General Physics I Lab

M2 Projectile Motion

Purpose

In this experiment, you will study the motion of a ball undergoing projectile motion for different inclination angles.

Equipment and components

PASCO 550 Universal Interface, mini launcher, Smart Gate on mounting bracket, steel ball, pushrod, safety goggles, Time-of-Flight accessory, G-clamp, measuring tape, plumb bob, hanging mass, carbon paper and white paper, adhesive tape.

Background

When a ball is fired by a launcher at an angle θ with respect to the horizontal, as shown in Fig. 1 below, its horizontal and vertical motions are completely independent of each other and can be solved separately, with time *t* as the common variable for both components.

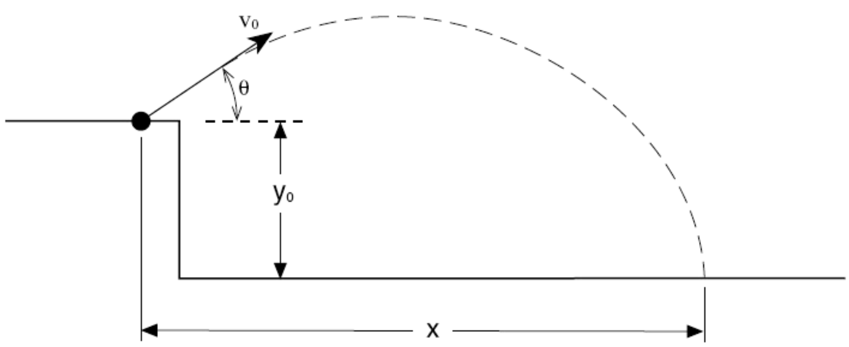

Figure 1 Vertical and horizontal motions of a projectile

The horizontal velocity, v_x, of the projectile remains constant since no force acts in this direction,

$$v_x = v_0 \cos\theta, \qquad (1)$$

where v_0 is the initial velocity of the projectile. However, the vertical velocity, v_y, undergoes uniform acceleration due to gravity,

$$v_y = v_0 \sin\theta - gt, \qquad (2)$$

where g = 9.8 m/s^2 and t is the elapsed time.

The horizontal displacement, x, of the projectile is simply given by

$$x = v_x t \qquad (3)$$

while the vertical displacement, y, has the form

$$y = y_0 + (v_0 \sin\theta)t - \frac{1}{2}gt^2 \qquad (4)$$

where y_0 is the initial height of the ball and y is the position of the ball when it hits the floor.

Procedure

This experiment contains two parts: (I) to determine the initial velocity, the time-of-flight and the horizontal travelling distance of the projectile, and (II) to study the effect of different angles of inclination.

Safety reminder:

- **Always wear the safety goggles during the whole experiment.**
- **Never look down the front of the barrel.**
- **Make certain that no person is in the path of the ball prior to launching.**
- **Never leave a loaded launcher unattended.**

Initial setup (as shown in Figure 2)

1. Connect the *PASCO 550 Universal Interface* to the computer. Turn on the interface and the computer.
2. Mount the base of the mini launcher to the edge of a sturdy table with a G-clamp. Aim the launcher away from the table toward the center of an open area at least two meters away.

