Number of Experiment : 2
Name of the Experiment : Projectile Motion
Purpose of the Experiment :

1- To determine the initial velocity of an object thrown horizontally by examining the horizontal motion of the shot.
2- To determine the horizontal distance taken by an object thrown at a certain angle with respect to the horizontal axis by examining the projectile motion.

Theoretical Information:

The motion of an object thrown at an initial velocity to make a certain angle with respect to the horizontal axis is called projectile motion. The projectile motion is 2-dimensional. The object moves with constant acceleration in the y-direction under the influence of the gravitational force. However, no force acts on the object in the x direction (air resistance is neglected).

Using Newton's second law and the basic principles of kinematics, the equations of motion in two dimensions can be written as:

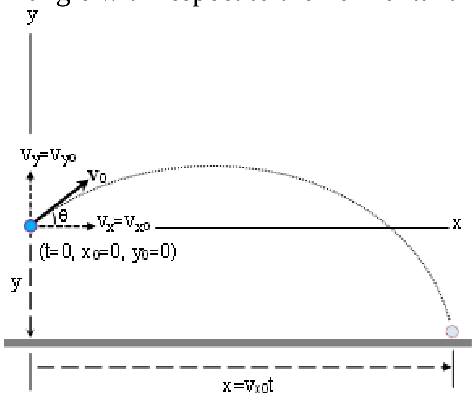

Figure 1 The motion of an object thrown at a given angle (θ) and initial velocity (v_0) relative to the horizontal axis.

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2 \quad (1)$$

$$y = x_0 + v_{y0}t + \frac{1}{2}a_y t^2 \quad (2)$$

In the experimental setup, we can choose $x_0 = y_0 = 0$ where the object just leaves the launcher at time t_0. Components of the initial velocity of the object;

$$v_{x0} = v_0\cos\theta \quad (3)$$
$$v_{y0} = v_0\sin\theta \quad (4)$$

In the projectile motion, the components of the acceleration of the object can be written as,

$$a_x = 0 \quad (5)$$
$$a_y = -g \quad (6)$$

since the acceleration is equal to the gravitational acceleration. When these expressions are substituted into equations (1) and (2), they become;

$$x = (v_0\cos\theta)t \quad (7)$$
$$y = (v_0\sin\theta)t - \frac{1}{2}gt^2 \quad (8)$$

The flight time can be found via equation (8) and by using this time in equation (7), the distance that the object will take in the x direction can be calculated.

The horizontal distance traveled by the thrown object is defined as the horizontal range, **R**. To calculate the horizontal range, the initial height is written as y=0 in equation 8, and then the flight time

$$t = \frac{2v_0\sin\theta}{g} \quad (9)$$

is obtained and horizontal range for this flight time is the following:

$$R = \frac{v_0^2\sin2\theta}{g} \quad (10)$$

Experimental Procedure

1. Place the launcher system (shooting mechanism) on the corner of the table as in Figure-2. Set the launcher angle to zero degrees for horizontal shot. Thus, the ball will be thrown horizontally.

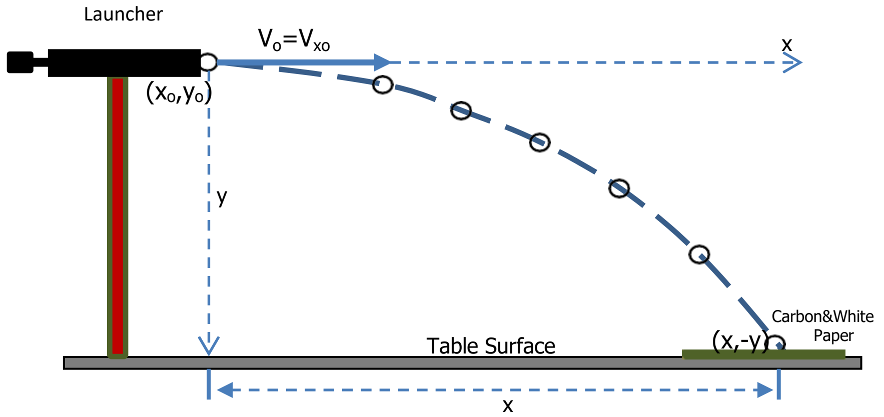

Figure 2 Experimental setup for finding the initial velocity of an object (ball) thrown horizontally (The initial velocity is in the horizontal direction and the initial velocity is zero in the vertical direction).

