Lab 5: Two-Dimensional Motion

Objectives:

- To study two-dimensional motion
- To understand the vector nature of velocity
- To understand the independence of motion in the x- and y- directions

Equipment:

- Ballistic gun
- Plain paper
- Carbon paper
- meter stick

In this lab, you will be firing a ball from a ballistic gun. The set-up is shown in the picture below. You can vary the initial angle and measure the initial height and the distance the ball travels in the x direction. You will be making measurements in order to determine the initial velocity of the ball. You will also examine the dependence of the distance traveled in the x-direction on the initial angle.

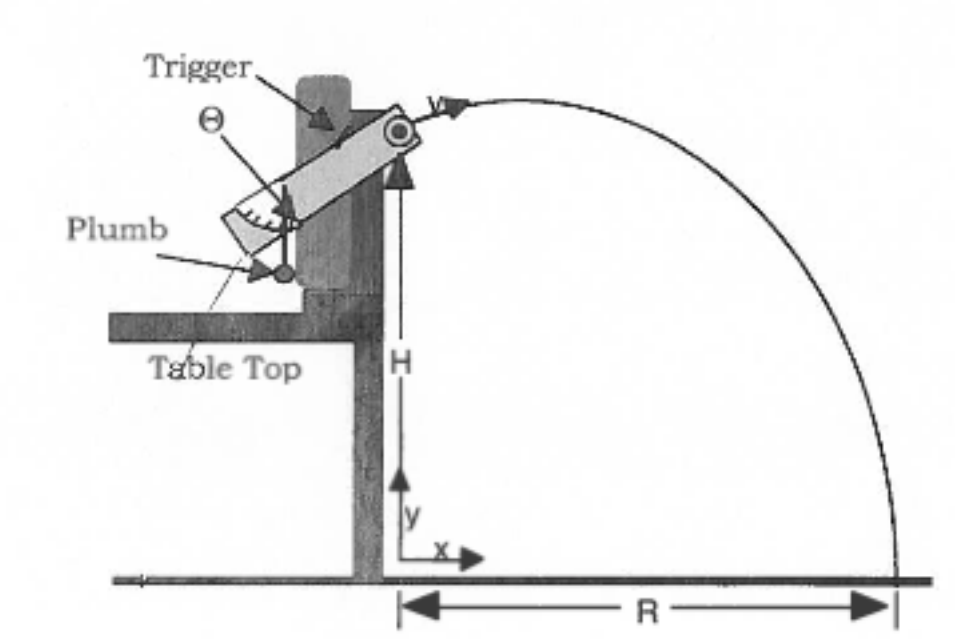

FIGURE 1: Projectile Motion

Exploration 1: Finding initial velocity

Exploration 1.1 Consider the case of the ball being projected horizontally. The initial velocity would be in the x- direction ($\theta = 0$) and the initial y- component of the velocity would be $v_{0y} = 0$. Write out the kinematics equations for the ball in the x- and y- directions in the space below.

Exploration 1.2 You will be measuring the initial and final positions, but not the time of travel. The time of travel is the same in both the x- and y-directions. Solve the kinematics equations for the initial velocity of the ball in terms of fundamental constants and quantities you can measure, such as initial and final positions. Show your work and write the equations in the space below.

Exploration 1.3 If you fire the ball at a different angle ($\theta \neq 0$), will the initial velocity be the same or different from the horizontal case? Explain. Explain the difference in the two cases.

Exploration 2: Angular dependence of range on angle

Exploration 2.1 Consider the case where the ball lands at the same level that it is fired. The range of the ball (distance travelled in the x- direction) can be determined in terms of the initial velocity, v, the initial angle, θ, and the gravitational constant, g. Use the equations of motion in both the x- and y- directions to determine the equation for the range. (Don't just write the equation down. Show your work on how it is derived.)

Exploration 2.2 Determine the angle at which the range is the greatest. Show your work or explain your reasoning.

Exploration 2.3 Suppose the ball does not land at the same level from which it is fired. Would the maximum range be at the same angle as in the case where it lands at the same level from which it is fired? Would it be greater or less? (This is a prediction. Record your prediction.)

Investigation 1 Initial velocity of the ball

Investigation 1.1 Now carry out the experiment of finding the initial velocity of the ball as it leaves the gun. The spring loaded gun has three settings. *Do not cock the gun past the first setting*. Also, *do not look down the barrel of the gun once it has been cocked*. Refer to Exploration 1.2 and make the measurements you need to make in order to determine the initial velocity of the ball when it is released from the gun. Measure the distance in the x-direction at least three times and take the average. Record your measurements from both the x- and y-directions in the table below or create your own table. (You may not need to use the whole table.) Choose appropriate row and column headings, as needed.

Investigation 1.2 Determine the initial velocity of the ball when it leaves the gun. Show your work and record the result in the space below.

Investigation 2 Range

Explore the dependence of the range on the angle for the case where the ball starts and ends at the same height ($y = y_0 = 0$).

Investigation 2.1 Fire the ball from the table at 10 different angles, from 30° to 75°. Measure the range (distance travelled in the x- direction) for each of those angles. (Make three measurements for each angle and take the average range.) Record your data in the table below.

angle	range 1st measurement	range 2nd measurement	range 3rd measurement	average range

Investigation 2.2 Plot the range vs. the angle on the graph paper provided and determine the angle of maximum range.

Investigation 3 Fired and lands at different levels

Investigation 3.1 If you have time, fire the ball at different angles for the case where $y \neq y_0$. You can record your data in the table below. Does this change the angle of maximum range?

angle	range 1st measurement	range 2nd measurement	range 3rd measurement	average range