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Simple System to Measure the Earth's Magnetic Field

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Our aim in this proposal is to use Faraday's law of induction as a simple lecture demonstration to measure the Earth's magnetic field (**B**). This will also enable the students to learn about how electric power is generated from rotational motion. Obviously the idea is not original, yet it may be attractive in the sense that no sophisticated devices are used. All the equipment needed is available in an elementary physics laboratory and is displayed in Fig. 1. The square wooden coil and handmade belt system to rotate the coil may require some craftsmanship; once made, it can be used for years. Using a compass, we first orient the table parallel to the direction of the Earth's horizontal component of **B** field. This is necessary to maximize the Earth's field which can suppress the noise effects as much as possible. It is preferable to minimize also any environmental effects by conducting the experiment away from power lines, if possible of course.

The induced emf according to the law of induction is given by[1,2]

$$\varepsilon = -N\frac{d\phi}{dt}, \tag{1}$$

where N = number of turns in the coil and ϕ is the magnetic flux, which is changing in time due to rotation.

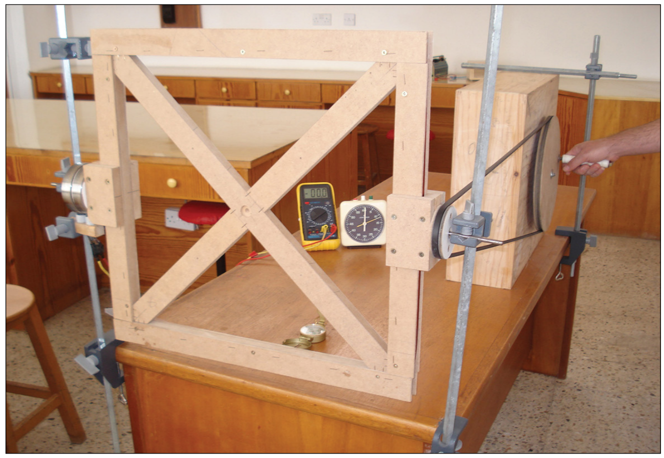

Fig. I. Experiment set-up when the axis of rotation is horizontal.

Fig. 2. Experiment set-up when the axis of rotation is vertical.

Apparatus and experiment

1) A square-shaped wooden block of area 0.25 m^2 to serve as coil having N = 100 turns of copper wire (1.1 mm in diameter).
2) A hand-driven mechanical system connected through a belt to the wooden coil. The handle is mounted on an empty wooden box fixed appropriately on the table. (Remark: A car's wiper motor can serve even better to rotate the coil. Since we conducted the experiment in both ways, we reached the conclusion that a wiper motor gives more efficient results).
3) A 200-mV voltmeter (or digital avometer) and a rheostat with their cables.
4) A compass to align the experiment table parallel to the Earth's horizontal component of **B** field. As the coil rotates, in this particular case its axis remains perpendicular to **B**.

The experiment table is shown in Fig 1. This shows also the brush system, which collects the generated alternating current (voltage) from the rotating coil. As remarked before, we set the coil in rotation, either manually or by getting power from a wiper motor. For each 10 rotations we read the emf from the voltmeter and prepare the data in Table I. Then, the amplitude of emf versus the inverse of the period T of rotation of the coil is given by

$$\varepsilon = \varepsilon_0 + 2\pi NAB\frac{1}{T}. \tag{2}$$

Here ε_0 is due to the background effect while A stands for the area of the coil. We plot ε versus $1/T$, which is a straight line with intercept ε_0, shown in Fig. 3. The total magnetic field B of the Earth is obtained as B = 0.41 G within the error limits.

We proceed next to determine the dip angle for the Earth's magnetic field. For this purpose we mount our system such that it is rotated by 90° to make the axis of rotation vertical (Fig. 2). We record the data for the horizontal component B_h and tabulate it in Table II. We plot the induced emf corresponding to B_h in Fig. 4. This determines B_h as B_h = 0.21 G. The dip angle follows from

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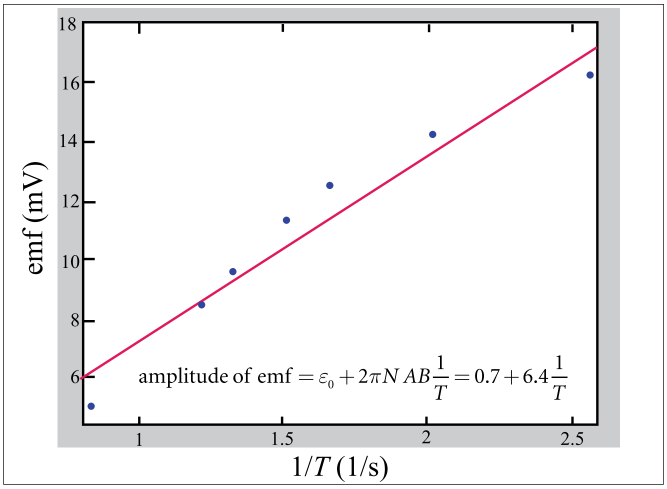

Fig. 3. A plot of the amplitude of the induced emf versus the period of rotation of the coil, when the axis of rotation is horizontal.

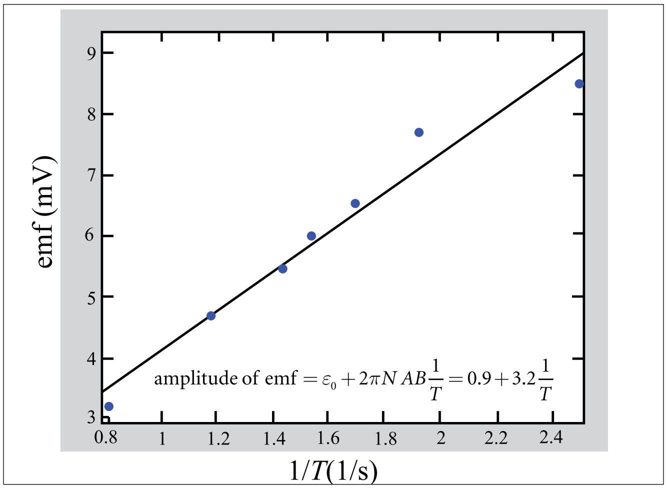

Fig. 4. A plot of the amplitude of the induced emf versus the period of rotation of the coil, when the axis of rotation is vertical.

$$\cos\theta = \frac{B_h}{B}, \quad (3)$$

which turns out to be $\theta \cong 59^\circ$ for Cyprus. The reason that we obtained more than expected ($\approx 50^\circ$ for the Mediterranean region) is due to the power lines in the surrounding area.

Table I.

	time for 10 turns (s)	emf (mV)
first	03.90	16.2
second	04.95	14.2
third	06.00	12.5
fourth	06.60	11.3
fifth	07.50	09.5
sixth	08.20	08.5
seventh	12.00	05.0

Table II.

	time for 10 turns (s)	emf (m V)
first	04.00	08.5
second	05.20	07.7
third	05.90	06.5
fourth	06.50	06.0
fifth	07.00	05.5
sixth	08.50	04.7
seventh	12.50	03.2

Acknowledgment

We wish to thank the anonymous reviewer, whose suggestions helped us to improve the experiment.

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