2. Measure the vertical distance from the point where the launcher fires the ball to the table surface and record it in Table 1 as y(m) value.
3. Take a few test shots at short range (pull the launcher to the first level). After determining the approximate location of the ball, place the carbon paper in this area with the writing side facing upwards.
4. Pull the launcher to the first level and then place the ball and shoot. Determine the point where the horizontally thrown ball hits on the table. Measure the horizontal distance between the projection of the thrown point of the launcher on the table surface and the point where the ball hits on the table surface, and record this in Table 1 as the x(m) value.
5. Calculate the initial velocity and flight time of the ball thrown horizontally by using the vertical and horizontal distance values you measured in the equations (7) and (8). Record these values as v_0 and t in Table 1. Initial velocity you calculated is fixed for first level shots.

Table 1 Horizontal Projectile (θ =0°)

Angle	**Launcher**	**Measured with Ruler**		**Calculated**	**Calculated**
		Horizontal Distance	Vertical Distance	Flight Time	**Initial Velocity**
					$V_{x0} = v_0 = \frac{d}{t}$
Θ(degree)	Range	x(m)	y(m)	t(s)	v_0= (m/s)
0°	Short Range				

6. Adjust the angle of the launcher as in Figure-3 to θ = 15°, 30°, 45° respectively. Measure the vertical distance from the launcher thrown point to the table surface for each angle value separately. Record these values as y(m) value in Table 2
7. Solve the equation by substituting the first velocity value you obtained in step 5 in the equation (8) and calculate the flight times for each angle values. Record these values as t(s) in Table 2.
8. As in the first step, determine the place where you will put the carbon paper with a few test shots.

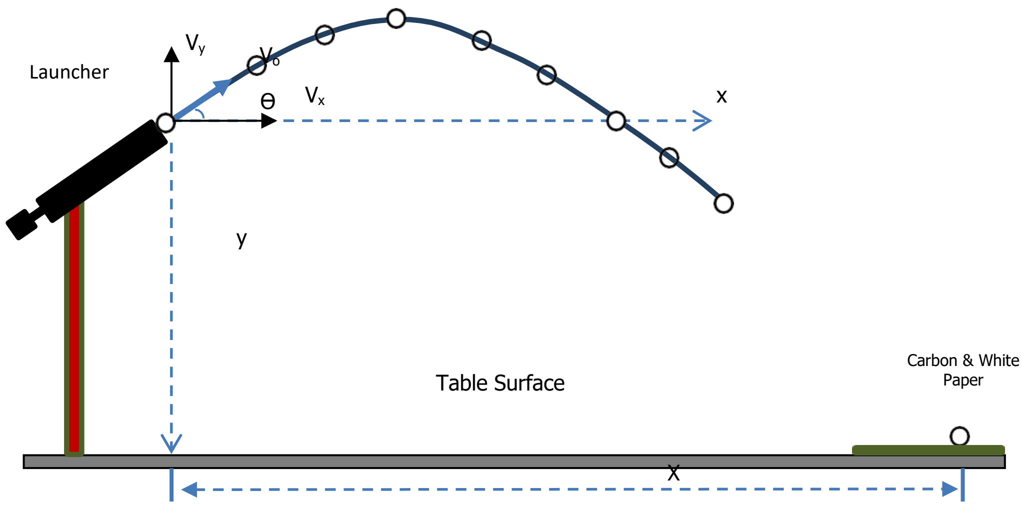

Figure 3. The experimental setup prepared to find the horizontal distance taken by the ball thrown at a certain angle with respect to the horizontal axis.

9. For each angle value, measure the horizontal distance from the projection of the ball launch point on the table surface to the point where the ball hits on the table. Record this value as x in Table 2.

10. Substitute the initial velocity value (you obtained in step 5) and the flight time values (you calculated in step 7) in equation (7) and record the obtained horizontal distance values in Table 2. Compare these values with the x(m) value you measured in step 9.

