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AN ON-LINE EXPERIMENT ON ELECTROMAGNETIC INDUCTION

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Abstract
Data acquisition techniques are largely used in scientific research for measuring physical quantities (Bosio 1996). The production of acquisition systems cheap and easy to use allow a large diffusion of the on-line experimental activities. These activities have a crucial role in physics education, because offer the possibility to understand fundamental conceptual knots, sometimes difficult to understand using traditional experimental methods.
In this context we have set up an experiment using on line acquisition, addressed to shed light on the specific knot of electromagnetic induction phenomenon. We present here first results of measurements and the analysis of obtained data.

1. Introduction
Data acquisition techniques are largely used in scientific research for measuring physical quantities (Bosio 1996). The production of acquisition systems cheap and easy to use allows a large diffusion of on-line experimental activities. These on-line experiments capture students' attention, allowing them to understand contents and increasing their knowledge.
Many studies highlight difficulties in students' comprehension of electromagnetic phenomena (Michelini 2007, Stefanel 2008). In particular students encounter difficulties in recognizing the role of magnetic field flux and its time variation as it appears in the Faraday-Newmann:Lenz law (Maloney 2001, Thong 2008, Galili 1997, Michelini 2008, Michelini 2009) . We propose a simple on-line experiment, developed for MOSEM[2] project, in which the induced current is directly linked to flux variation in order to focus this conceptual knot. Real time graphs of time depending (or not depending) phenomena play a central role in this analysis and may help in overcoming this conceptual knot, by offering the possibility to follow, in real time, the phenomenon evolution and to quantitatively investigate it through collected data (Gervasio 2009).
In this work we study the induced current in a coil when it's crossed by a falling magnet. This simple experiment highlights the dependence of the induced current on the magnet speed. The experimental set up, based on an Atwood machine, allows us to manipulate several parameters to control the magnet speed at our pleasure.
Furthermore a simple model based on time magnetic field flux variation is proposed.

2. Experimental set up
The experimental device is built with cheap and easy to find and use materials (figure 1):

1. An Atwood Machine
2. Some small Weights
3. Three coils
4. An inextensible string
5. Support poles
6. PC equipped with on-line acquisition software
7. Data Acquisition system

The induced currents in the coils are measured by a voltage/current sensor, when a magnet fall down into them.

Figure 2 shows a plot of induced current vs time. As the magnet approaches to the coil, there is an increase in the magnetic field flux and the induced current direction produces a magnetic field opposing to this increase. So, repulsion will be produced between the magnet and the coil. As the magnet enters the coil, a peak is observed in the measured signal. Until the second pole enters the coil, the magnetic field flux

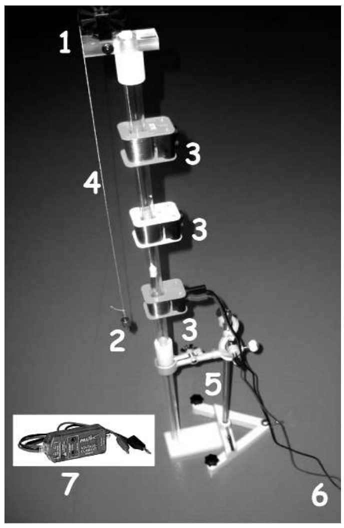

Figure 1: Atwood Machine

through it is nearly constant. Consequently in this temporal interval the inducted tension almost vanishes. When the second pole enters the coil, there is a decrease in the magnetic field flux so that the induced tension is therefore inverted (in sign) with respect to the previous situation.

