Teaching Physics by Arduino during COVID-19 Pandemic: Oscillation of a simple pendulum

Fausto Casaburo
Sapienza Università di Roma, Dipartimento di Fisica
Istituto Nazionale di Fisica Nucleare (INFN) Sezione Roma
E-mail: fausto.casaburo@uniroma1.it-fausto.casaburo@roma1.infn.it

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Abstract. The COVID-19 impacted the teaching; indeed, both schools and universities had to shift from face-to-face to distance teaching organizing on-line lectures. Thanks to easily accessible materials, smartphones physics apps, on-line tools and devices, it's possible to perform laboratory practice even in this period. In this paper, a method to measure the gravitational acceleration by oscillation of a simple pendulum, using Arduino board, is presented.

Keywords: Arduino board, COVID-19, Physics teaching.

Contents

Introduction

THE COVID-19 pandemic impacted on teaching worldwide. Despite that, to overcame the problem, the educational system replaced face-to-face by distance learning [1, 2, 3].

In particular, to preserve laboratory courses, during the COVID-19 pandemic, many schools and universities proposed to perform physics experiments at home [4].

For example, in Italy, the Lab2Go project [5, 6, 7, 8, 9] organized on-line seminars to show experiments that can be made at home using easily accessible materials and exploiting resources as the Arduino board [10].

Arduino is an open source platform made of electronic boards, sensors and expansion boards. Its usage also allows to acquire additional competences, as for example coding and programming [11, 12]. The original Arduino board can be bought for as low as about few tens of euro; moreover, there are many cheapest clones. Both the board and the sensors can be easily bought on-line or in electronics shops [12]. There are also many kits including the board and common sensors available for just 50-60 euro. Thanks to the low cost, the Arduino board and related component can be bought directly by students or by schools/universities to be provided to students.

In this paper an Arduino-based physics experiment regarding of oscillation of a simple pendulum will be presented. It consists in measuring the oscillation period by Arduino to estimate the gravitational acceleration value.

The experiment can be proposed both to high school and university students.

1. Theory

The simple pendulum (Fig. 1) is a mechanical system of length l, made of a point-mass m suspended by means of light inextensible string from a fixed support.

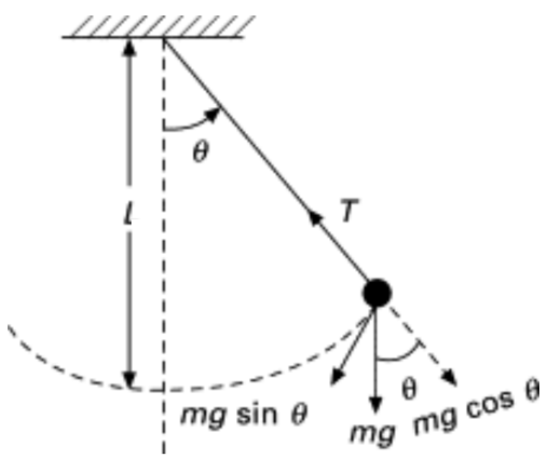

Figure 1: Simple pendulum.

The equilibrium position is when the string hangs vertically. When displaced to an initial angle θ and released, the pendulum will swing back and forth due to gravitational acceleration. If there aren't other forces acting on the pendulum, the motion is periodic of period T.

Moreover, for small θ, the period is given by:

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{1}$$

where g is the gravitational acceleration (the average value on the Earth is $g = 9.80665\,{}^{\mathrm{m}}/_{\mathrm{s}^2}$ [13]).

By equation 1, it follows that measuring the period T and the length l of the pendulum it's possible to estimate the gravitational acceleration.

2. Experimental setup

The experimental setup (Fig. 2) is made of an hand-made pendulum, an Arduino UNO R3 board, an Infra-Red (IR) trasmitter-receiver pair sensors, a meterstick, a breadboard, Dupont cables, USB cable, an hand-made support having U-shap, a calipers e and one computer.

