Study of oscillatory motion using smartphones and tracker software

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Study of oscillatory motion using smartphones and tracker software

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Abstract. The purpose of this contribution is to propose a workshop for acquiring data through the use of a smartphone, not necessarily high end, equipped with a camera and the required application installed. With a smartphone and the free Physics Toolbox application, it is possible to study the oscillatory motion of both simple and vertical pendulums. This is possible by measuring the components of acceleration on the three axes by means of a reading from the internal accelerometers of the smartphone. The vertical motion of the pendulum brings to light the concept of elasticity. Thanks to the Tracker software it is possible to study the damped oscillatory motion of a moving body on a semi-circular drive through the video analysis of the motion itself. Tracker is a free video analysis and modelling tool built on the Open Source Physics Java framework. Given the simplicity of the acquisition procedure and data analysis it is possible to study the motion of circular bodies of different sizes and materials in a short amount of time. The activity relating the vertical motion of the pendulum study also allows for the comparison between the classical procedure, using a stopwatch and both proposals procedures, using smartphones and Tracker. The analysis of subsequent data acquisition must be carried out using standard spreadsheet calculations by introducing the concept of error and the techniques to make it as small as possible. The use of the new widespread technologies allows students to approach the physical concepts even outside of a classic laboratory. The ease of use and low cost allow any school environment to propose activities to the entire class by offering more contemporary workstations and organizing groups of a few students.

1. Introduction

The course that has been proposed is a part of the course for the teaching qualification, designed as a series of laboratory activities suited to secondary school. Often in schools there isn't an equipped place to use as a laboratory. It is therefore necessary to think some alternative experimental activities carried out with everyday equipment in order to offer a good example that teacher can replicate in the classroom. The use of the software "Tracker", smartphones and tablets are a possible solution of these problems. Tracker is a free video analysis and modelling tool built on the Open Source Physics Java framework (only for PC).

By measuring the acceleration components on the three axes by the internal accelerometer of the telephone, it is possible to study the oscillatory motion of a simple pendulum and a vertical pendulum. The study of motion of vertical pendulum allows to introduce the concept of elasticity. It is also possible to study the damped oscillatory motion of a moving body on a semicircular guide.

Experience of simple pendulum

Using a smartphone as a mass it is possible to build a pendulum (Vogt & Kuhn 2012) of length l and measuring the period of oscillation by acquiring the data through the application "Physics Toolbox accelerometer" (Fig. 1). This App is free downloadable both for Android and iOS.

The software acquires the values of the components of acceleration on three axes, records them in a format compatible with the commercial programs for data processing and displays a screen trend graph. Analyzing the data is possible to study the relationships between the oscillation period and pseudo period depending on the length of the pendulum (Fig. 2).

Fig. 1. Screenshot of "Physics Toolbox"

Observing and evaluating the damping factor due to friction may be estimated how many oscillations the period remains constant.

By changing the angle of oscillation, the length of the wire and the hanging mass it is possible to study the dependence of the oscillation period by one of the three variables.

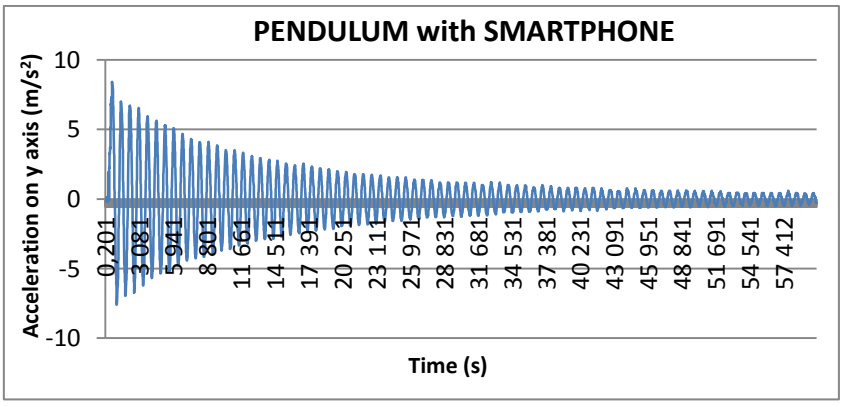

Fig. 2. Data of the pendulum acquired with Physics Toolbox

The results obtained with Physics Toolbox can be compared with the data extracted from the analysis of the motion of the pendulum.

The Tracker software allows the student to capture video and select the position of the mass of the pendulum with respect to the equilibrium point at fixed time intervals (Fig. 3). First of all, it is necessary to make a video of the physics phenomena with the smartphone camera and to choose a calibration length in the video that the program will serve as a reference unit. Then set and the frames interval in which the program will have to identify location of the object and select a point on the object. The program automatically goes to the next selected frame in which to repeat the reference point selection procedure (always the same point).

