Measurement of *g* by means of the 'improper' use of sound card software: a multipurpose experiment

2008 Phys. Educ. 43 297

(http://iopscience.iop.org/0031-9120/43/3/007) www.iop.org/journals/physed

Measurement of *g* by means of the 'improper' use of sound card software: a multipurpose experiment

S Ganci

Museo di Fisica e Meteo-sismologia 'G Sanguineti–G Leonardini', Piazza N S dell'Orto, 8 16043 Chiavari (GE), Italy

Abstract
A well-known experiment for the measurement of the acceleration of gravity is carried out on a personal computer using standard software for a sound card in a non-canonical way, which provides an improved, more accurate, result and is a useful teaching method for a traditional classroom experiment.

Introduction

A traditional classroom experiment to measure the acceleration due to gravity, g, is carried out by dropping a magnet in a glass or plastic tube which has three or more identical coils of enamelled copper wire wound round it at equal distances [1]. A pattern of induced emf proportional to the change of magnetic flux in time is shown on an oscilloscope screen with a suitable time-base setting. Since the *same* magnet is passing through *identical* coils, it should be possible to investigate the major features of Faraday's magnetic induction law, providing an interesting multipurpose experiment.

A standard storage oscilloscope cannot give measurements under 20% of relative uncertainty, but improved experimental results can be obtained by using a PC-based oscilloscope or dataloggers.

This note describes the use of standard PC software for a sound card used in an 'improper' way [2]. The major advantages are the very low cost of the proposed method and the ease of understanding for students due to their familiarity with the software when it is used 'properly' for editing musical tracks. The experiment can also be carried out at home, with further suggestions for more quantitative investigations on Faraday' law of magnetic induction.

Experimental set up and measurement

The proposed experimental set up is shown in figure 1(a). It consists of a glass tube about 0.78 m long with a diameter of about 7 mm, into which a small hard magnet from a popular toy is dropped. Three identical coils of ten turns of enamelled copper wire spaced 0.3 m apart are wound around the glass tube and connected together, as shown in figure 1(b). In the laboratory, the tube, connected with two supports to a wooden strip, can be hung against a wall, so that it can be vertically adjusted. As a home experiment, a similar tube can be simply held at the top in an upright position with two fingers. A light cable is used to connect the coil ends to the audio input

0031-9120/08/030297+04$30.00

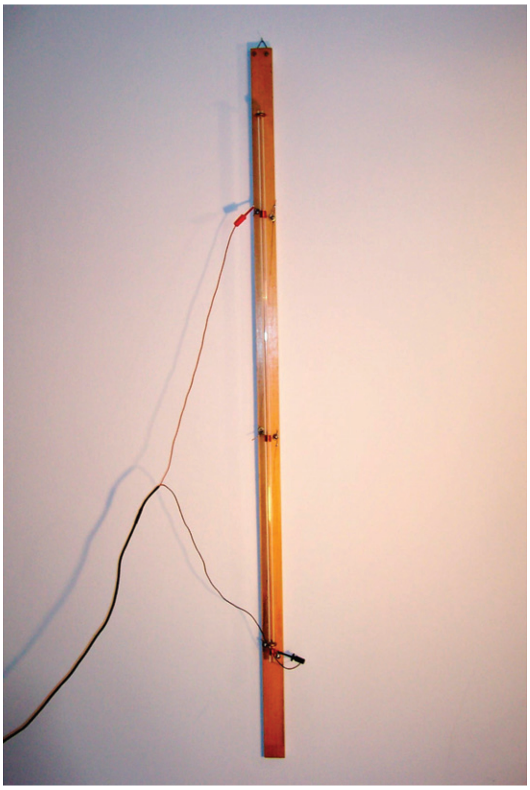

Figure 1(a). Experimental set up as a laboratory (or corridor) demonstration.

