

# Projectile Motion

## 1 Equipment

- Safety goggles
- Computer
- PASCO Scientific Interface Box
- Projectile Launcher
- Ramrod
- Ball (2.5cm diameter)
- Carbon copy paper

## 2 Introduction

The equations of motion allows us to predict the projectile motion of an object. In this experiment a ball will be launched at different initial angle and velocity. The resulting motion will be checked against predictions made using the initial velocity measured by a photogate.



Figure 1: Projectile launcher

## 3 Theory

Given the launch speed  $v_0$  and the launch angle  $\alpha$ , the horizontal and vertical components of the initial velocity is given by:

$$v_{0x} = v_0 \cos \alpha$$

$$v_{0y} = v_0 \sin \alpha$$

The vertical position of an object launched at height  $y_0$  with angle  $\theta$  is given by:

$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2.$$

Putting  $y = 0$  allows one to solve for the time when the object hits the ground  $t_{ground}$ :

$$0 = y_0 + v_{0y}t_{ground} - \frac{1}{2}gt_{ground}^2.$$

Once  $t_{ground}$  is known, the horizontal displacement can be found by:

$$x_{theory} = v_{0x}t_{ground}.$$

## 4 Procedure

1. Every student must wear safety goggles. Never look down the front of the barrel because it may be loaded. Be very careful walking around the lab because you may be in the line of fire from another group. If you are responsible for firing the launcher, you need to make sure the path is cleared before the trigger is pulled.
2. Place the launcher on the ground and point toward a long corridor. Do not aim the launcher at walls, ceiling or computers.
3. Connect the photogate to digital channel 1 on the interface box. Place the photogate immediately in front of the launch barrel such that the center of the ball will pass through the sensors on the photogate when shot.
4. Connect the PASCO interface box to the computer. Choose the program "Data Studio" on the computer. Click on "Create Experiment" after the program begins.
5. The **Experiment Setup** window automatically opens. Click on the image of channel 1. From the popup list scroll down and select **Photogate** and click OK.
6. At the bottom of the **Experiment Setup** window under the tab **Measurements**, make sure **velocity** is selected.
7. Under the tab **Constants**, type the value 0.025m as the **Flag Length**. This is the diameter of the ball which the computer uses to compute the velocity.
8. Close the **Experiment Setup** window. Anytime you wish to make changes to the setup you can click on **Setup** on the to left hand corner of the main window.
9. Under **Display**, you see the item **Digits**. Double click on it and a **Data Source** window opens. Click on **Velocity** and select OK. A blank window should open. This is the window which will display the launch velocity after the ball passes the photogate.
10. Set the angle to  $30^\circ$ .
11. Measure the vertical distance from the **bottom** of the ball as it leaves the barrel to the floor. For your convenience, the "Launch Position of Ball in the barrel is marked on the side of the launcher at the muzzle. Record this distance as  $y_0$  in Table 1.
12. Note the position of the launcher on the ground (it may shift during loading and launching), you will need to make sure every shot from now on be fired from the same location. Use the ramrod to load the ball into a low velocity setting (i.e. do not push the ball all the way in).
13. Have one student hold the launcher steady. On the computer, press the **Start** button.
14. Fire one shot to locate where the ball hits the floor. At that point, tape a piece of white paper to the floor. Place a piece of carbon paper (carbon-side down) on top of the white paper and tape it in place. When the ball hits the carbon paper on the floor, it will leave a mark on the white paper.
15. Shoot the ball at the same angle and the same velocity setting four times. Make sure the position of the launcher remains the same for these four shots. They should hit the carbon paper four times leaving four marks.

16. Find the point on the floor that is directly beneath the **release point** on the barrel. Measure the horizontal distance along the floor from the release point to the **leading edge** of the piece of white paper. Record the distance as  $x_p$  in Table 1.
17. Carefully remove the carbon paper and measure from the leading edge of the white paper to each of the dots. Record these distances in Table 1 and find the average  $x_m$ . Calculate and record the total horizontal distance (distance to paper plus average distance from edge of paper to dots),  $x_{measured} = x_p + x_m$ .
18. Repeat Step 10 to Step 17 six more times for different angles and velocity settings. Make sure that the velocity setting remains the same for each angular setting. For example, if you used a high velocity setting for  $50^\circ$  in the first shot, use a high velocity setting for the remaining three shots. Otherwise the ball will not land at the same place.

Table 1: Calculating Acceleration from the Slope of the Velocity vs Time Curve

Trial	1	2	3	4	5	6	7
$y_0$ , Launch height (m)							
$\alpha$ , Launch angle ( $^\circ$ )							
Launch velocity ( $m/s^2$ ) [Shot 1]							
Launch velocity ( $m/s^2$ ) [Shot 2]							
Launch velocity ( $m/s^2$ ) [Shot 3]							
Launch velocity ( $m/s^2$ ) [Shot 4]							
$v_0$ , Launch velocity ( $m/s^2$ ) [Average]							
$v_{0x} = v_0 \cos \alpha$ ( $m/s^2$ )							
$v_{0y} = v_0 \sin \alpha$ ( $m/s^2$ )							
Distance of mark from leading edge (m) [Spot 1]							
Distance of mark from leading edge (m) [Spot 2]							
Distance of mark from leading edge (m) [Spot 3]							
Distance of mark from leading edge (m) [Spot 4]							
$x_m$ , Distance of mark from leading edge (m) [Average]							
$x_p$ , Distance of leading edge from launcher (m)							
$x_{measured} = x_p + x_m$ (m)							
$x_{theory}$ (m)							
Percentage difference of $x_{measured}$ and $x_{theory}$							