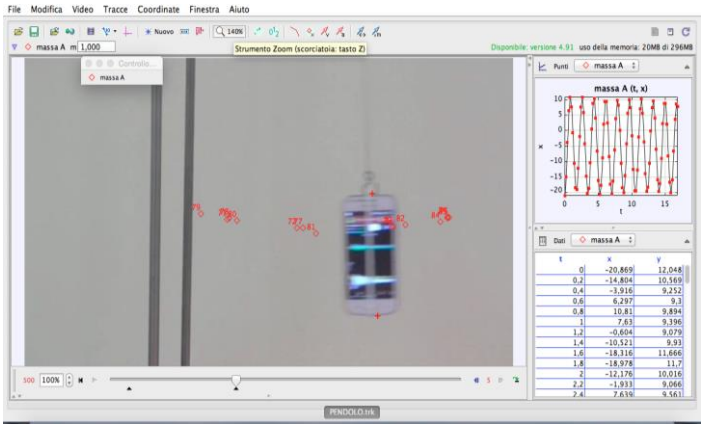

Fig. 3. Screenshot of Tracker for the pendulum

The Tracker software allows the view of motion of the pendulum and, in parallel, the construction of the point-by-point graph. In particular, in our case it is interesting to separately view the acceleration performance and its three components. The acquired data can be exported in a format compatible with leading software for a statistical analysis

Experience of vertical pendulum

Using a smartphone as a mass and a spring with a constant of elasticity k, it is possible to build a vertical pendulum (Kuhn & Vogt 2012). The law that describes the motion is harmonic damped along the vertical axis:

$$x(t) = A \cos(\omega t + \Phi)$$

through the measurement of the oscillation period it is possible to obtain the value of constant of elasticity k of the spring.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

The experimental measurement is carried out, similar to the pendulum one, using your smartphone as a mass m and "Physics Toolbox accelerometer" to acquire the period of oscillation of the vertical pendulum: the use of a smartphone as mass is not the best choice to study the motion of vertical pendulum (Fig. 4 – it's very difficult to get perfect vertical oscillations due to the size and mass of the smartphone).

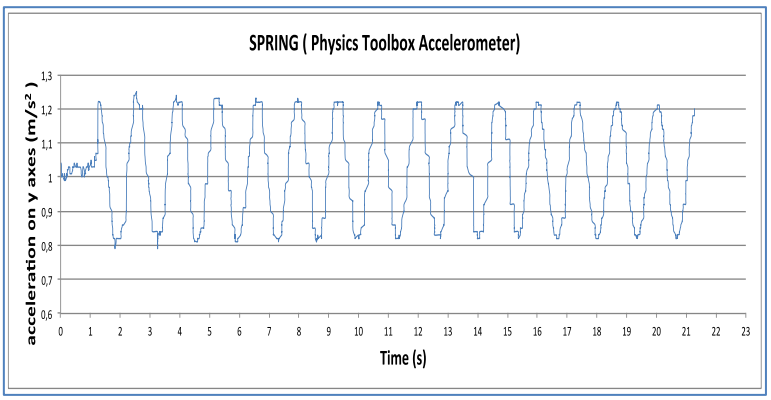

Fig. 4. Data of the vertical pendulum acquired with Physics Toolbox

In this case the use of the Tracker program is more effective (see Fig. 6). Through the video analysis of the oscillations, the experimental period can be obtained and then the experimental value of k.

