Electromagnetism - seeing and calculating

Krzysztof Rochowicz, Andrzej Karbowski, Krzysztof Służewski, Grzegorz Karwasz
University Nicolaus Copernicus, 87100 Toruń, Poland
kroch@fizyka.umk.pl

Abstract:

In the frames of a wider didactical path we propose some experiments in electrostatics and magnetism, tightly related to the solved problems in Physics available on the internet (www.physicstasks.eu). These materials form an important step towards understanding electromagnetism both experimentally as conceptually.

Teaching electromagnetism is not an easy task. In Polish basic-level Physics curriculum for instance, this section is practically neglected. While present in the extended course, it is often excessively formalized and not sufficiently illustrated with simple examples. Left-hand rule of induction and Oersted experiment dominates over the concept of energy conservation (i.e. Faraday- von Neumann- Lenz principle) or the continuity of magnetic lines (i.e. the inexistence of magnetic monopoles, or in other words difficulties in defining magnetic field lines in the same way as the electric lines). Some textbooks reduce magnetism to the relativistic explanation by Einstein, not giving a single bit of information on permanent magnets, coils, wires and so on. On the other hand, precise calculations of two interacting permanent magnets is not trivial, either [1].

In our previous collaborations at the EU level [2] we have developed some experiments illustrating Lenz law, magnetic interactions qualitatively and quantitatively, diamagnetism, Earth's magnetic field [3] and electrostatics [4]. The experimental kits (40 experiments) are under didactical testing in upper secondary schools all over EU.

In present work we suggest some of experiments in electrostatics and magnetism, both with real objects as well in interactive ways [5], but now tightly connected with problems selected by our Czech collaborators from Prague University [6,7]. The motivation for our work was the lack of didactical path towards understanding electromagnetism. One of the key abilities which students should reach during physics education is to explain the experiment's result. Connecting it to the solved problems seems to complement one another.

The well known problem of two electrically charged balls [4] is illustrated in our Christmas glass balls experiment [5]. We hang the glass balls on the two tight cords (about 1 cm apart). The cords are connected to the poles (ends) of piezoelectric gas lighter (Fig. 1).

Fig.1 The experimental set used in Christmas balls experiment.

Switching the lighter on, we observe the balls attracting one another. We can easily determinate the size ($r \sim 2$ cm) and the mass ($m \sim 5$ g) of the balls. It is now possible to estimate the force needed to deviate the ball (for the length $l \sim 20$ cm and the angle $\alpha \sim 2.5°$ we obtain $F \sim 2.5$ mN). From the Coulomb's law we derive the charge of each ball, $q \sim 10^{-8}$ C. We can now study the more complicated problem, such as two balls on a thread immersed in benzene [6]. Solving the problem after seeing the experiment is much easier and more interesting.

Interaction of a magnetic-dipole coil with the static magnetic field [7] forms the basis of another simple experiment [8]. Usually this experiment is done with a long dipole magnet.
We perform it using a big neodymium magnet. Using the PASCO force sensor we can measure the interaction force (Fig. 2).

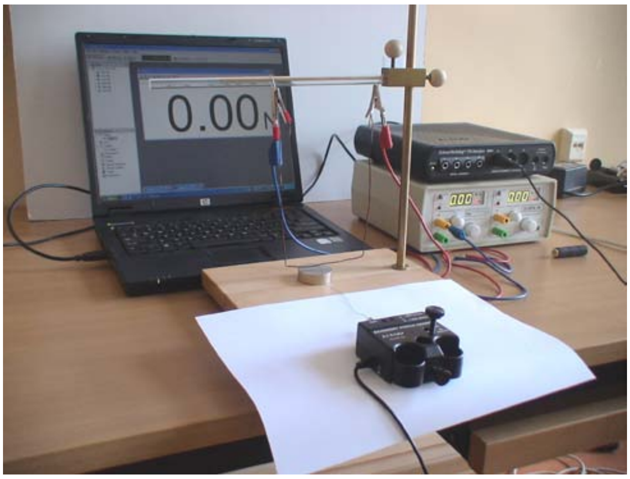

Fig.2 The experimental set used in the experiment on the interaction of a magnetic-dipole coil with the static magnetic field.

For the current $I = 1$ A we have measured $F = 0.01$ N. Putting the length of a conductor $l = 0.1$ m we can estimate the magnetic induction $B \sim 0.1$ T, which is in good agreement with the real value.

We would also like to note the experiment in which we measure the fall time of the neodymium magnet inside a copper tube. In order to calculate it, some assumptions on the geometry of the experiment (the thickness of wall tube, the tube diameter, electrical conductivity of copper) are needed. However, this simple experiment can be used by requiring students to predict trends from limited evidence [9].

The real experiments are very important and useful for pupils in secondary school. Taking it into account we propose to use the active and effective methods of teaching, in which simple experiments on magnetism and electromagnetism can be introduced at a secondary school level. The set of experiments is a result of our work and we offer schools and teachers a collection of simple, thought-provoking (minds-on) physics experiments (see Fig. 3).

Fig. 3. The set of simple experiments on magnetism and electromagnetism.

Investigating the encountered phenomenon and doing own research with the provided materials and other sources we expect to improve motivation of students to learning physics.

Summary and conclusions

We have showed only some examples of the interaction between the theory and practice. The two-direction interaction is highly stimulating: the experiment can enrich didactical aspects of solving EM problems and results of calculations can indicate the feasibility of didactical experiments.

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