Journal of Modern Education Review, ISSN 2155-7993, USA
October 2022, Volume 12, No. 10, pp. 737–743
Doi: 10.15341/jmer(2155-7993)/10.12.2022/006

http://www.academicstar.us

Free Fall Time Measurement Using a Smartphone

Petros Pitsilkas
(2nd Model High School, Volos, Greece)

Abstract: In this paper a way to measure free fall time is described. Free fall is the linear smoothly accelerating motion of a body when we let it fall from a height and the only force acting on it is its weight, which is considered constant. Air resistance is considered negligible. Free fall takes place accurately only in a vacuum. The free fall time is measured with the help of a smartphone application that includes an acoustic timer. The purpose of this paper is to show that in natural science courses of the secondary education high cost and not easy to use devices can be replaced with sensors that have smartphones.

Key words: smartphone, phyphox, acoustic timer, free fall, gravity acceleration

1. Introduction

A genuine interest in science is an important goal of science education. Recent research, however, has shown that this goal is not achieved in schools. The most important reason for this is the lack of knowledge about what makes science attractive to students (Swarat et al., 2012).

It is a fact that education in the natural sciences is based on the sterile memorization of laws and principles that human knowledge has accumulated over the centuries. However, observation and experiment should be the basis of teaching as this will stimulate students' interest in scientific research and will cultivate skills for tomorrow's citizens (Papastamatiou, 2015; Pallas, n.d.).

There are a lot of reasons for the non-laboratory way of teaching natural sciences by the teachers of the secondary schools. It can be mentioned indicatively the lack of training, the lack of laboratory equipment, the lack of will and insistence of the teachers to take the instruments off the shelf and bring them to the classroom as well as their fear of causing damage by the students. One way to deal with these difficulties is to use smartphones in experimental science teaching.

2. Use of Smartphones in Experimental Procedures

Smartphones are increasingly used as tools of everyday life. Almost every student has a smartphone. Smartphones can be used to enrich students' educational activities. In particular they can be used for data collection and analysis. For data collection they are equipped with various sensors that can be used for measurements of physical sizes such as microphones, acceleration sensors, gravity sensors, brightness sensors, GPS receivers. Free software-applications are available to utilize these sensors. For the Android operating system the most common are: GlobiLab, Lablet-Physics Sensor Lab, Physics Toolbox Accelerometer, Physics Toolbox Sensor Suite, Science

Petros Pitsilkas, MSc., Physics Teacher, 2nd Model High School; research area: use of ICT in education. E-mail: pppetrosuk@gmail.com.

Journal, Sensor Kinetics (Klein et al., 2014), choreography, choirs and expression of emotions (Figure 3). The work of professionals in image design and assembly technologies combines different elements mentioned above and makes them evident.

These sensors make these devices suitable for performing a large number of quantitative measurements and therefore enable them to function as new, inexpensive experimental tools in physics education and to replace expensive or unavailable equipment and instruments (Strawson, 2013). Various free software such as excel etc can be used for data analysis and recording. Compared to experiments carried out in the traditional way on the one hand they require much cheaper and easier to use equipment that can be used outside of school (Pierratos & Primerakis, 2016) and on the other hand cause greater interest of students. Each student can perform its own experiment individually so students are no longer passive recipients of demonstration experiments but they experiment freely and become the focus of teaching themselves (student-centered teaching approach) (Newhouse & Rennie, 2001).

In practice, however, the existing Greek legislation prohibits the use of mobile phones by students within the school (Protocol number 25/103373/D1/22-06-2018/Ministry of Education) while they can be used by teachers for the needs of teaching practice in compliance with the provisions for the protection of personal data of students and teachers. This means that a student can only perform experimental activities using a smartphone outside of school. The universal ban on mobile phones in schools is unrealistic according to current data. It would be more realistic to be able to activate them with the permission of the teacher for educational purposes. With the current legal framework the only thing that could be done would be the use of tablets belonging to the school

Even with the circumvention of the legislation, the question remains whether smartphones can be used in the educational process without creating other problems such as the use of mobile phones within the teaching hour for non-educational purposes (e.g., for communication through social networks), the distraction of students from the essence of the experimental process, the increased cognitive load, etc. Some other difficulties that the use of smartphones shows in the educational processes concern the high cost of a smartphone with good functionality, the small size of the screen (students may strain their eyes), the insufficient memory space of the devices etc. (Stamatelatos, 2018).

