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A simple measurement of the Earth's magnetic field

S Ganci

Liceo Scientifico di Stato 'G Marconi', Piazza del Popolo, 14, 16043 Chiavari (GE), Italy

E-mail: SALVATORE_GANCI@vodafone.it

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Abstract

This paper describes a simple laboratory measurement for measuring the Earth's magnetic induction field by means of a low cost experimental solution.

There are various experimental setups for measuring Earth's magnetic induction $\boldsymbol{B_E}$ [1–8] usually based on the action of $\boldsymbol{B_E}$ on a magnetic needle or on the measurement of an induced electric current due to a flux variation of $\boldsymbol{B_E}$. Therefore, this paper does not have the mark of novelty but simply proposes a low cost experimental solution that is simpler than a very elegant experiment proposed some time ago [1] which has been ignored to date [9].[1]

The 'basic philosophy' of the original experiment [1] is very simple: let a constant magnetic induction $\boldsymbol{B}$ produced by currents (Helmholtz's coils) interact with a dip needle compass initially aligned along the north–south direction (the inclination angle below north horizontal is known). The axis of the coils is oriented vertically and the current in the coils is adjusted until the needle is horizontal. This situation indicates that the coils produce a field equal and opposite to vertical component B_n of the Earth's magnetic induction. The axis of the coils is next oriented horizontally and the current in the coils is adjusted until the needle becomes vertical. This situation indicates that the coils produce a field equal and opposite to the horizontal component B_t of the Earth's magnetic induction.

Practical modifications of this experiment involve the coil system. Instead of Helmholtz's coils a single coil is made of 50 (or less) turns of 0.42 mm insulated copper wire on an Al mountain bike wheel-rim. A double plexiglass bar clamp holds the wheel ring and a brass rod is secured with a screw orthogonally in order to guarantee a ready change from vertical to horizontal axis orientation as shown in figure 1. A dip needle compass with a needle of about 8 cm is placed at the centre of the coil. A simple inspection of the magnetic field with a Hall magnetometer shows that the field is spatially constant within a sphere of radius 5 cm around the centre with an accuracy of some parts per 100 with a wheel-rim having a diameter

[1] It is surprising that such a simple and beautiful experiment as [1] was not quoted or reported in [9] or in other collections of selected papers, or in educational laboratory textbooks.

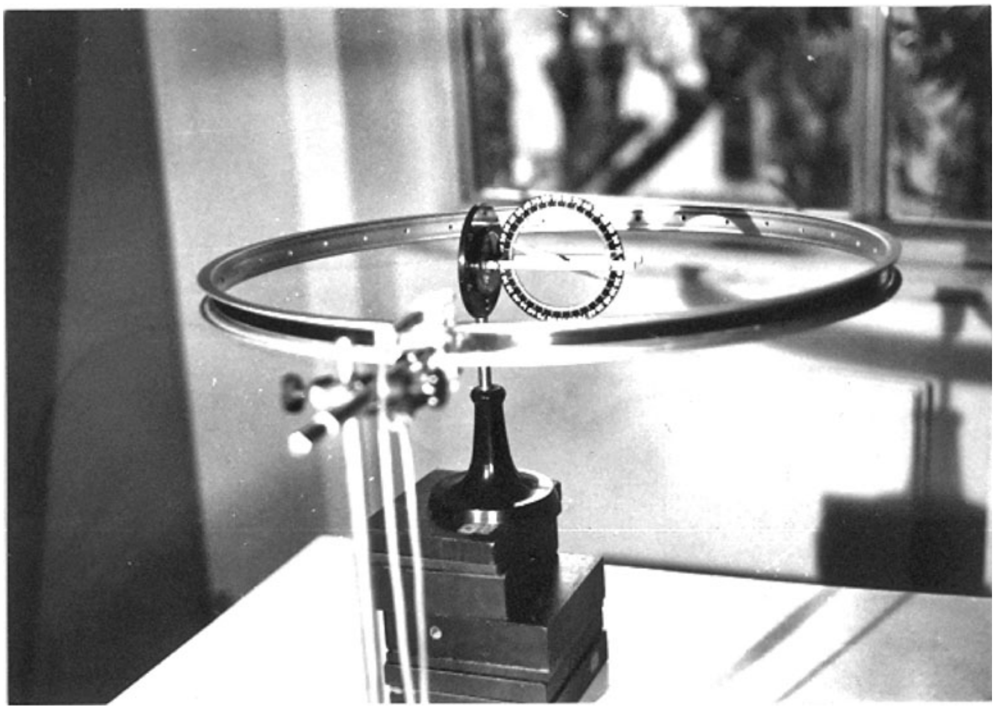

Figure 1. Experimental setup. With a single movement the coil can be rotated from horizontal to vertical position.

0.55 m. The advantages provided are twofold: a quicker rotation of the coil axis is possible and the geometry ensures a simpler formula for magnetic induction

$$B = N\frac{\mu_o}{2}\frac{i}{a} \tag{1}$$

to derive. In equation (1) a is the radius of coil, μ_o is the magnetic permittivity, N is the number of turns and B is the magnetic field at the centre. The north–south direction is previously determined with a compass and the apparatus (coil and magnetic dip needle) is assembled afterwards.

As a typical measure taken by students:

- angle below north horizontal: $\theta = 60^\circ \pm 1^\circ$; $N = 50$; $2a = 0.55 \pm 0.005$ m;
- for tangential component of the Earth's induction B_t: $i = 0.31 \pm 0.03$ A;
- for normal component of the Earth's induction B_n: $i = 0.21 \pm 0.03$ A.

From equation (1) it follows that

$$B_t = 3.5 \times 10^{-5} \pm 0.4 \times 10^{-5}\ \mathrm{T}$$
$$B_n = 2.4 \times 10^{-5} \pm 0.4 \times 10^{-5}\ \mathrm{T}$$

where the uncertainty (overestimated) is determined by a variation in the current giving a variation of about 1° on the horizontal or vertical direction of the dip needle.

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References

[1] Hull N 1959 Measurement of the earth's field using helmholtz coils *Am. J. Phys.* **27** 670–1
[2] Sutton R M 1938 *Demonstration Experiments in Physics* (New York: McGraw-Hill) pp 342–3
[3] Ainslie D S 1949 Fluxmeter measurement of the earth's magnetic field *Am. J. Phys.* **17** 444
[4] Gordon J E and Javier Murin H 1970 Use of an operational amplifier for measuring magnetic flux *Am. J. Phys.* **38** 94–8
[5] Smith R D and Eggert S B 1984 Recycling the earth inductor *Am. J. Phys.* **52** 279–80
[6] Pernick B J 1989 Simultaneous measurement of the straight wire and the earth's B field *Am. J. Phys.* **57** 90–1
[7] Berger R and Schmitt M 2003 Estimating the earth's magnetic field strength with an extension cord *Phys. Teach.* **41** 295
[8] Stewart G B 2000 Measuring earth's magnetic field simply *Phys. Teach.* **38** 113
[9] Meiners H F (ed) 1970 *Physics Demonstration Experiments* (New York: Ronald)