LabReport

September 26, 2020

<IPython.core.display.HTML object>

1 Ballistic Pendulum Experiment

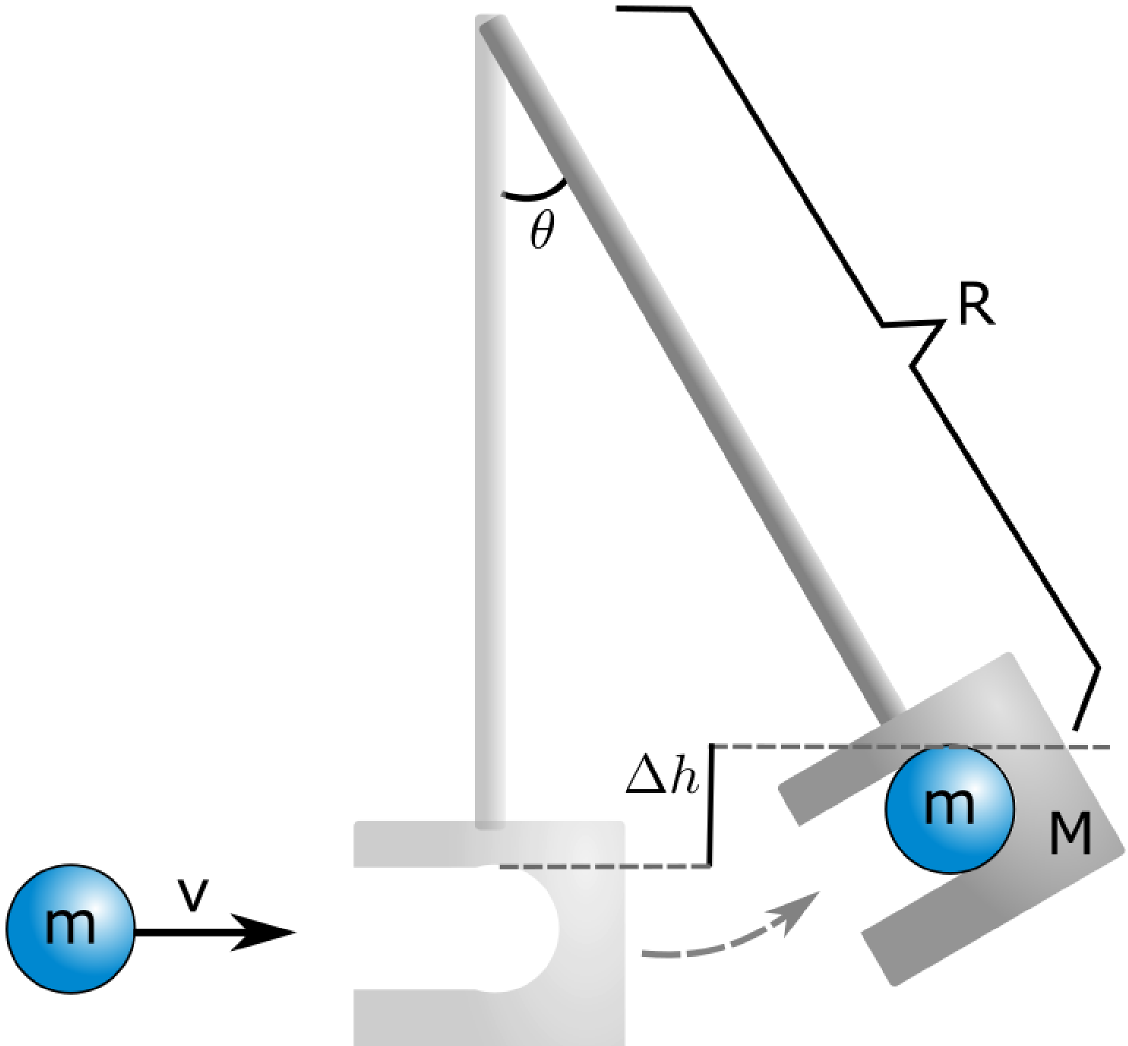
1.1 Abstract

1.2 Introduction

The goal of this experiment was to calculate the initial velocity of a projectile using two fundamental physical models, and compare the results to see if the models agree with each other. The two models that were used to compute the ball's initial velocity in this experiment were the conservation of energy laws and kinematics equations.

1.2.1 Method 1

First, the velocity of the projectile was calculated using the conservation of momentum and the conservation of energy laws. To do this, the projectile(a round metal ball) was launched into a pendulum, which captured the ball. Then the max angle of the pendulum was taken as it swung up, as shown in figure 1.



The collision between the pendulum and the ball is inelastic, and therefore the momentum before the collision must be maintained after the collision. If the mass of the ball is defined as m, the velocity of the ball as v, the mass of the pendulum as M, and the velocity of the pendulum and ball combined as V, the relationship can be defined as $mv = (m+M)V$. Rearranging this formula provides a way to solve for the original ball's velocity.

$$v = \frac{(m+M)V}{m}$$

By further observation of the system, it can be seen that the energy of the system is conserved, and is either stored in the form of kinetic or gravitational potential energy. Immediately after the collision, all energy is of kinetic form, and can be easily calculated using $KE = \frac{1}{2}(m+M)V^2$. When the pendulum reaches its maximum height or angle, the pendulum stops for a split second. Therefore, all energy is found in gravitational potential form, and can be expressed as $PE = (m+M)g\Delta h$. Applying the conservation of energy law, it can be assumed the initial kinetic energy is equal to the final potential energy. This can be written as below, and rewritten so as to solve for the velocity of the pendulum.

$$\frac{1}{2}(m+M)V^2 = (m+M)g\Delta h$$

$$V = \sqrt{2g\Delta h}$$

It is possible to compute the height the pendulum lifts by simple application of trigonometric functions. The height is the difference of the pendulum height and the final y component of the pendulum. If the length of the pendulum bob is defined as R, and the angle is defined as θ, the change in th height of the pendulum can be expressed as below.

