

PHYS 231 Lab Exercise: Projectile Motion

Objective: The primary objective for this lab is to determine if the equations you have developed in class to describe projectile motion are actually experimentally supported.

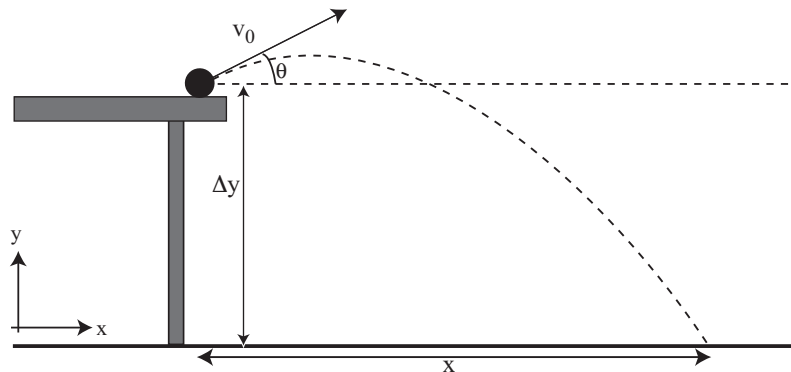
Introduction: When a projectile moves its horizontal velocity is constant and its acceleration is the same as for a freely falling object. The position of the projectile can therefore be described with the equations:

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

$$x = v_{0x}t \quad (2)$$

Here, v_{0x} and v_{0y} are components of the initial velocity vector given by:

$$v_{0x} = v_0 \cos \theta; v_{0y} = v_0 \sin \theta,$$



If a projectile is fired horizontally ($\theta=0^\circ$), then in time t it will fall vertically through a distance

$$\Delta y = y - y_0 = \frac{1}{2}gt^2 \quad (3)$$

In the same time its horizontal displacement will be given by

$$x = v_0 t \quad (4)$$

where v_0 is initial horizontal velocity. It follows from equation (3) that:

$$t = \sqrt{\frac{2(\Delta y)}{g}} \quad (6)$$

And thus, from equation (6) and (4) we can finally derive the initial velocity of the projectile from the range **if the projectile is fired horizontally**:

$$v_0 = x \sqrt{\frac{g}{2(\Delta y)}} \quad (7)$$

When the projectile is fired at an angle θ above the horizontal, the time of the flight can be calculated from the equation (1). Since the y position of the projectile at the end of the flight is just $y=0$, I can rewrite equation (1) as a quadratic equation in time:

$$0 = -\frac{1}{2}gt^2 + v_{0y}t + y_0 \quad (8)$$

and solve for time of flight as:

$$t = \frac{-v_{0y} \pm \sqrt{v_{0y}^2 + 2gy_0}}{-g}. \quad (9)$$

The horizontal distance covered by the projectile in this flight is just given by equation (2):

$$x = v_{0x}t$$

Apparatus: Projectile launcher, meter stick, plumbs line, and carbon paper.

Procedure: Today's lab involves a spring-loaded “gun” that fires a small metal ball at a fixed speed. You will check whether the mathematics you have learned to describe projectile motion are correct by firing the ball at two different angles and measuring how far it travels.

Part I: Projectile fired horizontally

a) Test fire the projectile horizontally at one of the three range settings (short, medium, or long range). **Make sure you have enough room to fire with that setting and stick to that range setting from now on.** Note the place on the floor where the projectile lands. At this position, place a sheet of carbon paper face down on a sheet of paper and tape them to the floor.

HINT: Be sure that the adjustment nut used to control the angle the projectile fires is very tight. If not, the projectile launcher may shift from horizontal due to vibrations during your firings.

b) Fire the projectile horizontally ten times. Measure the horizontal distance, x , from the point of release of the projectile to each imprint. **Record these measurements in Excel. Find the average and standard deviation of your measurements of x using Excel.**

c) Measure vertical distance y of the projectile's fall. **Record this in Excel.**

d) Calculate the time of flight and the initial velocity v_0 of the ball. **If you are feeling daring, you can do this in Excel and record it in the same spreadsheet, otherwise, show your work below.**

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Part II: Projectile fired at an angle

a) Now adjust the angle of the Projectile Launcher to an angle of 50° . Using the initial velocity and vertical distance found in first part of this experiment, assume the ball is shot at the new angle of 50° and **calculate the new time of flight and new horizontal distance. Show your work below.**

b) 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 distance from the Projectile Launcher. Shoot the ball ten times. **Measure the ten distances and record them in Excel (separate from the measurements for Part 1). Use Excel to determine the average horizontal distance the projectile travels.**

c) Compare your predicted value for the horizontal distance, x , the projectile should travel to your observations and determine if your observations support the “accepted model” for projectile motion. If your observed distances differ from your prediction, how do they differ? Are your observed distances systematically larger or smaller (or the same) as your prediction? If you see a systematic difference, speculate on the cause.

Discussion: Answer the following questions:

- 1) At which point in its path does a projectile have the least speed?
- 2) Is there any point in the path of a projectile thrown at some angle above the horizontal at which its acceleration is parallel to the velocity? Perpendicular to the velocity? Zero?
- 3) Suppose that a football is thrown at some angle above the horizontal, and there is a wind blowing in parallel with the ground. How would you expect the time of the flight of the football to be affected?
- 4) At the same instant that a bullet is fired horizontally from a gun, you drop another bullet from the height of the barrel. Which bullet hits the ground first? (Ignore air resistance in this case)

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