Note on the Inertia and Damping Constant of Ferromagnetic Domain Boundaries

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October 5, 1950

THE Bloch wall is the transition layer separating adjacent ferromagnetic domains. In the presence of a magnetic field a free wall moves as if endowed with mass and as if retarded by damping forces. The effective mass of a moving Bloch wall was calculated by Döring,[1] and recently Becker[2] has given a simplified treatment leading to the same result. The associated damping effect in substances in which eddy current losses may be neglected was calculated by Landau and Lifschitz.[3] Both the inertial and damping effects have been observed experimentally,[4] and they play important roles in magnetization processes in the ferrites at high frequencies.

The present letter generalizes the Döring equation in order to include the case where the intrinsic relaxation frequency of the substance is high; we then apply the device introduced by Becker to the Landau-Lifschitz problem, thereby greatly simplifying the calculation and giving insight into the physical mechanism of the wall damping, and extend the calculation to cubic crystals.

Becker noticed that the rotational motion of the local magnetization which accompanies the uniform motion of a Bloch wall (with velocity v in the z-direction normal to the wall) may be described as caused by an effective field $H_e(z)$ such that the resulting precessional velocity $d\varphi(z)/dt$ is equal to the rotational velocity required by the motion. We have

$$d\varphi/dt = -v(d\varphi/dz) = \gamma^* H_e, \tag{1}$$

with

$$(\gamma^*)^2 = \gamma^2 + (\lambda^2/M_s^2), \tag{2}$$

where $\gamma = ge/2mc$, and the relaxation frequency λ is defined by Eq. (5) below; the relaxation frequency may be estimated from the line width in a microwave resonance experiment. Döring and Becker write γ instead of γ^* in Eq. (1), and in this sense our equation is more general. The kinetic energy of the wall is given by the field energy, so that, per unit area,

$$\delta\sigma = \sigma - \sigma_0 = (1/8\pi)\int H_e^2 dz = (v^2/8\pi\gamma^{*2})\int_{-\infty}^{\infty} (d\varphi/dz)^2 dz, \tag{3}$$

σ_0 being the surface energy of the wall at rest. Now $\int (d\varphi/dz)^2 dz$ occurs in the elementary theory of the Bloch wall[5] and is in fact equal to $\sigma_0/2A$, A being the usual exchange factor.[5] The generalization of the Döring result follows dierctly:

$$\delta\sigma = \sigma_0 v^2/16\pi\gamma^{*2}A. \tag{4}$$

In calculating the damping effects we start from the equation of motion for the magnetization:

$$d\mathbf{M}/dt = \gamma \mathbf{M}\times\mathbf{H} - \lambda[(\mathbf{H}\cdot\mathbf{M})\mathbf{M}/M^2 - \mathbf{H}], \tag{5}$$

where λ is the relaxation frequency. The power dissipation per unit volume is $\mathbf{H}\cdot(d\mathbf{M}/dt) \cong \lambda H_e^2$, so that the power per unit area which must be supplied to keep the spins in uniform motion is

$$\int_{-\infty}^{\infty} \mathbf{H}\cdot(d\mathbf{M}/dt)dz = \lambda\int_{-\infty}^{\infty} H_e^2 dz = 8\pi\lambda(\delta\sigma) = v^2\lambda\sigma_0/2\gamma^{*2}A. \tag{6}$$

The power supplied by the constant external field H_0 which drives the wall along is $2H_0M_s v$ per unit area; we equate this to the dissipation, and find the result

$$v = 4(\gamma^2 M_s^2 + \lambda^2)AH_0/\lambda M_s\sigma_0. \tag{7}$$

Now for a wall parallel to the axis of a uniaxial crystal $\sigma_0 = 4(AK_1')^{\frac{1}{2}} = 4A\Delta$, where $\Delta = (A/K_1')^{\frac{1}{2}}$ is the usual wall thickness parameter, so that in this case $v_{\text{uniaxial}} = (\gamma^2 M_s^2 + \lambda^2)\Delta H_0/\lambda M_s$, which is exactly the Landau-Lifschitz result. Our Eq. (7) applies however to plane walls in general. For a 180° wall in an (001) plane of a cubic crystal, $\sigma_0 = 2(AK_1)^{\frac{1}{2}}$, so that $v_{(001)} = 2(\gamma^2 M_s^2 + \lambda^2)\Delta H_0/\lambda M_s$, where $\Delta = (A/K_1)^{\frac{1}{2}}$.

It should be noted that any result involving λ is in general no better than Eq. (5) defining λ in a phenomenological way; the applicability of this equation is by no means assured by existing microwave resonance results.

I wish to thank Dr. J. K. Galt and Dr. Conyers Herring for a helpful conversation.

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[2] R. Becker, Proceedings of the Grenoble Conference, July, 1950.
[3] L. Landau and E. Lifschitz, Physik. Z. Sowjetunion 8, 153–169 (1935).
[4] G. T. Rado, R. W. Wright, and W. H. Emerson, Phys. Rev., to be published; a discussion of other evidence is given by C. Kittel, Proceedings of the Grenoble Conference, July, 1950.
[5] See, for example, C. Kittel, Rev. Mod. Phys. 21, 541 (1949); ibid., pp. 560–565.

Radiative Capture of Neutrons in Deuterium

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October 9, 1950

IN a study of the γ-rays produced in the reacting vessel of the heavy water pile at this laboratory we have found only two strong peaks in the coincidence spectrum of our pair spectrometer. These peaks are superposed on a continuous unresolved background. One of these, corresponding to a γ-ray with an energy of 7.72 Mev, is due to the capture of neutrons in aluminum. The other peak is shown by the full line (A) in Fig. 1, where the coincidence counting rate is plotted against the energy. It is produced by a γ-ray with an energy of 6.244±0.008 Mev. This γ-ray is attributed to the capture of neutrons by deuterium for, as shown below, its energy is very close to the expected binding energy of the triton and its intensity has the value expected. The continuous background is due to uranium and to the other constituents of the pile. The only materials which are likely to produce a strong peak superposed on this background are those which, like Cu, Al, etc., emit very intense homogeneous γ-rays. We have found very few such elements and none of these emit a γ-ray at 6.24 Mev.

We have made a rough estimate of the relative peak coincidence counting rates of the 6.2 and 7.7 Mev-γ-rays to be expected if the former is due to capture in deuterium. In this calculation we have taken into account the geometry of the pile and measurements of the distribution of neutron flux near the periphery of the reactor. No excited states are known in H^3 and we assume therefore that

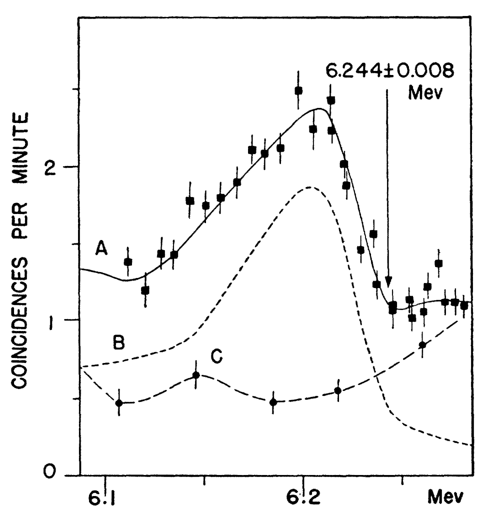

FIG. 1. (A) Coincidence spectrum of the γ-rays produced by the heavy water pile near 6.2 Mev. (B) Pile radiation with aluminum spectrum subtracted. (C) Contribution to the spectrum due to pure aluminum.