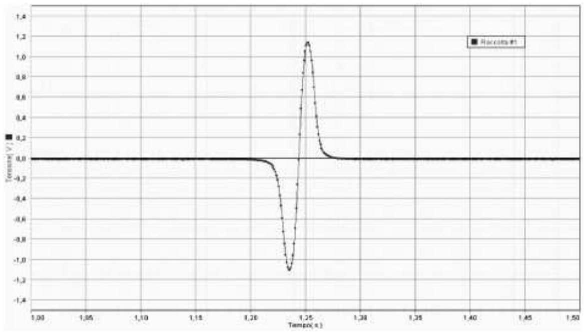

Figure 2: induced current vs time

3. Didactic proposal

Educational value of the proposed experiment is under evaluation on about 100 secondary school students. Our didactical proposal comprises a first introductory activities on the electromagnetic induction (through frontal lesson and/or problem solving activities), a second phase in which students perform the experiments in small groups, then a third part in which they analyze acquired data, and finally a conclusive brainstorming discussion of group results.
The described proposal presents various advantages, the main of which are:

i. Students plan and conduct the experiment, then analyze their experimental findings. In this way, learners can acquaint themselves with both data analysis and advantages of on line acquisition. In fact, such a real time technique gives an immediate feedback on the effects of some parameter variation (such as falling height or weight value), allowing students to choose their best set in order to maximize some observed outcomes (such as the current production).
ii. Experimental setup, due to real time acquisition, leads pupils to immediately link the crossing of magnet through the coil to the current therein appearing.
iii. Graphical field line pattern representation allows students to interpret observed correlation between magnet fall and induced current in terms of magnetic flux variation.

4. Experimental Data

Area Analysis (i.e. flux analysis) shows correctly that magnetic flux variation ($\Delta\Phi$(**B**)) is independent on both falling height and weight value (figure 3).

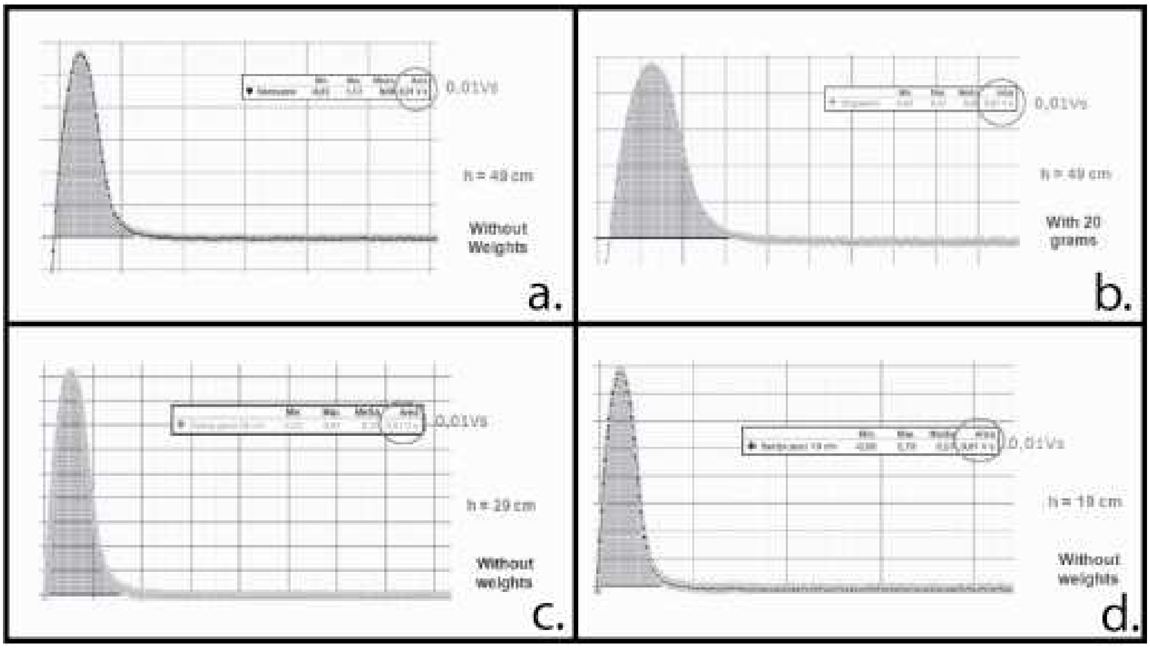

*Figure 3: □□(**B**) is independent from both falling height (3.a, 3.c e 3.d) and weight value (3.a e 3.b)*

Magnetic flux variation ($\Delta\Phi$(**B**)) is dependent only on coil characteristics (i.e. number and area of windings – figure 4).

