Physical pendulum experiment and HTML5 simulation

Péter FARAGÓ (1,2), Árpád BORDÁS (3)

(1) Department of Physics, Faculty of Sciences, University of Novi Sad, Serbia
(2) Dositej Obradović High School, Bačka Topola, Serbia
(3) Bolyai High School, Senta, Serbia

Abstract. Physical pendulums are commonly used to study the dynamics of rotating systems. The aim of our study is to describe a simple physical pendulum experiment and provide an HTML5 simulation designed for investigating the experiment. In the experiment, we utilize a system consisting of a steel rod and a movable solid sphere as the pendulum. Both the experiment and simulation are intended for high school and undergraduate students.

Introduction

One of the mean goals of basic courses in dynamics is to understand pendulum motion. The motion of a physical pendulum is similar to that of a simple pendulum, but with more complex dynamics due to the distribution of the mass. Physical pendulum experiments are very useful to examine the relationship between torque and moment of inertia, the parallel axis theorem, conservation of energy, etc.

In this study we represent a simple physical pendulum experiment and an HTML5 simulation designed for theoretical investigation of the pendulum motion. The period of a physical pendulum is dependent on both its mass distribution and its geometry. By measuring the period of oscillations versus position of centre of mass, it is possible to obtain information about rigid body motion.

Experiment

Our pendulum was made using a homogeneous full-thread steel rod pivoted at one end and a movable solid sphere (Figure 1.). The position of the sphere on the rod is determined by two hexagonal nuts. If the pivot point joint is frictionless, in the regime of small oscillations, the period (T) can be calculated as:

$$T = 2\pi \sqrt{\frac{I}{\left(m_1 + m_2\right) g\, x_c}} \,,$$

where m_1 and m_2 represent the masses of the rod and sphere, respectively, g is the acceleration due to gravity, x_c is the distance of the position of the centre of mass due to pivot point and I denotes the moment of inertia (according to the parallel axes theorem $I = 1/3\, m_1 l^2 + 2/5\, m_2 r^2 + m_2 x^2$; where, l is the length of the rod, r is the radius of the sphere and x is the distance of the position of the sphere due to the pivot point). Using an L-profile, it is possible to create a seesaw balance and experimentally determine the position of the centre of mass of the system (see Figure 1.).

By conducted a series of measurements of the period of oscillations, position of sphere and position of the centre of mass from the pivot point, as well as representing $T^2\left(m_1 + m_2\right) g\, x_c / 4\pi^2$ versus $m_2 x^2$, it is possible to estimate the aggregate moment of inertia of the rod and sphere ($1/3\, m_1 l^2 + 2/5\, m_2 r^2$) by defining the linear regression's intercept of the vertical axis (Figure 1.). The difference between direct measurements (m_1 = 283 g, m_2 = 583 g,

l = 1 m and r = 2.5 cm) and indirect estimation is up to 2%. The period was measured using a photogate and multipurpose instrument Meter ZD1301A [1].

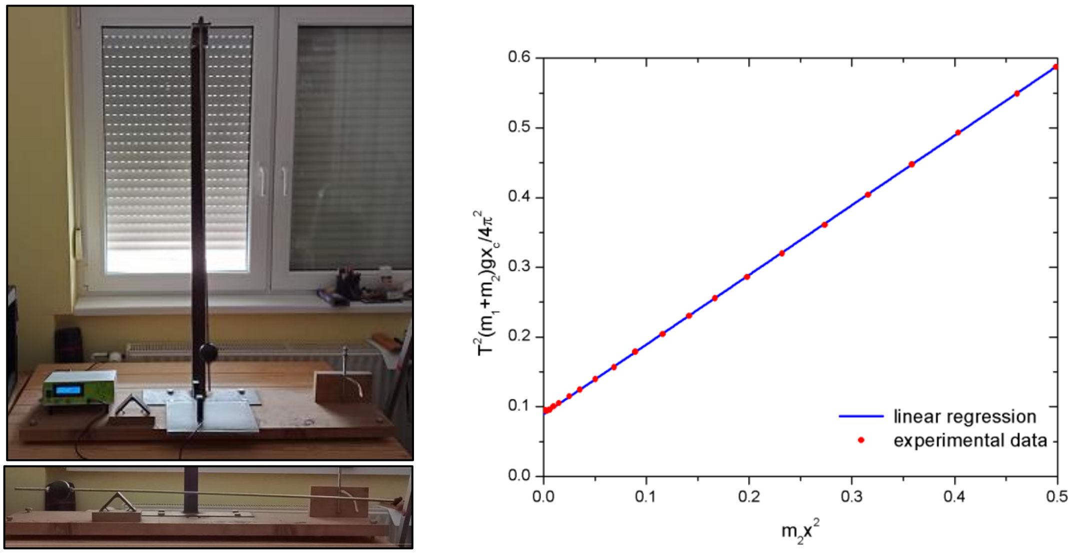

Fig. 1. The physical pendulum with a photogate and Meter ZD1301 (left top), a seesaw balance on the L-profile (left bottom). The graph for estimation of the aggregate moment of inertia (right).

HTLM5 simulation

Figure 2. shows screenshot of the operative version of the HTML5 simulation [2]. Running the simulation allows the user to define the density, length and diameter of the rod, the density, radius and position of the sphere due to pivot point, as well as the initial angle of the physical pendulum. The software calculates the mass of the rod and sphere, the system's centre of mass position from the pivot point, the pendulum's moment of inertia, current angle of displacement, angular velocity and angular acceleration, as well as potential, kinetic and total energy. Angular displacement, angular velocity and acceleration, and energy conservation diagrams are also presented. Our further plan is to extend the simulation with large angle displacement analysis.

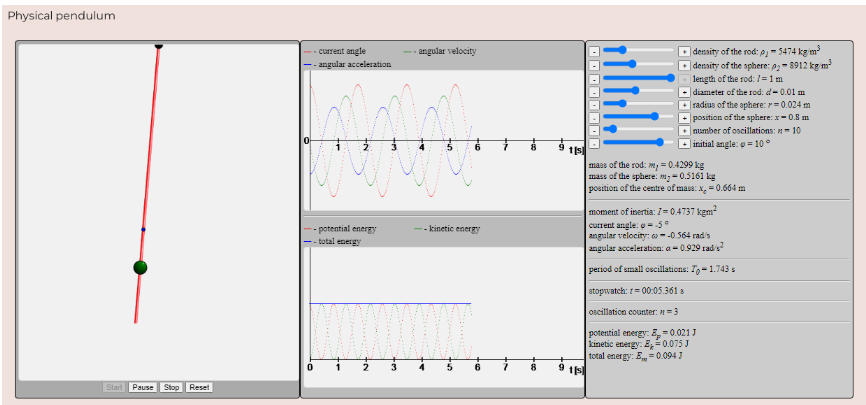

Fig. 2. Working version of the HTML5 simulation.

References

[1] https://drive.google.com/file/d/16pMX9o8qLTQ5CmgxiazOGHirhLKMe4kJ/view?usp=sharing
[2] https://sites.google.com/view/fizika137/f%C5%91oldal