Although there are many references in the literature for experimental activities with smartphones, studies on their learning effects are few. In some of them there is an increase in students' interest in Physics and better learning outcomes (Koumaras, 2006). In the digital age we live in today we have to go from the sterile way of transferring knowledge to the discovery and exploration of knowledge by the students themselves (Stamatelatos, 2018). The use of smartphones increases the collaboration, the self-action and the communication of the students who can now achieve the educational goals in a pleasant and fun way. An educational scenario for measuring the speed of sound using two smartphones is described below.

This paper aims to raise readers' concerns about the current legal framework for banning the use of smartphones by students in the classroom for educational activities and to give teachers a suggestion for conducting experimental activities via smartphones, even as demonstration experiments.

3. Description of the Phyphox Application

An app for smartphones that has an audio timer is Phyphox (You can download it free from https://phyphox.org/). The experiment could also be performed with another application that has an acoustic timer. Phyphox includes the following main menus: Sensors, acoustics, tools, daily life, everyday life, engineering, timers.

Each main menu has subcategories.

With this application the sensors of the phone can be used to perform experiments, e.g., the acceleration sensor can be used to measure the frequency of an oscillation. When installing the application, the main menus with their subcategories are displayed as shown in Figure 1:

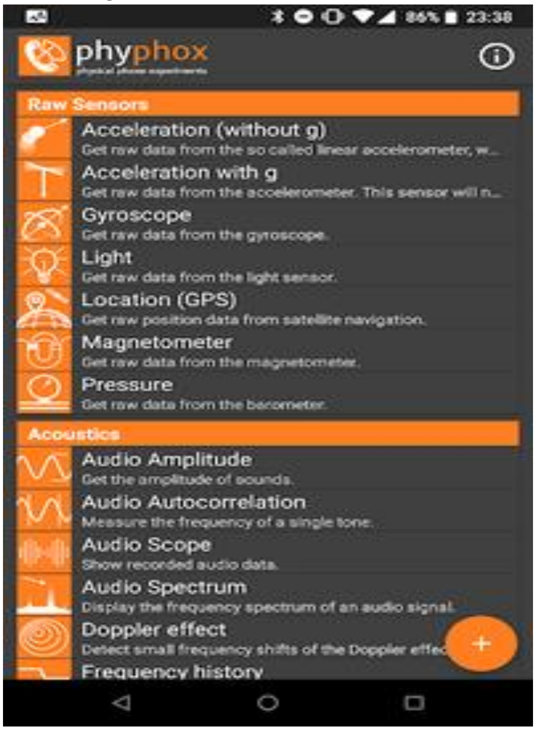

Figure 1 The Phyphox Application

From the timers option, select Acoustic timer. The activation threshold can be changed so that it is above the ambient noise level (but definitely below the activation sound). For example it is possible to increase it from 0.1 a.u. which is the initial value(as shown in Figure 2) to 0.3 a.u. in order to zero the effect of environmental noise.

Figure 2 Threshold of the Acoustic Timer Can Be Raised From 0.1 a.u to 0.3 a.u.

Below there is a detailed description of how to measure the free fall time of an object with the help of the phyphox application. It can be done as part of one hour teaching class as a laboratory exercise performed by students.

4. Teaching Scenario

Teaching scenario title: Calculation of free fall time using a smartphone

Estimated duration of the teaching scenario: 1 teaching hour

Integration of the didactic scenario in the curriculum/prerequisite knowledge:

The present didactic scenario can be realized in the context of first high school class. A teaching unit must have been preceded for the free fall of the bodies.

Aims and objectives of the teaching scenario

- The measurement of free fall time and its comparison with the theoretical value.
- Familiarizing students with applications that utilize the sensors of smartphones.
- Students to gain more self-efficacy, cooperation and to have a positive attitude towards Physics.

