Experiment 4
Projectile Motion

Advanced Reading
University Physics by OpenStax 4.3

Equipment

- PASCO ballistic Pendulum (spring gun)
- two-meter stick
- piece of carbon paper
- meter stick
- ruler
- *plumb bob*

Objective

The objective of this experiment is to measure the speed at which a projectile leaves a spring gun and to predict the landing point when the projectile is fired at a nonzero angle of elevation.

Theory

Projectile motion is an example of motion with constant acceleration. In this experiment, a projectile will be fired from some height above the floor and the position where it lands will be predicted. To make this prediction, one needs to know how to describe the motion of the projectile using the laws of physics. The position as a function of time is

$$\vec{r} = \vec{r_0} + \vec{v_0}t + \frac{1}{2}\vec{a}t^2. \qquad (1)$$

By measuring appropriate quantities, one can predict where the projectile will strike the floor. Eq. (1) is a general form describing the position of an object. It can be resolved into x and y components as

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \qquad (2)$$

and

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \qquad (3)$$

which give the position of the projectile in the x and y directions. The x and y components of the initial velocity are (Fig. 4-2)

$$v_{0x} = v_0 \cos\theta_0 \text{ and } v_{0y} = v_0 \sin\theta_0 \,. \qquad (4)$$

For a projectile, there is no horizontal component of acceleration after the gun is fired. The only acceleration is due to the gravitational attraction of the earth. This acceleration has magnitude g acting in the negative vertical direction (Fig. 4-2). Hence, the Eqs. (2) and (3) become

$$x = x_0 + v_{0x}t \text{ and } y = y_0 + v_{0y}t - \frac{1}{2}gt^2. \qquad (5)$$

These equations of motion describe the motion of a projectile.

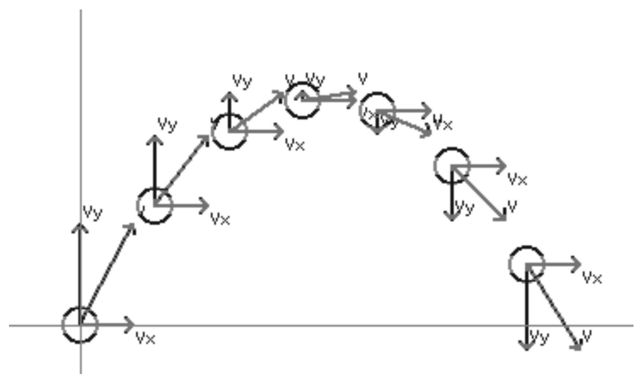

Fig. 4-2 Projectile motion. The trajectory is a parabola.

Procedure

1. Record the number inscribed on the firing mechanism of the ballistic pendulum. You will need it for a future experiment.
2. Place the ballistic pendulum on a platform with pendulum arm in the up position (Fig. 4-1). Measure the height from the floor to the *bottom* of the ball as follows: Use the height gauge to measure the distance from the table top to the bottom of the ball and the meter stick to measure the height of the table above the floor. Add these two distances together to get the total height h.

3. Calculate the amount of time the ball will be in the air when fired horizontally. Recall that if two balls are released at the same time, one falling vertically and the other projected horizontally, *both will hit the ground at the same time.*

4. Fire the spring gun from the 1st detent. (**Be sure that no one is in the flight path!)**). Note where the ball lands and tape a target composed of carbon and white sheets of paper at that spot. Fire the spring gun 3 times.

5. For each trial, measure the total distance the ball traveled horizontally. (Be sure to measure the total distance from the pendulum in the *uncocked position* to the point of impact on the floor). Find the average horizontal distance of all the trials. From this value and the time calculated in step 3, calculate the speed at which the ball leaves the gun.

6. Reconfigure the ballistic pendulum to shoot from an angle of 45 degrees. Measure the distance from the bottom of the ball to the floor. Return to your own lab table with your spring gun.

7. Using Eqs 4&5 and the quadratic equation calculate the horizontal range of the ball when fired at the above angle and height. in step 6.

8. Mark the floor at the location the ball is calculated to land. Place the line on the target at this location. Fire the ball at the target three times and determine the average distance. Calculate the percentage difference between the range R and the average measured range. If the distance calculated and the distance obtained from firing the gun are substantially different, check your calculations. Fire the gun again after locating and correcting your errors.

9. From the range equation we know that maximum range for a projectile is 45 degrees (if air resistance is ignored). Determine if this is true for the configuration that you are using (i.e., shooting to a point below the horizontal starting point). In other words, try other angles and see if you can get the projectile to travel farther.

Questions/Conclusions

1. Comment on the following statement: "When a bullet leaves the barrel of a gun, it doesn't drop at all for the first 100 meters of flight." Is this statement true or false? Explain.

2. What is the acceleration of a projectile fired vertically upwards? What is the acceleration of a projectile fired vertically downwards?

3. If the ball had twice the mass, but left the spring gun at the same speed, what effect would this have on its distance of flight? Neglect air resistance. Explain.

4. In Fig. 4-2, suppose v_o is constant and is varied. Is the angle that maximizes the range R equal to, less than, or greater than 45^o? Explain using **"range equation"**.

5. Take the sine (in degrees) of (10x2) & then (80x2). What do you notice? Take the sine of (30x2) & then (60x2). What did you notice again? Try other pairs of angles.

What does this say about the range given by the **range equation**?

Is your answer above true above true for all angles?

6. Discuss what you observed when you changed the angle from 45 degrees to some other angle (i.e., was there some other angle other than 45 degrees which gave you a maximum value.) What do you think would happen to this angle as the distance to the floor (ground) approached infinity?