LETTERS TO THE EDITORS

PHYSICS

The Possibility of a Self-sustaining Corbino Disk

An impressed radial current and an axial magnetic field combine in the Corbino disk[1] to induce a circulating component of current due to the Hall effect. Whichever sense the axial field may have, it is aided by the field of the circulating currents themselves, provided that the radial current is always inwards. This applies to a material with the normal sign of Hall coefficient for n-type conduction.

Without the impressed axial field, the disk would be a two-state element, which could form the basis of a digital computer. The two states would be self-sustaining current vortices of opposite spin. The existence of such vortices is suggested by a solution of the field-equations for an indefinitely thin disk of infinite radius, immersed in a medium of permeability μ:

$$J_r = \frac{I}{2\pi r.\delta z} \qquad J_\theta = \sigma.E_\theta$$

$$E_\theta = R.J_r.B_z \qquad J = \frac{\text{curl } B}{\mu.\eta_0}$$

where r,θ,z are cylindrical co-ordinates; I, total current (amp.); J, current density (amp./sq. metre); E, electric field intensity (volts/metre); R, Hall coefficient (metre^3/coulomb); σ, conductivity (mho/metre); $\eta_0 = 4\pi \times 10^{-7}$ henry/metre.

B_z, E_θ and J_θ all satisfy an equation of the form:

$$\frac{dB_z}{dr} + \mu.\eta_0.\frac{\sigma.R.I.B_z}{2\pi r.\delta_z} = 0$$

which has the solution: $B_z = A.r^{-k}$

where A is a constant of integration, and k is $\sigma\mu\eta_0 R.I/2\pi\delta z$.

More significant than the increase towards the centre in the flux density B_z is the increase in total flux within a ring of width δr when $k \geqslant 1$. This establishes a critical value for the radial current, above which amplification and regeneration are possible. A transformer exploiting the creation of a secondary flux in excess of the primary flux would behave as a magnetic power amplifier. The introduction of a magnetic feedback path in such a transformer would lead to a bi-stable trigger circuit.

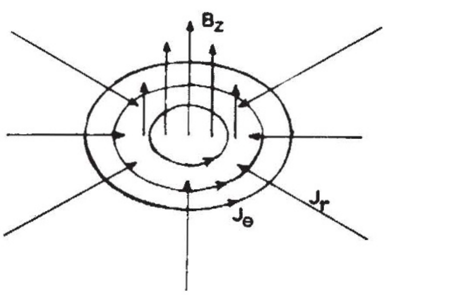

Fig. 1. Axial magnetic field in relation to the radial and circulating components of the current density

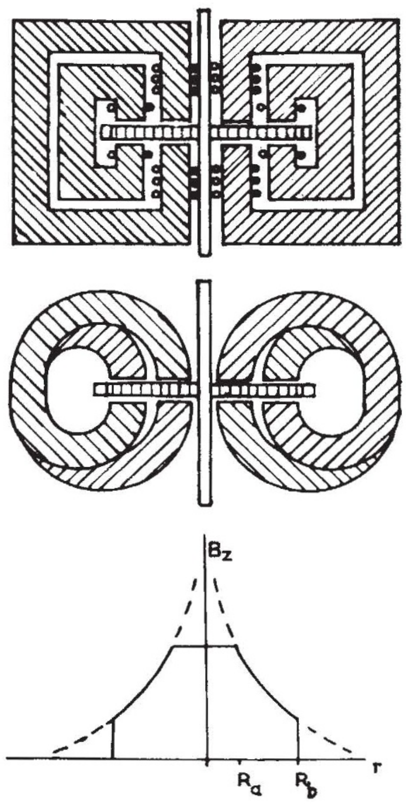

Fig. 2. Top: A magnetic amplifier having an input coil to provide B_z at R_b and an output coil at R_a. (Permeable material is diagonally shaded and Hall-sensitive material vertically shaded. The radial current is introduced by a conducting rim on the disk and is removed along the two halves of the axis)
Centre: A magnetic feedback circuit for a two-state element. (If a fraction f of B_z at R_a is returned to R_b, the fields become self-sustaining when $k = \frac{\ln(f)}{\ln(R_a/R_b)}$)
Bottom: Axial flux density, circulating current density and circulating electric field-strength for an infinite disk: - - -. The same for a finite disk: ——

A vital question is whether the critical current is necessarily destructively large, as it would be for the conductivities and small Hall coefficients of ordinary metals at room temperature. However, products of conductivity and Hall coefficient of the order unity have been observed in germanium alloys at low temperatures[2]. Assuming that, by restricting the thickness of the disk to 0·01 per cent of the magnetic path, an effective permeability of 10^4 could be maintained, a current of 5 amp. per cm. of magnetic path would be required for criticality.

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[1] Von Corbino, O. M., *Phys. Z.*, **12**, 561 (1911).
[2] Debye, P. P., and Conwell, E. M., *Phys. Rev.*, **93**, 693 (1954).