THE GOILLOT EFFECT AS TRANSLATIONAL INERTIAL SPIN EFFECT

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A new electromagnetic effect is deduced, qualitatively similar to Goillot's, but much smaller, it is thus concluded that Goilrot's effect is dynamical rather than electromagnetic, and implies, as in many spin theories, a non-collinearity of the momentum and velocity 4-vectors.

Considering, 1) the observed features of the new effect experimentally demonstrated by Goilrot [1], 2) vector and dimension analysis, there are only two possible formulas for the kinetic momentum $\Delta p$ imparted to the test body:

$$\Delta L = k_1 c^{-1} \int \left[ D \times B \right] \, dv,$$

(1)

$$\Delta L = k_2 \int \sigma \times s,$$

(2)

In (1), $D(\mathbf{B}, 0, 0)$ denotes a constant radial electric induction and $B(0, B_0, 0)$ a variable tangential magnetic induction in mixed Heaviside units; in (2), $\sigma(0, \sigma, 0)$ denotes a variable tangential spin density, the surface element $\sigma_0$ being radial on the cylindrical internal and external surfaces of the test body; $k_1$ and $k_2$ are dimensionless coefficients, and $c$ the velocity of light. Thus, in both cases, $\Delta L(0, 0, \Delta L, 0)$ is axial, with a sign depending on that of $\Delta B$ or $\sigma_0$, as is observed.

First we show that Goilrot's test body may well exhibit a recoil effect of expression (1) which : 1) is a new electromagnetic effect, that is, a yet undeduced consequence of Maxwell's theory; 2) is a new direct proof that the asymmetric electromagnetic energy momentum tensor as defined by Maxwell and Minkowski is operationally the good one*; 3) is numerically smaller than Goilrot's observed effect by a factor of order $10^{-8}$.

If the axial wire [1] has a permanent uniform charge $q$ per length unit, it will receive, when the magnetic polarization $\mathbf{M} = \mathbf{B} - \mathbf{M}$ is reversed inside the test body, a momentum of value

$$\Delta L = -c^{-1} q \int_{r_0}^{\infty} (\Delta A, n) \, dz$$

(3)

where $A$ denotes the vector potential and $u$ the unit vector along the $z$ axis. Applying the induction flux formula to a closed contour comprising the recircular wire and a semi-circle with infinite radius and center at the center of the test body yields

$$\Delta P_2 = -c^{-1} q \Delta \Phi = -c^{-1} q a b \Delta M,$$

(4)

with $a$ denoting the height and $b$ the difference between the internal and external radii of the test body.

The conservation of momentum requires that an opposite momentum appears either in free space or inside the test body. The only possibility is the latter one, the corresponding expression being (1) with $k_1 = 1$, and the electric field

A long controversy has opposed the proponents of the asymmetric electromagnetic energy momentum tensor (Maxwell, Heaviside, Minkowski, Nordström) the partisans of the symmetrized tensor (Hertz, Abraham, Grammel, Pauli). Precise arguments in favor of the asymmetric tensor due are to Tamm and von Laue. For a résumé of the discussions and references see ref. 2.
Thus, formula (1) is excluded, and we are left with formula (2) as the only possible explanation of the Goëlliot effect. Such a formula, with \( b_2 = 1 \), was in fact the one that we [4] had initially put forward, and it is for testing it that Goëlliot devised his experiment. It had been rightly objected [5] to our deduction that, calculating the surface integral (2) just outside rather than just inside the test body would yield \( b_2 = 6 \) rather than \( b_2 = 1 \). In fact, Goëlliot’s experiment yields very definitely \( b_2 \approx 0.03 \).

In our opinion, the conclusions derived from experimental facts should be: 1) that Goëlliot’s spin containing test body has in effect a momentum non-collinear to its velocity, as is the case in numerous spinning particles theories; 2) that our initial theory was oversimplified, and that the intricate collective theory of electrons inside ferromagnetic solids may leave room for the possibility that the overall momentum is not collinear with the velocity of the solid.

References
4. O. Costa de Beauregard, Phys. Rev. 120 (1963) 465. See formulas (35) and (54) p. 499.
5. A. Papapetrou, J. S. Bell, B. d'Espagnat and F. Halbwachs, private communications.

* If the signal reversing the magnetization of the test body is in the form of a propagating rather than standing wave, it will; 1) charge the wire (either negatively or positively) and thus induce a recoil effect as shown in the text; 2) create a field gradient \( \mathcal{B}_H \) and thus a Stern-Gerlach force density \( M \delta \mathcal{B}_H \). It is easily verified that these two perturbing effects exactly compensate each other, so we are left only with the effect of a permanent charge of the wire, as discussed in the text.

** Noether’s theorems which entail the formula \( \mathcal{T}_L \cdot \mathcal{D}_L \) used in (9), do not say anything about velocities.