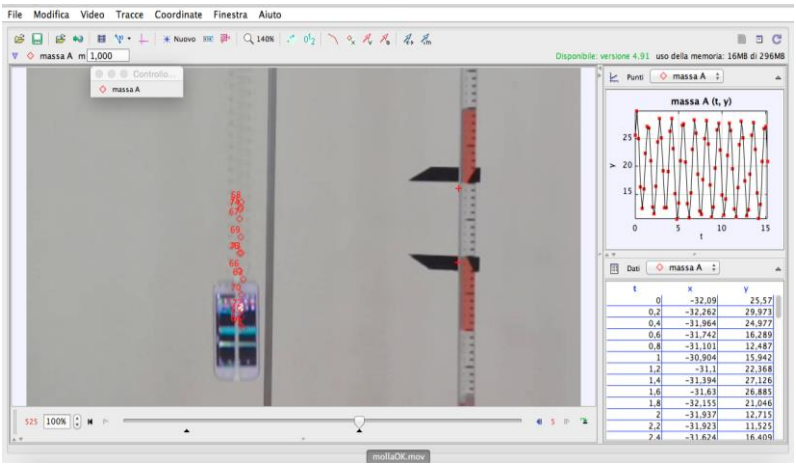

Fig. 5. Screenshot of Tracker for the vertical pendulum

Damped oscillatory motion

Using a rigid semi-circular guide it is possible to view the damped oscillatory motion of an object free to move on the guide itself. The rear fender of a bicycle and a styrofoam ball (Fig. 6) are sufficient to obtain an adequate experimental setup to the proposed study; and the size of the ball was chosen so as to be always easily visible in any frame of the video analyzed with the Tracker program, the lightweight material (polystyrene) instead allows an adequate number of oscillations. Using objects of different sizes and materials, it is possible to study (for short time intervals) their oscillatory motion and the relation between amplitude and speed.

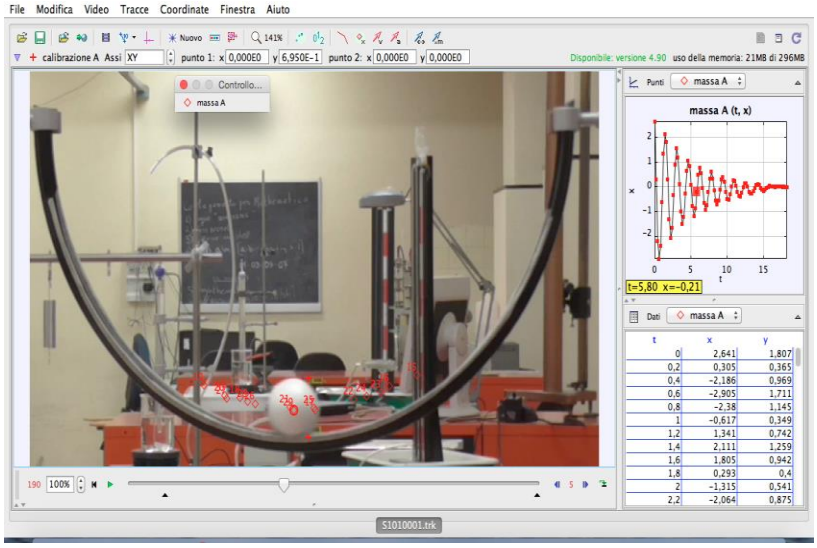

Fig. 6. Screenshot of Tracker for the damped oscillation

This experience allows to introduce, experimentally, the concept of damping e, of gravitational potential energy, and to study the dependence of the oscillation amplitude oscillation period itself (Fig. 7).

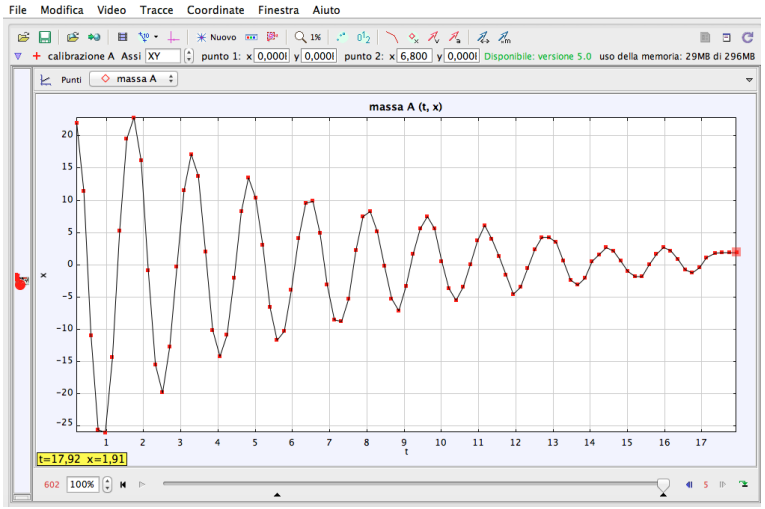

Fig. 7. Graphic obtained with Tracker

2. Conclusions

Proposals experiences are an example of how the use of new technologies widely deployed to enable students to approach the physical concepts, even outside of a classical laboratory. The ease of use and low cost allow any school environment to propose activities to the whole class with the possibility to set up multiple workstations and groups made by few students. The data analysis can be carried out using a common spreadsheet associating to the physical quantities the related errors.

The proposed software can be used to prepare a wide range of experiences allowing the teacher to show practical applications of physical theories discussed in class.

References

Vogt P., Kuhn J. (2012) Analyzing simple pendulum phenomena with a smartphone acceleration sensor, *The Physics Teache*r **50**, 439-440.

Kuhn J., Vogt P. (2012) Analyzing spring pendulum phenomena with a smart-phone acceleration sensor, *The Physics Teache*r **50**, 504-505.