Union College Winter 2022

Physics 120: Lab 6

The Ballistic Pendulum

In this experiment you will determine the muzzle speed of a gun using a setup called a ballistic pendulum. The ball will be fired into the ballistic pendulum (shown in Figure 1) and by properly analyzing the collision between the ball and pendulum and the swing of the pendulum to a maximum height, you'll determine "the muzzle speed."

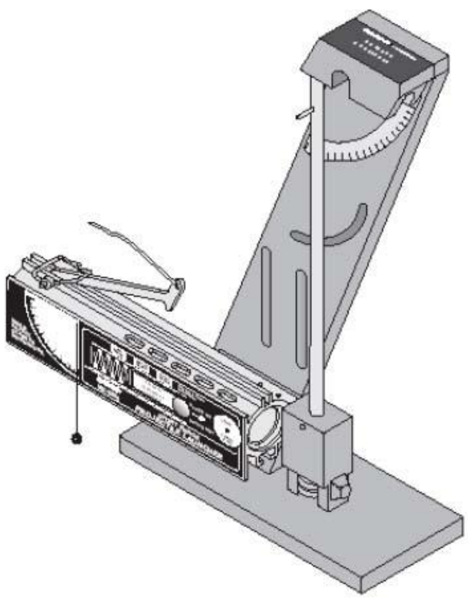

Figure 1: The ballistic pendulum apparatus

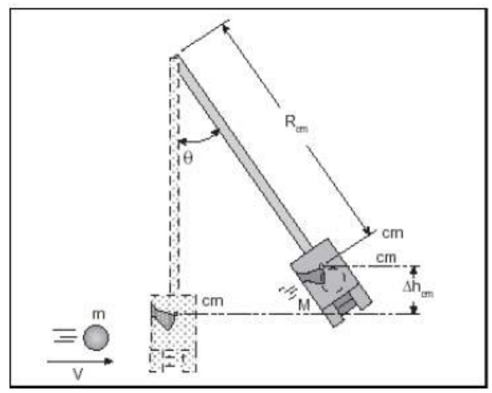

Figure 2: A ball of mass, m, and speed, v, is caught by the pendulum, which swings up to an angle θ.

Derivation of the Equation for Muzzle Speed

A ball fired with speed, v, will get caught by the ballistic pendulum, which will then swing upward to some maximum angle, θ, as shown in Figures 1 and 2. Apply the proper principles in the two events—the collision between ball and pendulum and the swing upward of the pendulum with ball--to derive an expression for v in terms of:

- the mass of the ball, m,
- the mass of the pendulum, M,
- the length of the pendulum pivot point to the center of mass, R_{com},
- the strength of the gravitational field, g,
- and the maximum angle of the pendulum's swing, θ.

The Experiment

1. Remove the pendulum and obtain the masses of the steel ball and pendulum, and estimate the uncertainties. Record these data in an Excel table.

2. Determine the center of mass of the pendulum with the ball in it by finding the point where it best balances on the edge of a ruler. Measure the distance from the pivot point to this balance point, estimate the uncertainty, and record in the data table.

3. Reattach the pendulum, insert the ball into the launcher, and cock it to medium range.

4. Let the pendulum hang at its vertical position and move the angle indicator to zero degrees. Fire the launcher and note and record the angle reached.

5. Reload the launcher and set the angle indicator to an angle of 5^o less than that reached in step 4. This will nearly eliminate the drag on the pendulum caused by the angle indicator, since the pendulum will only move the indicator the last few degrees.

6. Fire the launcher and record, in the Excel table, the angle reached by the pendulum. Try to estimate the angle to the nearest 1/2 degree.

7. Repeat steps 5 and 6, recording the angle each time, completing 10 trials.

8. Input the expression you derived in Section 2 into Excel to calculate the muzzle speed of the launcher for each trial. Calculate the average v and uncertainty, and record the result as $v \pm \Delta v$.

Photogate measure of muzzle velocity

9. As one test of your measured and calculated value of the ball's velocity, set up the photogate as close, as possible, to the exit of the ball launcher.

10. On the desktop, open Capstone and set up as follows:
    a. Open Capstone, click hardware setup and under hardware setup choose *photogate 1 flag*.
    b. After selecting *photogate 1 flag*, click on the blue cog in the lower right corner of the dialog box.
    c. Set the flag width to the width of the ball, $25mm = 0.025m$.
    d. Close the dialog box and the hardware setup box.
    e. Select table from the options on the right and choose **speed** (m/s) and **time in gate** (in ms) for the two table columns.

11. When ready, click "Record," launch the ball through the gate, and note the ball's speed. Repeat. Get 10 measurements, average, and obtain the uncertainty.

12. Compare your two values of the measured muzzle velocity. Are they consistent?

Projectile Motion measure of muzzle velocity

13. Orient the launcher horizontally and measure the height of the projectile above the ground.

14. Load and fire the launcher and measure the horizontal distance that the projectile strikes the ground from its launch point.

15. Repeat the measurement 10 times and determine an average value of the muzzle velocity of the projectile with uncertainty.

16. Compare this value of the muzzle velocity with your two previously measured values of the measured muzzle velocity. Are they consistent?

To be collected on Wednesday, 2/23/22. Everyone needs to hand in an individual copy which includes answers to the following in complete sentences. This is not a group project and the answers to the questions should be your own work and words.

The excel file with your data and any calculations made in excel. Typically, these are the averages for values you need in a calculation. All of the derivations and calculations based on these derivations in each experiment should be done by hand.

Ballistic Pendulum

Derivation of the muzzle velocity of the launcher.

Derivation of the uncertainty in the muzzle velocity of the launcher.

Calculation of the muzzle velocity of the launcher with uncertainty. This needs to show the numbers that were input to the calculation as well as the numerical answer.

Derivation of the percent of the kinetic energy lost in the collision.

Calculation of the percent of the kinetic energy lost in the collision.

Photogate

Calculation of the uncertainty in the velocity from the photogate experiment.

Calculation of the muzzle velocity of the launcher from the photogate experiment.

Calculation of the muzzle velocity of the launcher with uncertainty from the photogate experiment.

Comparison between the muzzle velocity of the projectile from the ballistic pendulum to the photogate. This needs to be written in words explaining how the two speeds agree or disagree (within experimental uncertainties) and why.

Projectile Motion

Derivation of the muzzle velocity of the projectile.

Derivation of the uncertainty in the muzzle velocity.

Calculation of the muzzle velocity of the launcher with uncertainty. This needs to show the numbers that were input to the calculation as well as the numerical answer.

Comparison between the muzzle velocity of the projectile from the ballistic pendulum and from the photogate to the muzzle velocity determined from projectile motion. This needs to be written in words explaining how the three speeds agree or disagree (within experimental uncertainties) and why.

Discussion

Discuss briefly the three experiments you performed and their outcomes. In particular answer the following questions in analyzing the outcome of the experiments you performed. How do the muzzle velocities compare for all three methods? Which method do you think is more accurate in determining the muzzle velocity and why? Considering the projectile motion and ballistic pendulum experiments, which of these is more accurate and why? Based on your reasons, which is a better method for determining the initial velocity of an object, using forces or by energy/momentum?