Energy Conservation in Two Dimensions

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June 4, 2024

1 Motivation

Energy conservation is a cornerstone idea in all of science. In this experiment, we will verify this basic principle by observing the collision of two objects who are moving in a two dimensional plane.

KEYWORDS

Conservation of Energy · Projectile · Pendulum

APPROXIMATE PERFORMANCE TIME 4 **Hours**

2 Conceptual Objectives

In this experiment, we will,

1. understand the concept of energy conservation,
2. create and observe a fully-translational collision,
3. quantitatively demonstrate the near-elasticity of a collision,

4. learn how to compare theoretical predictions with experimental observations and

5. run through a complete cycle of experiment, data generation, analysis and presentation.

3 The Experiment

The apparatus consists of a ball attached with a thin stainless rod connected with a bearing to form a relatively low-loss pendulum [1]. By construction, the pendulum ball follows a circular arc and is not allowed to twist as it swings through the arc. The pendulum ball is held at its highest position by a thread strung over a pulley like attachment and is shown in the accompanying Figure. To start the ball in motion either a match can be used to sever the thread [2] or the thread can be pulled and released manually by hand from the desired position.

In order to achieve pure translational motion of the projectile ball, the balls must touch at the exact bottom of the swinging ball's arc in such a way that the line connecting the center of the two balls at collision is in both the plane of the arc and in a horizontal plane. To achieve this precision, a screw adjusts the height of fulcrum to ensure that struck ball leaves the tee along an initially horizontal path.

The ball flies off the setup and drops to the floor on a platform where its position is recorded when it strikes a piece of carbon paper, leaving a small dot on the graph paper. The parameters that are measured before the experiment is performed are L and h. Variables measured during the experiment include θ, the angle swinging ball pendulum is positioned at, and d, the horizontal distance the struck ball travels before hitting the floor. The linear distances are measured with a meter-stick and the angle is determined from the protractor attached to the apparatus.

Q 1. Using the principle of conservation of energy, derive a formula for d. Measure d and see comparison with theory. What is the percentage error between predicted and measured distances?

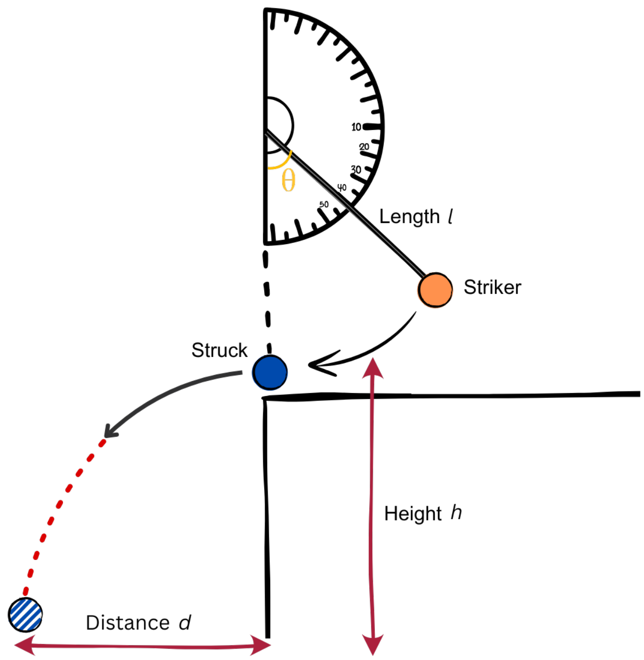

Figure 1: A depiction of what the experiment looks like. We also identify the parameters to measure.

Q 2. You are required to present your data graphically. Choose your axes and variables. Plot the uncertainties as well. You will be given points for (a) selecting the most suitable variables for plotting, (b) calculating uncertainties in the variables, (c) comparing a best fit to your data and the predicted curves. [This is an open-ended and you are required to explore and come up with the best strategy of presenting your data.]

Q 3. Compare a best fit of your data with a graph for the predicted outcome. Use these two graphs to estimate the energy lost in a collision.

References

[1] A thin rod with a bearing was used because attempts to construct the setup using threads was not successful. With threads, after the colli-

sion the pendulum ball almost always twists back and forth as the two threads on either side of the ball oscillate out-of-plane. This twisting added an intolerable energy loss.

[2] The thread and match are used in starting the pendulum to ensure that there is no additional momentum to disturb the ball as it begins its swing. This technique was pioneered by Foucault as described in Amir D. Aczel's biography "Pendulum: Leon Foucault and the Triumph of Science" (Atria Books, New York, 2003).