

Experiment 4

Projectile Motion

Advanced Reading

(Halliday, Resnick & Walker) 4-5 & 4-6

Equipment

- Beck ballistic Pendulum (spring gun)
- two-meter stick
- height gauge
- piece of carbon paper
- meter stick
- inclinometer
- block to incline spring gun
- 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

$$\mathbf{r}(t) = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2} \mathbf{a} t^2. \quad (1)$$

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

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

and

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

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)

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

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

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

These equations of motion describe the motion of a projectile.

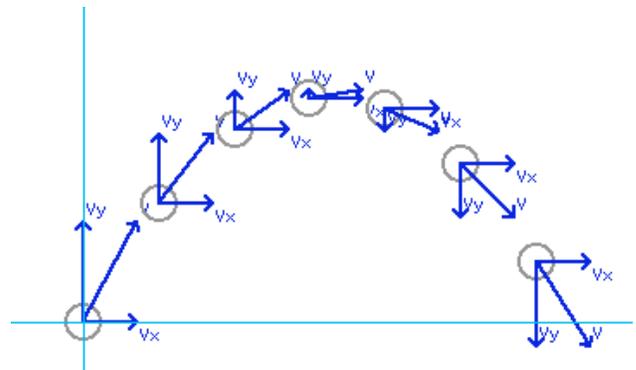


Fig. 4-2 Projectile motion. The trajectory is a parabola.

Procedure

1. Record the number inscribed on the firing mechanism of the 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. Video instructions on firing the ballistic pendulum can be found on your computer. Fire the spring gun from the 1st detent, being sure to hold the gun firmly in position. (**Also, 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. Place the front feet of the spring gun on the incline block and use the inclinometer to measure the angle of inclination. 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.

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_0 is constant and θ_0 is varied. Is the angle that maximizes the range R equal to, less than, or greater than 45° ? Explain using "**range equation**".

5. Take the sine (in degrees) of (10×2) & then (80×2) . What do you notice? Take the sine of (30×2) & then (60×2) . 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?