SIMIODE Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations

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Article Review and Annotation

Greenwood, Margaret Stautberg. 1987. Using videotapes to study underdamped motion of a pendulum: a laboratory project. *American Journal of Physics*. 55(7): 645-648.

Article Abstract: Using a video camera with a stopwatch feature and a VCR enabled my class to study the effects of air resistance acting on the following pendulum bobs: Ping-Pong ball, styrofoam spheres, and a brass sphere. We measured the maximum return angle on each swing for a pendulum (L=1 m) released from an angle of 70°. The students wrote a computer program to analyze the data, assuming that the force of air resistance equals cr^2v^2, where c=0.87 kg/m^3. We found that c was larger than this and extracted the force of air resistance acting on the string. As part of the lab project, we also measured the period and position-versus-time when a pendulum with a brass bob was released at a large angle.

Keywords: Laboratory experiments, apparatus, pendulum, bob, second order differential equation.

This article describes several experiments in the study of resistance to pendulum motion with discussion as to just what to set up in a laboratory, how to collect data, student data, and summary conclusions for various bobs at the end of the pendulum.

Basically the efforts is done by ,"Studying the effects of air resistance acting on a lightweight pendulum bob, such as a Ping-Pong ball, by measuring the maximum return angle at each swing." Several numerical methods for solving the nonlinear differential equation for the motion of the pendulum. The equation of interest is

$$\ddot{\theta} = -g \sin\theta / L - (cr^2 L / m)\dot{\theta}\,|\dot{\theta}\,|$$

where the parameters are the obvious ones, g is the acceleration due to gravity, L is the length of the rod, r is the radius of the bob, m is the mass of the bob, and c is the coefficient of resistance, and, of course, θ is the angular displacement of the pendulum rod.

From the data plots of model and actual data in Figure 3 it appears that the modeling was successful!

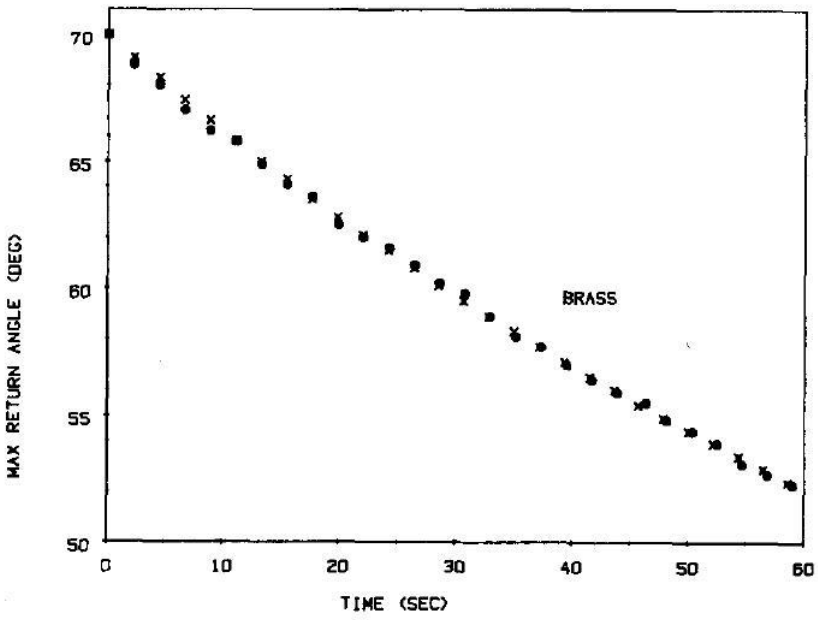

Fig. 3. Maximum return angle versus time for the brass sphere. The experimental data are indicated by circles and the theoretical values by X's.