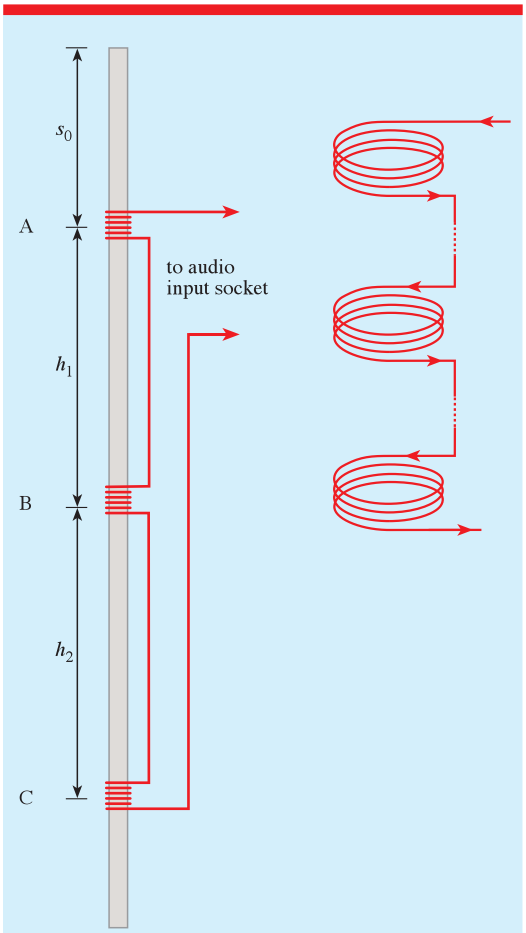

Figure 1(b). Schematic diagram and coil winding. In our case $h_1 = h_2$; equation (1) is independent from s_0.

socket of a PC on which is running 'Creative Wave Studio'[1].

After having activated the *recording* button, the magnet is dropped through the tube; the *stop* button is then pushed and the recorded trace is shown and viewed as in figure 2. The time intervals between the first and second coils and second and third coils are identified and marked (i.e. at the central point of the signals), and the time intervals are directly read in a window at the bottom right-hand side of the screen with a maximum uncertainty of 0.002 s.

From the equations of linear motion with constant acceleration g, it is easily shown that

$$g = \frac{2\left(\frac{h_2}{t_2} - \frac{h_1}{t_1}\right)}{t_1 + t_2}, \qquad (1)$$

where h_1 and h_2 are the space between the first and the second coil and the second and the third coil, respectively, and t_1 and t_2 denote the corresponding times of transit. In our case $h_1 = h_2 = 0.30$ m $\pm$ 0.001 m and the times of transit are respectively $t_1 = 0.135$ s $\pm$ 0.002 s and $t_2 = 0.091$ s $\pm$ 0.002 s. No significant casual errors are evidenced from the various measurements so, within the uncertainties claimed, a single measurement is sufficient for our purpose. By substituting the above data in equation (1), we find

$$g = 9.5 \text{ m s}^{-2} \pm 0.5 \text{ m s}^{-2}$$

with about 5% relative uncertainty.

[1] The *Creative Wave Studio* software is part of the various software furnished in a CD-ROM enclosed in any 'Creative Sound Blaster' card package. Another software (Sigview) has identical features and more functions. It is freely downloadable as shareware and licenced at very low cost after 21 days at: http://www.sigview.com.

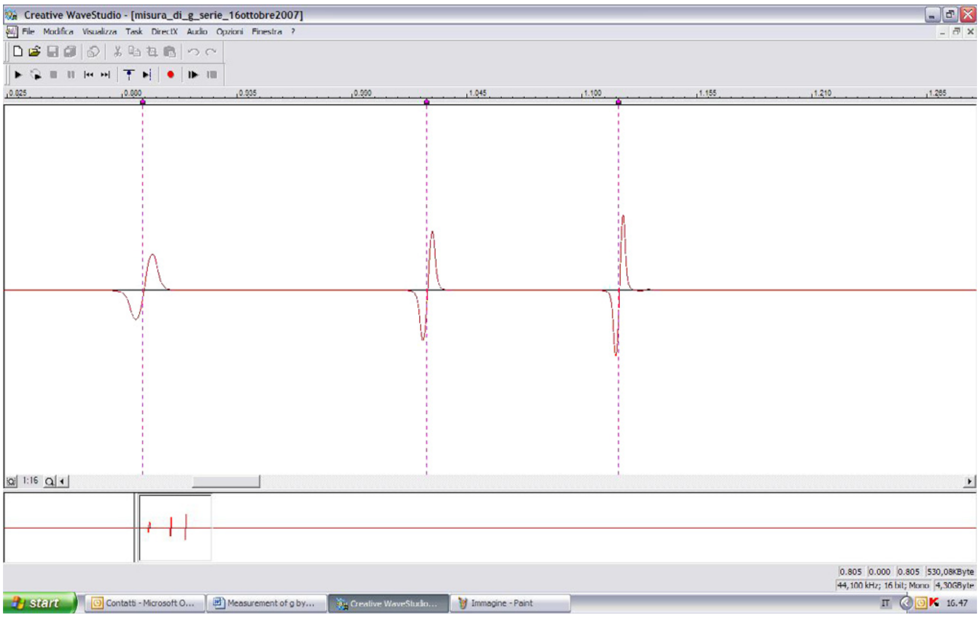

Figure 2. Screenshot of the traces due to the magnet dropping. The three markers point to the centre of each peak. Selecting the times between these markers, these times are directly read on the little window near the bottom right-hand side of the screen. The resolution in time of this software is 1 ms.