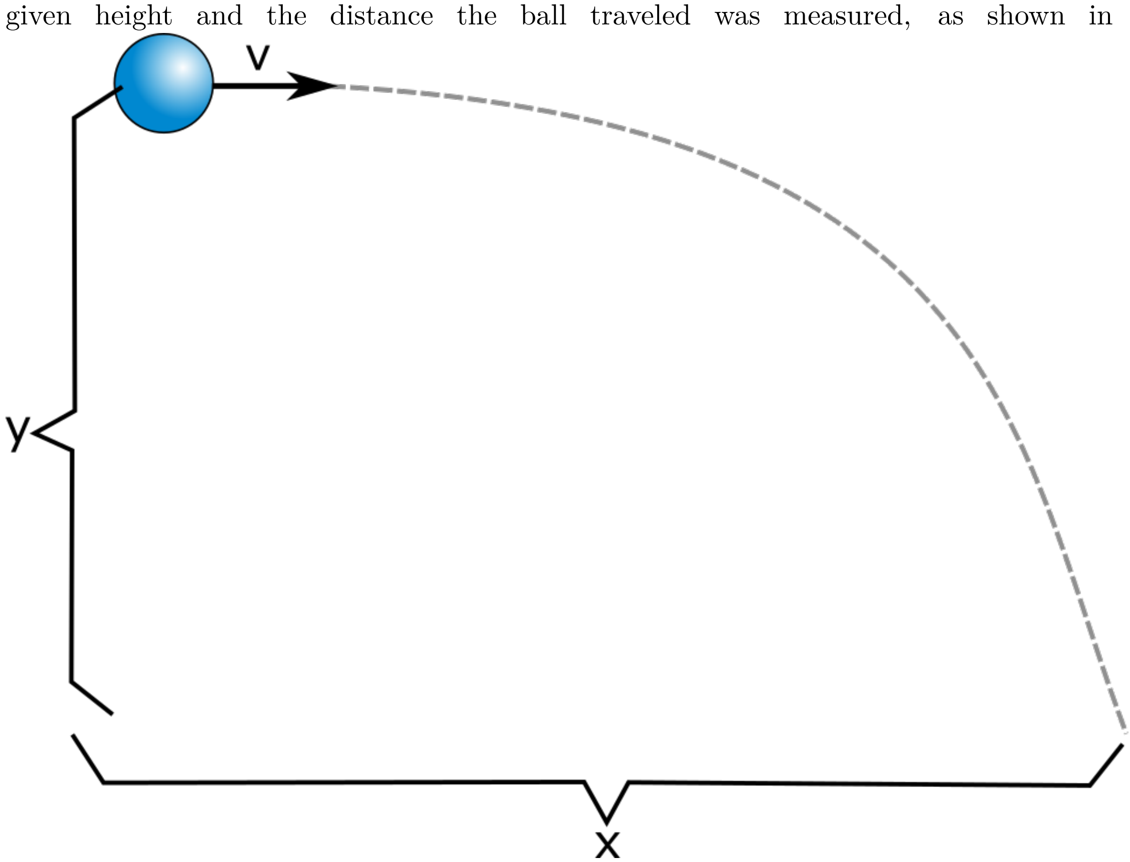
$$\Delta h = R - R\cos(\theta) = R(1 - \cos(\theta))$$

By combining equations (1), (2), and (3), as shown above, the initial velocity of the ball can be computed from the pendulum height and angle using the formula shown below.

$$v = \frac{m+M}{m}\sqrt{2gR(1-cos(\theta))}$$

1.2.2 Method 2

For the second part, the velocity of the projectile was measured using kinematics equations. To accomplish this, the ball was launched from a table with a given height and the distance the ball traveled was measured, as shown in figure 2.



Ignoring air resistance, given its impact on the system is minimal, there is no acceleration in the x direction. The only acceleration which affects the system is the acceleration due to gravity, which only acts on the y component of the motion. This system can be represented using 2 kinematic equations, namely $\Delta x = v_i t$ and $\Delta y = \frac{1}{2}gt^2$, where Δx is the displacement on the x-axis, Δy is the displacement on the y-axis, and v_i is the initial velocity. Solving this system for v_i gives us the formula below for computing the initial velocity.

$$v_i = \Delta x\sqrt{\frac{g}{2\Delta y}}$$

1.3 Data

1.3.1 Method 1

For the first part of the experiment the length of pendulum R, mass of the pendulum M, and the mass of the ball m where needed. The length of the pendulum from the pivot point to the center of mass was measured to be $R = 27.70 \pm 0.20$ cm. The center of mass was determined by adjusting the pendulum until it balanced on a thin metal pole. The mass of the pendulum was measured on a digital scale to be $M = 191.70 \pm 0.10$ g. The mass of the ball, also measured on a digital scale, was determined to be $m = 65.50 \pm 0.10$ g. Once all preliminary measurements were taken, the ball was launched into the pendulum 10 times, and the max angle the pendulum reached was recorded.

Table1

Trial

Theta θ°

0

45.0

1.0

1

46.0

2.0

2

45.5

3.0

3

46.0

4.0

4

46.0

5.0

5

46.0

6.0

6

46.0

7.0

7

46.0

8.0

8

46.0

9.0

9

46.0

10.0

1.4 Data Analysis

1.5 Results/Conclusions