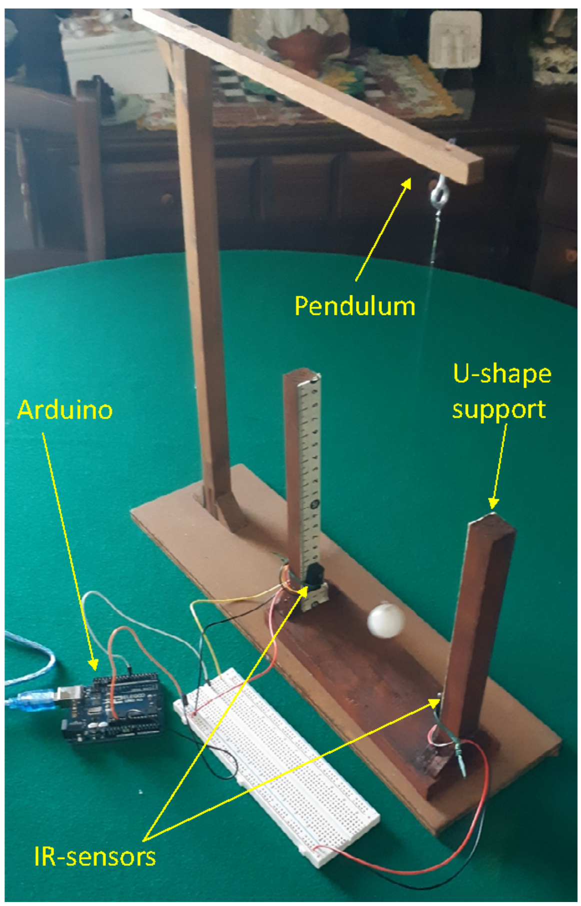

Figure 2: Experimental setup.

The IR sensors are connected by digital pin to Arduino and are supported by the hand-made U-shape support, positioned near the pendulum, so that it can moves through the IR sensors and the oscillation period can be measured.

The overall setup is connected to the computer for data acquisition by the USB cable.

3. Experimental procedure

The sketch for Arduino allows the user to measure the oscillation period.

The IR light is constantly emitted from the transmitter of the the IR pair sensors and, if there aren't obstacles, it will hit the IR receiver and it is read by the Arduino board as a HIGH state of the pin whose the sensor is connected. When the pendulum moves through the beam light, this one is interrupted, therefore the pin state of the sensor will be switched to LOW state. The period is measured as the time between two passages of the pendulum through the IR sensors and it's printed on the terminal.

The periods for several pendulum lengths have been measured and analyzed. The length l of the pendulum is the distance from the suspension point to the barycenter of the mass m (a sphere). Therefore, it has been measured the diameter d of the sphere by the calipers and the length l^* of the string by the meterstick. The total length l of the pendulum is

$$l = l^* + \frac{d}{2} \tag{2}$$

Data of T^2 in fuction of l have been interpulated, using ROOT [14], by the linear function :

$$y = kl \tag{3}$$

where $y = T^2$ and $k = \frac{4\pi^2}{g}$. Therefore, the gravitational acceleration is given by:

$$g = \frac{4\pi^2}{k} \tag{4}$$

4. Results

The graph of T^2 in function of l is shown in Fig. 3.

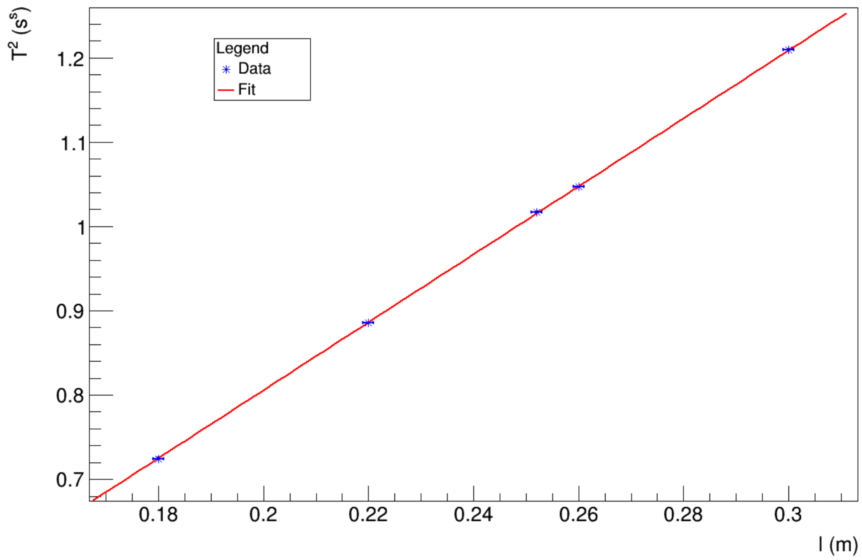

Figure 3: Fit.