Required Materials

- An object that will perform a free fall
- A ruler
- Paper and pen for recording measurements and graph design
- A balloon and a needle
- A support base
- Wire for making a balloon support loop
- A smartphone with the phyphox application installed

4.1 Description of the Teaching Scenario — Execution of the Experiment

4.1.1 With a Ruler

Place the ruler horizontally with one end protruding and place the object on it (Figure 3).

Figure 3 Execution of the Experiment With a Horizontal Ruler and an Object on It

Hit the ruler behind the object so that it does not accelerate vertically from the impact. The beep produces a sound that starts the acoustic timer. When the object hits the ground a second sound is produced which stops the acoustic timer.

4.1.2 With a Balloon

If you perform the experiment in front of a large audience, e.g., in a classroom you may need a louder sound to activate the acoustic timer. Here a broken balloon could be used to activate the acoustic timer and a metal disc on the floor to stop it. Attach a hook to the mouth of an inflated balloon. Create a wire loop and adjust the balloon to a support base (Figure 4).

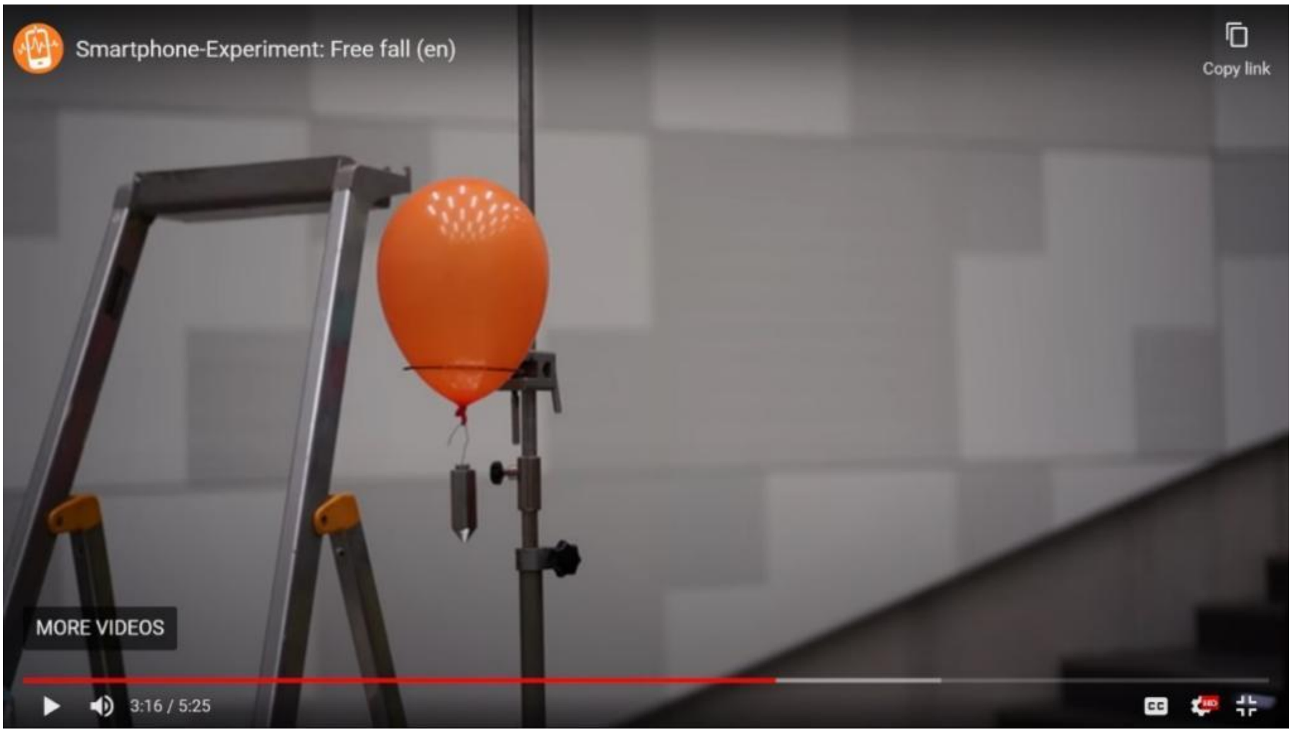

Figure 4 Execution of the Experiment With a Balloon

Adjust a metal disc to the floor to increase the intensity of the collision and the sound produced. You also need a needle to pop the balloon.

