Experiment 1: Projectile Motion

EQUIPMENT NEEDED:

- Mini Launcher and steel ball
- Plumb bob
- Meter stick
- Carbon paper
- White paper

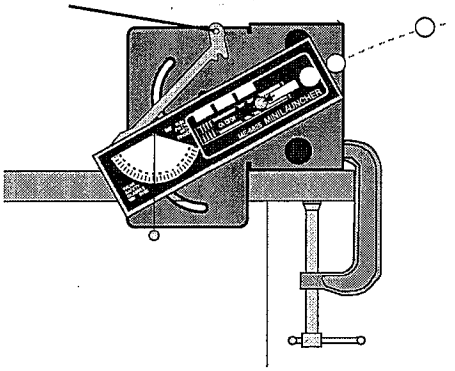

Figure 1.1: Setup to shoot horizontally off table

Purpose

The purpose of this experiment is to predict and verify the range of a ball launched at an angle. The initial velocity of the ball is determined by shooting it horizontally and measuring the range and the height of the Launcher.

Theory

To predict where a ball will land on the floor when it is shot off a table at an angle, it is necessary to first determine the initial speed (muzzle velocity) of the ball. This can be determined by launching the ball horizontally off the table and measuring the vertical and horizontal distances through which the ball travels. Then the initial velocity can be used to calculate where the ball will land when the ball is shot at an angle.

INITIAL HORIZONTAL VELOCITY:

For a ball launched horizontally off a table with an initial speed, v_o, the horizontal distance travelled by the ball is given by $x = v_o t$, where t is the time the ball is in the air. Air friction is assumed to be negligible.

The vertical distance the ball drops in time t is given by $y = y_0 + (v_0 \sin\theta)t - \frac{1}{2}gt^2$.

The initial velocity of the ball can be determined by measuring x and y. The time of flight of the ball can be found using:

$$t = \sqrt{\frac{2y}{g}}$$

and then the initial velocity can be found using $v_0 = \frac{x}{t}$.

INITIAL VELOCITY AT AN ANGLE:

To predict the range, x, of a ball launched with an initial velocity at an angle, θ, above the horizontal, first predict the time of flight using the equation for the vertical motion:

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

where y_o is the initial height of the ball and y is the position of the ball when it hits the floor. Then use $x = (v_0 \cos\theta)\, t$ to find the range. If the ball is shot at an angle below the horizontal, then θ is negative.

Setup

① Clamp the Mini Launcher near one end of a sturdy table as shown in Figure 1.1.

② Adjust the angle of the Mini Launcher to zero degrees so the ball will be shot off horizontally.

Procedure

Part A: Determining the Initial Velocity of the Ball

① Put the ball into the Mini Launcher and cock it to the long range position. Fire one shot to locate where the ball hits the floor. At this position, tape a piece of white paper to the floor. Place a piece of carbon paper (carbon-side down) on top of this paper and tape it down. When the ball hits the floor, it will leave a mark on the white paper.

② Fire about ten shots.

③ 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 floor. Record this distance in Table 1.1.

④ Use a plumb bob to 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 paper. Record in Table 1.1.

⑤ Measure from the leading edge of the paper to each of the ten dots and record these distances in Table 1.1.

⑥ Find the average of the ten distances and record the value in Table 1.1.

⑦ Using the vertical distance and the average horizontal distance, calculate the time of flight and the initial velocity of the ball. Record in Table 1.1.

⑧ Calculate the Total Average Distance. Record in Table 1.1.

Table 1.1 Determining the Initial Velocity

Vertical distance = _____ Horizontal distance to paper edge = _____

Calculated time of flight = _____ Initial velocity = _____

Trial Number	Distance
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Average Distance	
Total Average Distance	

(Total Average Distance = Distance to paper edge + Average Distance)

Part B: Predicting the Range of the Ball Shot at an Angle

① Adjust the Mini Launcher to launch at an angle between 20 and 60 degrees above the horizontal. Record this angle in Table 1.2.

② Using the initial velocity and vertical distance found in the first part of this experiment, calculate the new time of flight and the new horizontal range for a projectile launched at the new angle. Record in Table 1.2.

③ Draw a line across the middle of a white piece of paper and tape the paper on the floor so the line is at the predicted horizontal distance from the Mini Launcher. Cover the paper with carbon paper.

④ Shoot the ball ten times.

⑤ Measure the ten distances and take the average. Record in Table 1.2.

Analysis

① Calculate the Total Average Distance. Record in Table 1.2.
(Total Average Distance = Distance from Edge of Paper + Horizontal Distance to paper edge)

② Calculate and record the percent difference between the predicted value and the resulting average distance when shot at an angle.

③ Estimate the precision of the predicted range. How many of the final 10 shots landed within this range?

Table 1.2 Confirming the Predicted Range

Angle above horizontal = _____ Horizontal distance to paper edge = _____

Calculated time of flight = _____ Predicted Range = _____

Trial Number	Distance from Edge of Paper
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Average	
Total Average Distance	