°$ at 113 Mev, $\pm 6°$ at 78 Mev. These new values do not alter the qualitative conclusion deduced on the basis of the old values.
[4] Panofsky, Aamodt, and Hadley, Phys. Rev. **81**, 565 (1951); the sign of the slope is left undetermined.
[5] See H. Anderson and E. Fermi, Phys. Rev. **86**, 794 (1952); also R. E. Marshak, Revs. Modern Phys. **23**, 137 (1952).
[6] Introduced by R. Jastrow [Phys. Rev. **81**, 165 (1951)] to explain high energy nucleon-nucleon scattering.
[7] In testing (4) and (5) it may be necessary to correct for Coulomb effects [see L. Van Hove, Phys. Rev. (to be published)].
[8] S. Drell and E. Henley, Phys. Rev. **88**, 1053 (1952). In this paper the repulsive core term actually does not contribute to charge exchange scattering. See also G. Wentzel, Phys. Rev. **86**, 802 (1952).

Magnetostriction of Single Crystals of Cobalt and Nickel Ferrites

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An unusualy large magnetostrictive contraction $\Delta l/l = -540 \times 10^{-6}$ has been observed in the [100] direction in a crystal of cobalt ferrite having the approximate composition corresponding to $Co_{0.8}Fe_{2.1}O_4$. After cooling the crystal in a magnetic field, we observed $\Delta l/l = -720 \times 10^{-6}$.

The crystal was obtained from Dr. G. W. Clark of Linde Air Products Company. A disk was cut parallel to the (001) plane with dimensions 0.57×0.19 cm, and strain gauges[1] were set to measure the changes in length parallel to [100] and [110] directions. Fields up to 5000 oersteds were applied successively parallel and perpendicular to each gauge. The longitudinal and transverse changes so measured are shown in Fig. 1(a), where they are plotted against the applied field.

Similar data were taken for specimens cut from two crystals of nickel ferrite ($Ni_{0.7}Fe_{2.2}O_4$), one cut parallel to (001) as described above, and the other cut parallel to (011), the gauges in the latter case being set parallel to [100] and [111] directions. Results are shown in Fig. 1(b).

Definite saturation is obtained in all cases except in the [110] direction in the cobalt ferrite. The magnetostriction constants obtained for cobalt ferrite are $\lambda_{100} = -515 \times 10^{-6}$ and $\lambda_{111} = 45 \times 10^{-6}$, if we use the two-constant formula. The data for nickel ferrite are not entirely compatable with this formula, but we find approximately $\lambda_{100} = -36 \times 10^{-6}$, $\lambda_{111} = -4 \times 10^{-6}$; however, results for the two sets of data for the material are self-consistent if we use three constants:[2] $h_1 = -54 \times 10^{-6}$, $h_2 = -4 \times 10^{-6}$, $h_5 = -54 \times 10^{-6}$. The differences in the four curves for the [100] direction in Fig. 1(b) are attributed to differences in initial domain distributions in the two specimens. The broken lines show the values of magnetostriction at saturation calculated for specimens having domains distributed equally among the directions of easy magnetization in the demagnetized state.

The value of $\lambda_{100} = -515 \times 10^{-6}$ for cobalt ferrite is considerably higher than that reported for any other material, as far as the writers are aware. The previous high values of magnetostriction have been reported in a polycrystalline iron-cobalt-vanadium alloy,[3] and in polycrystalline cobalt ferrite.[4] In the single crystal the ratio $|\lambda_{100}/\lambda_{111}|$ is large, namely 11. This, combined with a slight misalignment of the gauges, may account for the peculiar shape and lack of saturation of the [110] curves.

After obtaining the data given above, the crystal was cooled from 400°C to room temperature in a magnetic field of 10,000 oersteds. The magnetostriction, measured in the [100] direction perpendicular to the field H_t present during the cooling, was -710×10^{-6}. That measured parallel to H_t was about $+70 \times 10^{-6}$. A preliminary measurement of the magnetic crystal anisotropy constant yielded $K = -1.7 \times 10^6$.

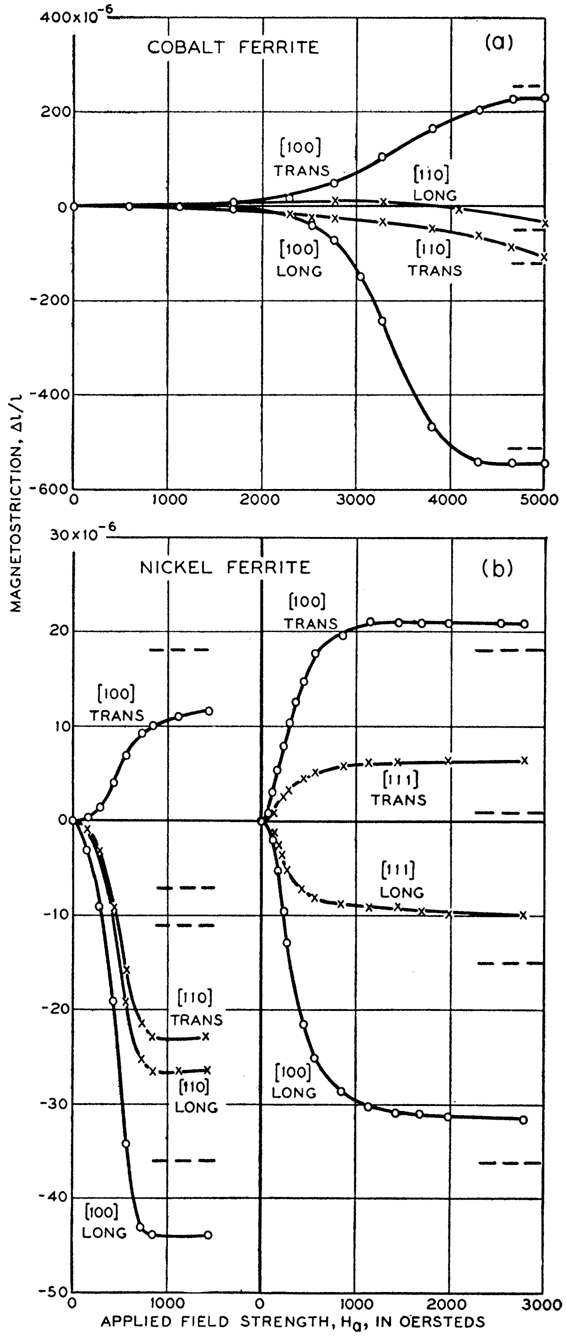

FIG. 1. Longitudinal and transverse magnetostrictive charges for Co and Ni ferrites, plotted against the applied field strength.

[1] J. E. Goldman and R. Smoluchowski, Phys. Rev. **75**, 140 (1949).
[2] R. M. Bozorth, *Ferromagnetism* (D. Van Nostrand and Company, New York, 1951), p. 650.
[3] E. A. Nesbitt [J. Appl. Phys. **21**, 879 (1950)] observed 130×10^{-6} in a cold-rolled tape.
[4] Guillaud, Vautier, and Medvedieff [Compt. rend. **230**, 60 (1950)] observed -200×10^{-6} in an "oriented" polycrystalline specimen (Vectolite), and this was confirmed by L. Weil [Compt. rend. **234**, 1351 (1952)].