The slope k got by fit and the obtained g value are given in Tab. 1

Table 1: Fit result slope and obtained g value.

m ($^{s^2}/_{m}$)	g ($^{m}/_{s^2}$)
4.0298 ± 0.0074	9.797 ± 0.018

The obtained g value is compatible with the one in literature within 1σ.

Conclusions

Due to COVID-19 pandemic, students couldn't access to schools and universities laboratories. To overcame this problem it's useful organizing laboratory activities made at home using easily accessible materials and exploiting resources as smartphones physics apps, on-line tools and devices, as for example Arduino.

In this paper it has been shown a technique to study the oscillation of a simple pendulum and to measure the gravitational acceleration using Arduino. Beyond the numerical result, the article goal is to encourage teachers to propose the experiment to their students in order to carry on the laboratory practice even in this pandemic period.

Lastly, thanks to its low-cost, the usage of Arduino for physics experiments can also be useful in school laboratories not adequately equipped (obsolete or non-functioning instrumentation, poor assortment, lack in maintenance, missing catalog) even when the COVID-19 emergency is over.

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References

[1] P. Klein, L. Ivanjek, M. N. Dahlkemper, K. Jeličić, M.-A. Geyer, S. Küchemann, and A. Susac, "Studying physics during the covid-19 pandemic: Student assessments of learning achievement, perceived effectiveness of online recitations, and online laboratories," *Phys. Rev. Phys. Educ. Res.*, vol. 17, p. 010117, Mar 2021.

[2] F. Casaburo, "Teaching physics by arduino during covid-19 pandemic: The free falling body experiment," 2021.

[3] F. Casaburo, "Teaching physics by arduino during covid-19 pandemic: Measurement of the newton's cooling law time-constant," 2021.

[4] E. G. Campari, M. Barbetta, S. Braibant, N. Cuzzuol, A. Gesuato, L. Maggiore, F. Marulli, G. Venturoli, and C. Vignali, "Physics laboratory at home during the covid-19 pandemic," *The Physics Teacher*, vol. 59, no. 1, pp. 68–71, 2021.

[5] Lab2Go collaboration. https://web.infn.it/lab2go/.

[6] Lab2Go collaboration. https://lab2go.roma1.infn.it/doku.php.

[7] G. Organtini, F. Ameli, G. Cavoto, E. Di Marco, F. Piacentini, S. Morganti, E. Pasqualucci, A. Polimeni, M. Rescigno, F. Safai Tehrani, G. Salmé, P. Vicini, and R. Faccini, "Promoting the physics laboratory with lab2go," in *EDULEARN17 Proceedings*, 9th International Conference on Education and New Learning Technologies, pp. 5264–5268, IATED, 3-5 July, 2017 2017.

[8] M. Andreotti, P. Astone, D. Campana, F. Casaburo, A. Cartoni, F. Cavanna, G. Cibinetto, A. D. Cort, G. D. Bonis, M. D. Seta, F. D. Mauro, G. D. Sciascio, R. Faccini, F. Favino, L. Iocchi, M. Lissia, G. Morganti, M. Mancini, G. Organtini, F. Pennazio, F. Piacentini, A. Piras, M. Ragosta, L. Roberti, A. R. Rossi, L. Sadori, and F. S. Tehrani, "Il progetto lab2go per la diffusione della pratica laboratoriale nelle scuole secondarie di ii grado," 2021.

[9] P. Astone, R. Balaudo, F. Casaburo, F. Cavanna, G. D. Bonis, R. Faccini, D. Fallara, A. Grigoruta, G. Organtini, F. Piacentini, and F. Pennazio, "Studio di un urto anelastico: una proposta per le scuole secondarie di ii grado nell'ambito del progetto "lab2go"," 2021.

[10] Arduino collaboration. https://www.arduino.cc/.

[11] G. Organtini, "Arduino as a tool for physics experiments," *Journal of Physics: Conference Series*, vol. 1076, p. 012026, sep 2018.

[12] G. Organtini, *Fisica con Arduino*. Zanichelli, 2021.

[13] E. R. Cohen and B. N. Taylor, "The 1986 codata recommended values of the fundamental physical constants," *Journal of Physical and Chemical Reference Data*, vol. 17, no. 4, pp. 1795–1803, 1988.

[14] ROOT collaboration. https://root.cern/.