LAB 5
Projectile Motion

OBJECTIVES

(1) Observe the two-dimensional motion of a projectile.
(2) Use the kinematics equations to compute the initial speed and the range of a launched projectile.

EQUIPMENT

Spring-loaded gun, photogate timers, computers, targets and meter sticks.

THEORY

Projectile motion is the motion of a particle that is launched with an initial velocity $\vec{v}_0$ in the absence of air resistance. During the flight, the particle's horizontal acceleration is zero and its vertical acceleration is 9.8 m/s^2 downward. If $\vec{v}_0$ is expressed as a magnitude v_0 and an angle θ, the particle's equations of motion along the horizontal x-axis and vertical y-axis are

$$(v_x)_f = (v_x)_i, \qquad x_f = x_i + (v_x)_i \Delta t, \qquad \text{where } (v_x)_i = v_i \cos\theta$$
$$(v_y)_f = (v_y)_i + a_y \Delta t, \quad y_f = y_i + (v_y)_i \Delta t + \tfrac{1}{2} a_y t^2, \quad \text{where } (v_y)_i = v_i \sin\theta$$

The **horizontal range R** of a projectile is the **horizontal** distance it has traveled when it returns to its initial launch height, given by:

$$R = \frac{v_i^2 \sin(2\theta)}{g}$$

PROCEDURE

Part 1: Measuring the Muzzle Velocity

Horizontal Projections with Laser Timer

(a) Place the spring gun on the lab table and set up the photogate timer so that it records the time it takes for the ball to pass through the photogate.

(b) Fire the ball horizontally and measure the time it takes the ball to interrupt the laser beam. Repeat this 10 times.

(c) Measure the diameter of the ball with a Vernier or micrometer caliper.

(d) From the diameter of the ball, calculate the initial speed v_i of the ball for each of your ten times. Make sure that your initial speed is in units of m/s.

(e) From your ten values of v_i, calculate your average v_{ave} and standard deviation σ_{vi}. Express your results as $v_i = v_{ave} \pm \sigma_{vi}$.

Projections at a 45° Angle

(f) Fire a ball from a launcher tilted at an angle of 45° such that its landing place is at the same height as its initial launch height (you will need to use a pile of books or catalogs to raise your target spot). Place a sheet of paper where it hits the target, circling the marks that the ball leaves on the paper.

(g) Repeat a total of 10 times. Organize all data into a table.

(h) For each of your ten values of R, use the range equation to find the initial speed v_i of the ball.

(i) From your ten values of v_i, calculate your average v_{ave} and standard deviation σ_{vi}. Express your results as $v_i = v_{ave} \pm \sigma_{vi}$.

(j) *How do your two calculations for the initial speed compare? Which do you think is more accurate and why?*

Part 2: Predicting the Range for a Horizontally Launched Ball

(a) Place the spring gun horizontally on the lab bench and measure the vertical distance y between the floor and the ball's center. Use the equations of constant acceleration to find the time Δt the ball will be in the air before hitting the ground (Hint: consider the y-components).

(b) Use the equations of constant acceleration to **predict the distance x_{thy}** the ball will move while in the air (Hint: consider the x-components). Organize all data into a table.

(c) Place a target at your predicted distance x_{thy} and see if you can hit it on the first try! Find the instructor to watch your shot. **(Prizes are awarded for groups who hit their target on the first shot.)**

(d) Shoot and report the results. If the launched ball does not land in the target, readjust the range of the target and retake the shot until it does go in. The range where the ball goes into the target is the **experimental distance x_{exp}.**

(e) *Use a percent difference to compare the predicted range x_{thy} with the experimental range x_{exp}. How do they compare?*