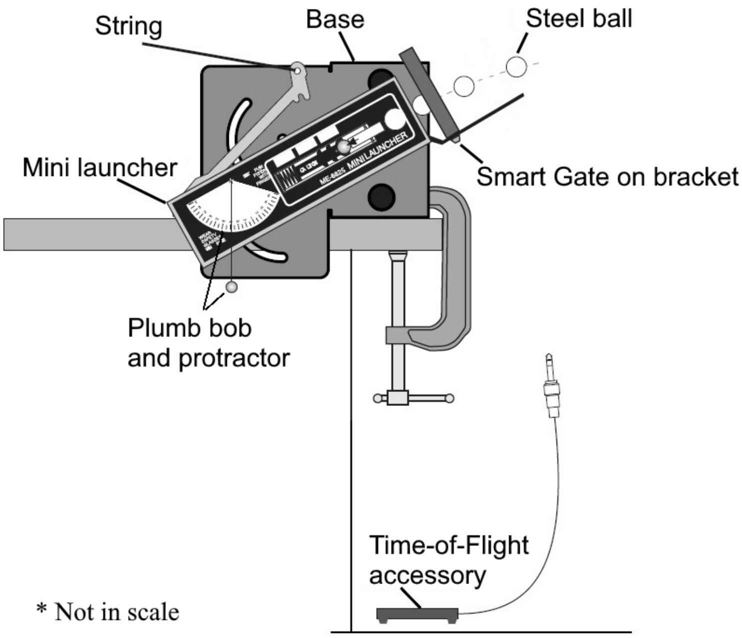

Figure 2. Initial experimental setup

3. Mount the Smart Gate to the mounting bracket. Slide the bracket into the T-slot on the bottom side of the launcher. **NOTE:** The Smart Gate consists of two photogates that are closely packed (the separation between them is 15mm); it can measure the time for the motion of a moving object.
4. Loose the two thumbscrews that mounted the launcher to the base and slide the launcher backwards such that the square nut that the launcher pivots around should be slid to the front of the launcher. As a result, when the angle of the launcher is changed, the launch position does not change. Tighten the two thumbscrews.
5. Connect the Smart Gate into the "PASPORT 1" input on the interface.
6. Adjust the position of the mounting bracket until the Smart Gate is as close to the barrel as possible without blocking the beam. **NOTE:** The red LED (light-emitting diode) indicator on the Smart Gate is on when anyone of the infrared light beam of the photogates on the Smart Gate is blocked.

7. Connect the stereo phone plug of the Time-of-Flight accessory into the Auxiliary port on the Smart gate using the extender cable. Put the Time-of-Flight accessory right below the barrel of the launcher. **NOTE:** *Be careful not to trip on the extender cable and **not to step** on the Time-of-Flight accessory.*

Part I. Measurement of the initial velocity, time-of-flight and horizontal travelling distance of the projectile

1. Adjust the angle of the mini launcher to 58° above the horizontal and record this value in Table 1. The angle of inclination is adjusted by loosening the thumbscrews and rotating the launcher to the desired angle as indicated by the plumb bob and protractor on the side of the launcher. When the angle is selected, tighten the thumbscrews.
2. Measure the vertical distance from the bottom of the ball as it leaves the barrel (this position is marked on the side of the barrel) to the top of the Time-of-Flight accessory, Record this distance in Table 1.
3. Open the “M2” program in the course folder. The program will open with Digits displays of time between photogates (sec), initial velocity (m/sec) and time-of-flight (sec).
    - The program measures the elapsed blocking time of two photogates and then calculate the initial velocity, which is equal to the separation between the two photogates divided by the elapsed blocking time. It also measures the time-of-flight when the ball enters the first photogate until it hits the Time-of-Flight accessory.
4. Place the steel ball in the barrel and cock it down to the medium range position. Two audible clicks indicate that the piston is cocked in the medium range.
5. Test fire the ball by pulling straight up the yellow string attached to the trigger and determine where to place the timer plate on the floor. Put the Time-of-Flight accessory on the floor where the ball hits.
6. Tape a piece of white paper on the Time-of-Flight accessory and put a piece of carbon paper with carbon-side DOWN above the piece of white paper (**NOTE:** Do NOT paste the carbon paper) to record where the ball lands.

<u>Data recording and analysis</u>

1. Load the steel ball to the medium range position.
2. Click the “Record” button in the Controls palette and then shoot the ball.
    - Data recording will stop automatically when the time-of-flight value is larger than zero (that is, when the ball hits the Time-of-Flight accessory). “Run #1” will appear in the Data set.
3. Record the values of the initial velocity and time-of-flight in Table 1.
4. Mark the trial number on the white paper where the steel ball lands.
5. Repeat steps 1 to 4 for four more trials.
6. Use a plumb bob to find the point on the floor that is directly beneath the release point on the barrel. Measure the horizontal distances for each of the five dots and record these distances in Table 1.
7. Calculate the average and the standard error of the initial velocity, time-of-flight and horizontal distance and record the values in Table 1.

Part II. Study of the effect of different angles of inclination

Change the angle of inclination to 35°. Repeat the measurements in Part I with five trials. Record the results of the measurements in Table 2.