Lab 2: Projectile Motion

Name: ____________________________

Lab Partner(s): ____________________________

Honor Code Statement: I affirm that I have carried out my academic endeavors with full academic honesty. ____

Please neatly answer all of the questions in the lab packet. Make sure you attach any graphs generated, Excel files you produced, and any calculations/derivations you did. You can hand write the calculations/derivations or type them. This lab packet is due one week from the completion of the lab.

Introduction

In this lab, we will study the motion of small metal balls fired from a spring-powered projectile launcher. You will use two different methods to determine the velocity of the balls as they leave the launcher, and use that velocity, together with the equations governing projectile motion, to predict the range of a projectile fired horizontally from the table top. As a test of your prediction, you will be asked to use the prediction to place a target on the floor at the spot where the ball will land. Along the way, you will also investigate some new techniques of error analysis, and the differences between systematic and random errors.

Apparatus

The apparatus for this lab consists of a spring-powered projectile launcher (shown in Figure 1) which will fire a small ball into the air. The goal of the lab is to determine the velocity of the ball leaving the launcher, and use that velocity to predict the flight of the ball when the launcher is used to fire the ball across the room.

For the first part of the experiment, the launcher will be fired straight up into the air. Place the launcher on the floor, and make sure the protractor reads 90° measured from the horizontal, and that the screws holding the launcher to the mount are tightened down. Make sure that the launcher is not aimed at a light (launchers which are mistakenly fired on the "high" setting will fire a ball into the ceiling hard enough to shatter light bulbs and make a mess), set the launcher to the "medium" setting (the second notch down), and fire the ball by tugging sharply on the launch cord. When firing the launcher, be sure to hold it down with your free hand. For the second part of the laboratory experiment we will determine the angle at which the ball was fired by measuring parameters associated with the projectile's flight.

Figure 1: Pasco projectile launcher. https://www.pasco.com/products/lab-apparatus/mechanics/projectiles/projectile-launcher

Procedure

Part 1: Muzzle Velocity from Time of Flight

a. One method you can use to find the velocity of a ball leaving the launcher is to measure the time it takes for the ball to reach its maximum height. Fire the launcher straight up, and use a stopwatch to measure the time between the firing of the launcher and the highest point the ball reaches. Each member of your group should repeat the measurement a total of ten times. Enter the time of flight for each of your measurements in Excel and determine the average and standard deviation σ of the repeated measurements.

$t_{avg} =$

$\sigma =$

b. For the uncertainty in the time measurement Δt, we will use two times the standard deviation of the mean given by

$$\Delta t = 2\sigma_m = 2\left(\frac{\sigma}{\sqrt{N}}\right)$$

where N is the number of measurements. Calculate the uncertainty and record the time-of-flight as $t_{avg} \pm \Delta t$ using the correct number of significant digits.

$\delta t =$

$t = t_{avg} \pm \Delta t =$

c. Using an appropriate equation for projectile motion and the average value of the time of flight you obtained, calculate the initial velocity of the ball when it left the. Also, derive an expression for and then determine the uncertainty in the velocity Δv from the uncertainty in the time measurement and record the final answer in the form $v_{avg} \pm \Delta v$ in the space below with the proper number of significant digits.

$v_1 = v_{avg,1} \pm \Delta v$

Part 2: Muzzle Velocity from Maximum Height

a. A second method of determining the initial velocity is to instead measure the maximum height y reached by the ball. You may need to stand on the table in order to read the height. Take a few practice shots to determine the best way to read the ball's height using the meter stick. Each member of your group should repeat the measurement a total of ten times. Enter the height the ball reaches for each of your measurements in Excel and determine the average and standard deviation σ of the repeated measurements.

$y_{avg} =$

$\sigma =$

b. For the uncertainty in the height measurement Δy we will use two times the standard deviation of the mean given by

$$\Delta y = 2\sigma_m = 2\left(\frac{\sigma}{\sqrt{N}}\right)$$

where N is the number of measurements. Calculate the uncertainty and record the average value of y and the uncertainty as $y_{avg} \pm \Delta y$ below with the proper number of significant digits.

$\Delta y =$

$y = y_{avg} \pm \Delta y =$

c. Using an appropriate equation of motion governing free-fall and the average value of the maximum height, calculate the initial velocity of the ball when it leaves the launcher (remember to include the height of the launcher in your calculation). Also, derive an equation for and then determine the uncertainty in the velocity from the standard deviation of the maximum height measurements and record the final answer in the form $v \pm \delta v$ in the space below with the proper number of significant digits. Do the muzzle velocities determined in Parts 1 and 2 agree within experimental uncertainties? If not, explain why. Which value do you have more confidence in and why?

$v_2 = v_{avg,2} \pm \Delta v$

Part 3: Projectile Motion

a. Clamp the projectile launcher to the edge of your lab table. Make sure that the launcher is pointing in a direction such that the projectile can travel a horizontal distance of about $2m$ without hitting anything or anyone. Have your instructor set the projectile launcher to a random angle between $0 \leq \theta \leq 90^0$. Measure the height h of the muzzle from the floor and record it below along with an estimated uncertainty as $y \pm \Delta y$ with the proper number of significant digits. The muzzle height is the height from the floor to where the projectile leaves the launcher.

$h = y \pm \Delta y =$

b. Load the ball and fire it. Measure the horizontal distance D the ball lands from the launcher and record it as $x \pm \Delta x$ with the proper number of significant digits.

$D = x \pm \Delta x =$

c. Using your best value of the launch speed of the ball and the measurements made in parts 3a and 3b, derive an expression for and determine the launch angle θ_{lauch} along with its uncertainty, $\theta_{lauch} = \theta \pm \Delta\theta$, at which the ball was launched.

$\theta_{lauch} = \theta \pm \Delta\theta =$

d. How reasonable do you think your value of θ_{launch} is? Explain.

e. What assumptions does your calculation depend on? Are these reasonable? Explain.