Repeat this experiment a few times for different heights. The result for the fall time should be equal to:

$$\boldsymbol{t} = \sqrt{\frac{\boldsymbol{2h}}{\boldsymbol{g}}}$$

Where h is the height of fall and g is the acceleration of gravity (g = 9.81 m/s2).

E.g., for a free- fall from a height of 1.2 m the free-fall time is about 0.5 s.

Giving values to h and calculating t from the above formula we can construct the theoretical diagram t-h (as shown in Figure 5).

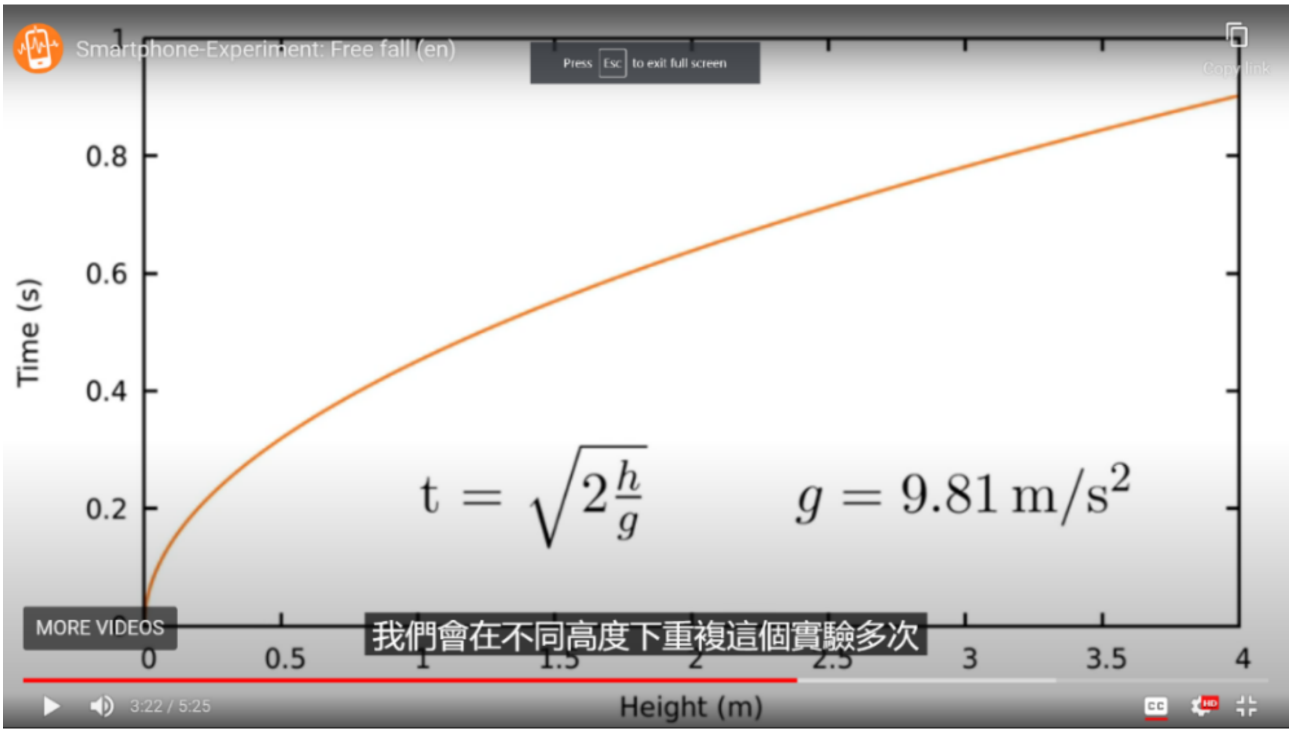

Figure 5　Theoretical Diagram h-t

The next step is to perform the experiment for the same values h, to measure the fall time with the acoustic timer and to construct the experimental t-h diagram. It is expected that there will be some slight differences with the theoretical diagram due to some small errors that will inevitably occur during the experimental process (The measurement of time will start and stop with a slight delay as the smartphone is a short distance away from where we pop the balloon and the point at which the object falls to the floor).