Table 2 Projectile Motion

Set	Known	Set	Measured	Calculated	Measured			Calculated
Launcher	Initial Velocity v_0 (m/s) (from table 1)	Angle θ (degree)	Vertical Distance (m)	Flight Time (s)	Horizontal Distance (m)			Horizontal Distance (m)
			y(m)		x(m)			$x = (v_o \cos\theta)t$
					x_1	x_2	x_{avg}	
Short Range (First Level)		15°						
		30°						
		45°						

11. Set up the mechanism in Figure-4 using the electronic timer.

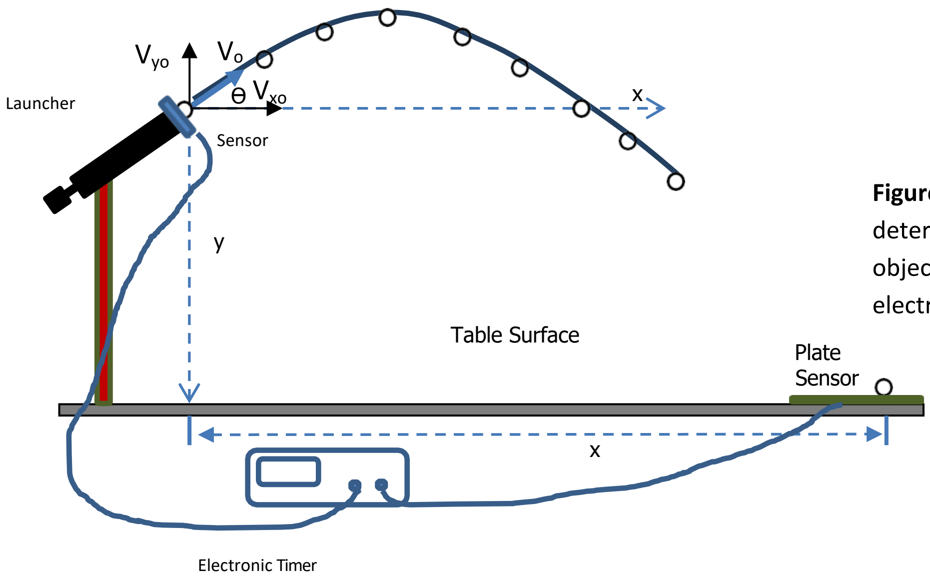

Figure 4. An experimental setup to determine the initial velocity of an object thrown horizontally using an electronic timer.

- To find the initial velocity of the object, set the launcher at θ = 0° and place the ball in front of the firing mechanism.

- Press the "Start" button on the timer and throw the ball horizontally (ϴ=0°) from the shooting mechanism. From the timer screen, read the time that the ball passes through the 1st sensor and record it as t_1 value in Table3.
- As the thrown ball passes through the 1st sensor (ie when the ball closes the photogate sensor), t_1 measurement starts and stops as soon as the ball exits the sensor. Thus, the block time (t_1) is the time elapsed in the distance "d" traveled by the ball.

Table 3 Horizontal Projectile (θ=0°)

Angle	**Diameter of Ball**	**Launcher**	**Measured Time**			**Calculated Initial Velocity**
θ (degree)	d (m)	Short Range	t_1(s) with timer			
0°	0,01585 (15,85 mm)		t_{11}	t_{12}	t_{avg}	$V_{x0} = v_0 = \frac{d}{t}$

12. Set the angle of the launcher to θ = 15°, 30°, 45° respectively.

- Place base plate sensor in the position where you expect the ball to hit the surface.
- Press the start button on the timer and throw the ball. Read the total time between the time of the shot and when the ball hits on the plate and record it in Table 4 as t_2. This value is the "time of flight" of the object launched at an angle of θ. Compare these values with the values you obtained in Table 2 and fill in Table 4 by making the necessary calculations.

Tablo 4 Projectile Motion

Set	**Set**	**Calculated**	**Measured**			**Calculated**
Laucnher	Angle	Initial Horizontal Velocity	Flight Time			Horizontal Distance
	ϴ (degree)	$v_{xo} = (v_o \cos\theta)$	t_2 (s) with timer			$x = v_{xo}\, t_{avg}$
		v_{xo} (m/s)	t_{21}	t_{22}	t_{2avg}	x (m)
Short Range	15					
	30					
	45					

13. Record the calculated and measured x_{ort} values and percentage differences for each angle value in Table 5. Compare these calculated and measured x_{ort} values.

Table 5

Set	**Set**	**Calculated**	**Measured**	**Percentage Difference**
Launcher	Angle	Horizontal Distance	Horizontal Distance	$difference\% = \left(\frac{\lvert Measured\ - Calculated\ \rvert}{Calculated}\right)*100$
	θ (degree)	X_{avg} in Table 4	X_{avg} in Table 2	
		x (m)	x (m)	Δx(±%)
Short Range	15			
	30			
	45			