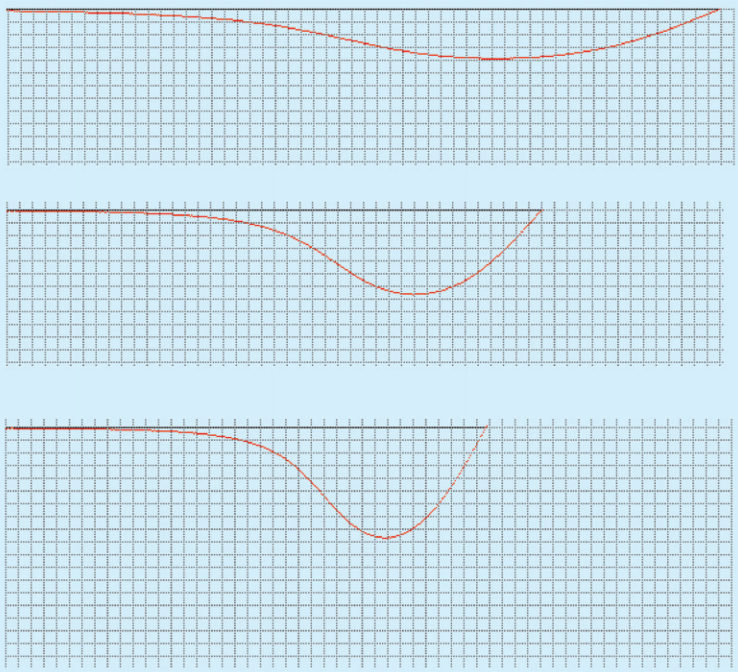

Figure 3. Graphical work of cut/paste of three peaks in figure 2 with 1:1 zoom and grid superposition using 'Paint' package of Windows.

Conclusion

In an Italian 'Liceo' curriculum, this experiment was run in two different contexts. The first time was at the beginning of the study of kinematics; the second time was two years later, when Faraday's law was being studied: this had the twofold goal of providing a quantitative verification of Faraday's law and of reinforcing the concept of 'definite integral'. In this second discussion the following quantitative analysis of the areas of the three peaks was proposed.

Let

$$Q = \int_{\Delta t} \mathrm{d}q \propto \int_{\Delta t} V(t)\,\mathrm{d}t \qquad (2)$$

where Q is the *total charge induced* in a time interval Δt and $V(t)$ the instantaneous induced emf. Obviously, a good graphical analysis requires a 1:1 zoom of figure 2 and a copy/paste of the half peaks from 'Creative Wave Studio' using the 'Paint' software tool on a fine grid. Figure 3 shows a copy/paste view with a convenient choice of a fine square grid. By defining S_1, S_2 and S_3 as the areas of the trapezoids in the first, second and third peak, respectively, it is easy to establish that

$$82 < S_1 < 118;$$

$$83 < S_2 < 123;$$

$$84 < S_3 < 117,$$

where the integer numbers refer to internal and external 'unit area' squares approximating area. Areas are therefore seen to be *equal* within a few per cent of uncertainty.

From a pedagogical point of view, students have found this approach to a delicate concept in mathematics useful.

Acknowledgments

It is a pleasure to acknowledge a critical reading by Roberto De Luca of DIIMA at Salerno University. My sincere thanks to Andrea Pomroy at IOP for her valuable language editing.

Received 20 October 2007, in final form 21 October 2007
doi:10.1088/0031-9120/43/3/007

References

[1] Huebner J S and Humphries J T 1974 Storage oscilloscope in the modern physics laboratory *Am. J. Phys.* **42** 870–6

[2] Ganci S 2007 Quantitative measurements in beats with 'improper' use of sound card software *Eur. J. Phys.* **28** L45–8

Salvatore Ganci graduated in physics in 1972. He was Professor of physics and mathematics in Liceo Scientifico di Stato 'G Marconi' in Chiavari until 2004. His major area of interest is in the Scalar Theory of Diffraction. Nowadays he is on the staff of the Museum of Physics and Meteo-seismology 'G Sanguineti–G Leonardini' in Chiavari, attending to historical and pedagogical aspects of Physical Science.