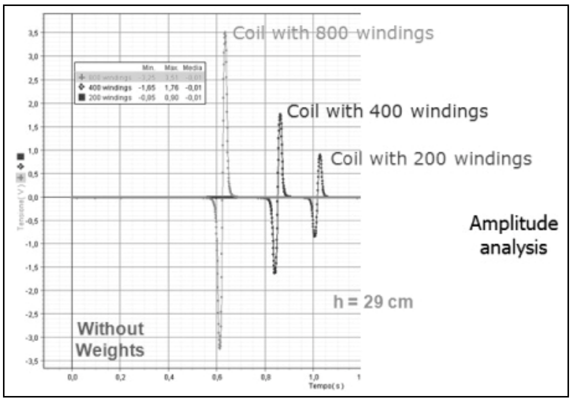

Figure 4: Φ**(B)** *is dependent on coil characteristics (i.e. number and area of windings)*

It's interesting to analyze that, when the falling height decreases, peak amplitude decreases while peak width increases (figure 5). We obtain the same results when decreasing weight value (figure 6)

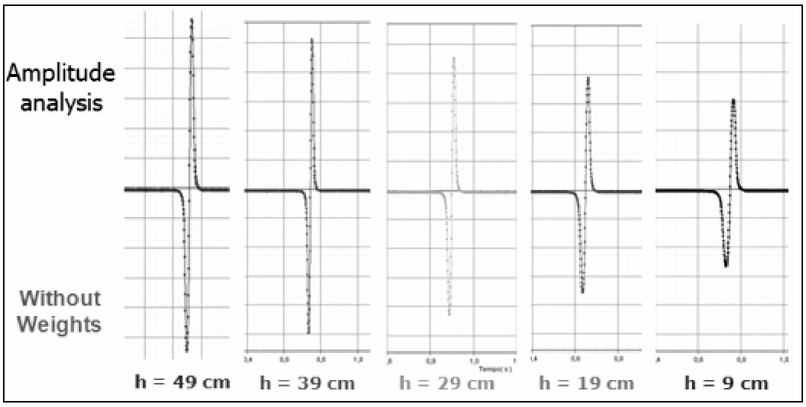

Figure 5: when the falling height decreases, peak amplitude decreases while peak width increases

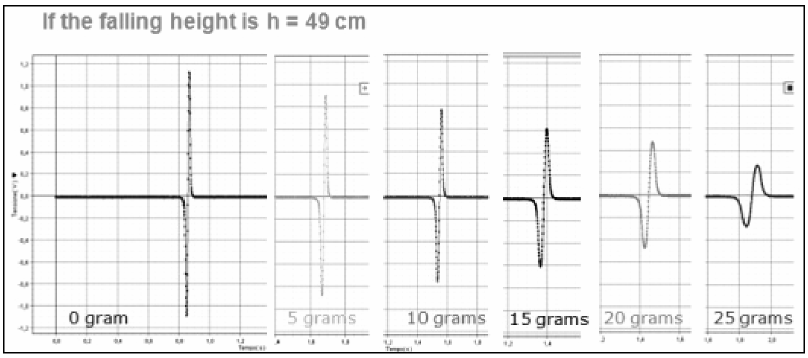

Figure 6: when weight decreases, peak amplitude decreases while peak width increases

5. Conclusions

This experimental set up, supported by a suitable acquisition system cheap and easy to use, allows students to understand Faraday-Newmann-Lenz law, recognizing the central role of magnetic field flux variation.
Real time graphs of either time depending or stationary phenomena play a central role in this didactical activity, focusing students attention on the role of several parameters (coil number, falling height and employed weights) characterizing our Atwood Machine.
In this regard, we stress the advantage of on-line acquisition, also from a didactical point of view, since it allows students/experimenters to have an immediate feedback on the effects of parameter variation (such as falling height or weight value). Such a real time information, in turns, permits students to choose the best set of experimental parameters in order to conduct the experiment.

Moreover the brainstorming discussion show how pupils link induced current to the magnetic flux variation through the coil. A typical student observation was: “current appears when *spaghetti* through the coil increase or decrease in time”, where *spaghetti* obviously are magnetic field lines.

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