PHYS 1401 – General Physics 1
Laboratory # 5
Projectile Motion

Introduction

In this lab exercise we will investigate the two-dimensional motion of a projectile in flight. First, we will examine a computer simulation / game involving a baseball batter. Then we will study the motion of an actual sphere flying off the lab tables.

Part 1: Computer Simulation

First we will examine the computer simulation of a baseball player trying to hit a home run. Note that there are two things that you can change: the speed of the ball when it leaves the bat, and the angle of the ball. Try changing these quantities and see how the path of the ball is affected. Click the button marked "Tracking" to illustrate how the x- and y-components of the ball's velocity change in flight. The ball may pause at the tip of its flight; just click "Run" to resume

Question 1: How does the y-component of the ball's velocity change as it goes up? How does the y-velocity change as the ball goes down? Explain this behavior in terms of forces and accelerations.

Question 2: How does the x-component of the ball's velocity change as it goes up? How does the x-velocity change as the ball goes down? Explain this behavior in terms of forces and accelerations.

Question 3: Set the velocity in the simulation to 30 m/s and the angle to 45 degrees. Use the two-dimensional kinematics equations discussed in class to calculate how long the ball will stay in the air, and how far it will travel. Note *carefully* the starting and finishing points of the ball! Show all of your calculations in your lab report. Use the simulation to check your answers. How do your calculated answers compare to the numbers from the simulation?

Set the velocity of the ball to 40 m/s. Start with the angle set at 10 degrees, and determine the time of flight and the distance traveled. Increase the angle by 10 degrees and repeat. Continue this until the angle is 80 degrees. Construct a data table with your results. Create two graphs: one of travel time (y-axis) vs. angle (x-axis), and another of distance traveled vs. angle. For both graphs draw the line or curve that best fits your points.

Question 4: Based on your graphs, what angle will give the longest travel time? Note: it may not be one of your original data points!

Question 5: Based on your graphs, what angle will give the longest distance traveled? Note: it may not be one of your original data points!

Question 6: Based on your data and graphs, what other angle would I have to hit the ball to reach the same point as if I had hit it at an angle of 35 degrees? How are these two angles related geometrically?

Part 2: Testing our Assumptions

In all of our work with projectiles, we make the big assumption that gravity is the only significant force acting on the projectile as it flies. In other words, we neglect air resistance. In this part of the lab, we will test that assumption.

In this "real world" part of the lab, we will launch a ball horizontally from the edge of the lab table. The ball will get its speed by being rolled down a ramp prior to launch. A photogate will measure the ball's horizontal velocity as it leaves the table, and we shall measure the height of the table and how far the ball travels horizontally. We can use our data to calculate how far the ball *should* travel horizontally, and compare that to the *measured* value.

Question 7: If air resistance is important, should the measured value for the range be longer or shorter than the ideal, calculated value? Justify your answer.

Position the photogate so that the ball will pass right through the center of it. Use the plumb bob to find the spot on the floor right underneath the launch point. Mark that spot; it will be your starting point for measuring the range. Measure the distance from the floor to the launch point to determine the height of the fall. The time it takes for the projectile to reach the ground can be found from the formula for free fall from Lab #3:

$$\textbf{Height} = \mathbf{(1/2)gt^2}$$

Question 8: How long does it take the ball to fall? Will it be the same for every time you launch the ball? Why or why not?

We can then use this time, combined with the speed of the ball as it launches, to calculate the range:

$$\textbf{Range = Launch Speed x Time}$$

Hold the ball a near the top of the ramp. Place a piece of white paper on the floor where you think the ball will land. Let the ball roll down the ramp and "launch" into the air. If the ball does not reach the paper upon hitting the ground, move the paper and try again. Once you hit the paper with the ball, tape the white paper down. Then place the carbon paper over the white paper – do not tape it down! Now when the ball lands on the paper, the carbon paper will make a black dot.

Click the "collect" button to activate the photogate and release the ball. Record the velocity of the ball as "velocity #1" as it launches through the gate. After the ball lands, pick up the carbon paper and label that dot #1. Repeat this for 10 trials. You should have 10 velocities (labeled 1-10) and 10 dots (labeled 1-10). Now for each dot, measure the distance from the starting point to the dot. Record each value of distance along with the corresponding velocity measured by the photogate. In a little data table, show the values for starting velocity and distance for each trial, and values of average velocity and average distance for all 10 trials.

Repeat the procedure for another 10 trials, this time launching the ball midway down the ramp. Do yet another 10 trials, launching the ball from close to the bottom of the ramp. Record all your results in data tables as above. You should have three data tables total.

Using your average values for velocity, and the value for travel time you found above, calculate a theoretical value for the distance traveled in all situations. Compare this to the value you actually measured in each trial by finding the percentage difference:

$$\text{Percentage Difference} = 100\% \text{ x } \frac{(Measured - Calculated)}{Calculated}$$

Create a final data table with the following columns for all three positions on the ramp:

- Average Initial Launch Velocity
- Average Measured Horizontal Distance Traveled
- Calculated Horizontal Distance Traveled
- Percentage Difference

Question 9: We can reasonably expect a percentage difference of 15% based upon the instruments we are using, if air resistance is not important. Using your data, assess in a few sentences the importance of air resistance in this instance. Remember your answer to Question 7!

<u>Materials List</u>

Interactive Physics simulation 9
Projectile launch ramp and ball
Photogate
Plumb bob
Meterstick
Carbon paper