4.2 Classroom Organization

The teaching scenario can be done in the classroom except for the experimental part which could be done in a quiet outdoor or indoor space, e.g., the closed gym of the school. The class can be divided into groups of 3–4 students who will each perform the experiment and complete the worksheet described in section 5. Each student must have a role, e.g., one must be responsible for the acoustic timer, another must make height measurements with a tape measure, a third must record the results of the measurements and the fourth must check for any errors.

In the end all the groups compare the results they found (They must be about the same). If there are discrepancies one team reads the results of another team and tries to identify the errors. In case of inability to detect errors the teacher should help.

5. Work Sheet

CLASS: NAMES OF GROUP MEMBERS:

Draw the height- time theoretical diagram by giving values to h and calculating the time from the formula with the help of a calculator. Alternatively you can calculate the free fall time using online calculators giving only the free-fall distance h (there is one in the following address: https://keisan.casio.com/exec/system/1224852055).

Time t(s)								
Height (m)								

Perform the experiment and draw the experimental fall-height time diagram (for the same values that you calculated in the theoretical diagram).

Is it different from the theoretical one?

What do you think is the cause of the difference?

Perform the same experiment with an object of the same shape but of different mass (hence weight). Is the fall time different?

What is the conclusion about the dependence of the free-fall time with the mass?

6. Summarizing

In this work a method of measuring free fall time has been demonstrated using a smartphone with the Phyphox application installed. This application (as well as others like it) can replace expensive laboratory equipment in school experiments. Thus it can be performed in schools with limited access to laboratory equipment and offer learning opportunities for students in both experimental methods and data analysis. Due to the portability of smartphones, the experiments can be performed in places outside the laboratory such as the classroom or the school yard, while they can also be performed by students out of school hours in their own space. This is likely to increase students' interest in the natural sciences and maximize the benefits that students receive in terms of skills and knowledge. For educators, the use of smartphones is expected to greatly reduce the preparation time required to perform experiments and increase their digital skills.

References

Klein P., Grober S., Hirth M. and Kuhn J. (2014). "Classical experiments revisited: Smartphones and tablet PCs as experimental tools in acoustics and optics", *Physics Education*, July 2014.

Koumaras P. (2006). "Is it possible to create interest in students for Physics?", Proceedings of the *3rd Panhellenic Conference of the Union for the Teaching of Natural Sciences*, pp. 30–39.

Newhouse P. and Rennie L. (2001). "A longitudinal study of the use of student-owned portable computers in a secondary school", *Computers & Education*.

Papastamatiou N. (2015). *Experimental Teaching in High School* (2nd ed.), Athens.

Pallas A. (n.d.). "Pilot teaching in physics using the physics toolbox suite application for smartphones and its evaluation".

Pierratos Th. and Primerakis G. (14–16/10/2016). "Quantitative Physics experiments with the use of smart mobile phones and tablets: Teacher training in their use in a playground", in: *2nd Panhellenic Conference With International Participation for the Teacher Material in Mathematics and Natural Sciences*.

Stamatelatos D. (2018). "The use of smart devices in the teaching of mathematics and physics", Diploma Thesis, Athens.

Swarat S., Ortony A. and Revelle, W. (2012). "Activity matters: understanding student interest in school science", *Journal of Research in Science Teaching*, Vol. 49, No. 4, pp. 515–537.

Strawson R. (2013). "Map and apps widen the scope of school physics", *Physics Education,* Vol. 48, pp. 409–410.

Available online at: https://phyphox.org/experiment/free-fall-2/, Retrieved 20/06/2021.