Lab 4 Projectile Motion

Purpose: The purpose of this lab is to investigate the relationships among the initial velocity, time of flight and distance traveled for an object in projectile motion. You will compare theoretical calculations with real experiments, and will obtain experimental results for a situation that is difficult to predict theoretically.

Part I: Time of Flight for Horizontal Launches
1. Obtain a projectile launcher, two photogates, a time of flight accessory with extension cord, and a c-clamp. Attach the two photogates to the extension arm of the projectile launcher and plug them into digital channels 1 (for the photogate nearest the launcher) and 2. Use the c-clamp to attach the launcher firmly to the table. Plug the time of flight accessory into digital channel 3.
2. Open "Science Workshop", and put a digital plug into channel 1. Configure the program to use "Time of Flight (2 gates)".
3. Measure the spacing between the two photogates and enter this (in meters) as the photogate spacing.
4. Configure "Science Workshop" to display the data in a table of "time of flight". When the table is open, configure it to display another column containing "initial velocity".
5. Measure the height of the ball above the floor when the ball leaves the launcher. This will be your initial height (y_o). Measure the height of the time of flight pad; this will be your final height (y). Record these values in your notebook. Does Δy = y - y_o change as the angle of the launcher change?
6. Using this value for Δy, predict the time the ball will be in the air if it is fired horizontally. Show your work and record this value in your lab book.
7. Adjust the projectile launcher to horizontal flight (an angle of zero degrees) and aim it away from any people. Set it to launch on the "short range" setting. Make sure that no one is looking into the launcher when you launch, or is standing where they could be hit by the projectile. Launch the ball and mark where it lands. Set the time of flight pad where the ball lands.
8. Make three launches at each range setting, and record the time of flight for each launch in a table. Make sure that you keep the launcher horizontal at all times. Summarize your data with a statement about how the time of flight depends on the initial velocity for horizontal launches. How did the average measured time of flight compare with your predicted value?
Part II: Time of Flight for Various Angles
1. Move the time of flight pad out of the way and set the launcher to launch at some angle. Launch the projectile on the short range setting and mark where it lands. Measure and record this value as \( \Delta x \), the horizontal distance. Record the initial velocity measured by the computer. Use the equations of motion to predict the time of flight knowing the angle and initial velocity and \( \Delta y \) and \( \Delta x \).
2. Place the time of flight pad where the projectile landed and repeat the launch, measuring the actual time of flight.
3. Make a table with columns for the trial number, the angle, initial velocity, predicted time of flight, actual time of flight and percent difference (between the actual and predicted). Repeat the experiment and prediction for a different initial velocity and a different angle (for a total of two trials for Part II).
4. How close were your predictions? Explain any differences.

Part III: Range, Time of Flight, and Angle

1. Obtain a box that is the same height as the projectile launcher. Set the launcher to 10°, and arrange the box so the projectile lands on it. Place the time of flight pad on the box so the projectile lands on it. Launch the ball at the short range setting. In a table, record the angle, the distance the projectile travels (the range) and the time of flight.
2. Repeat Step 1 for angles up to 80° in 10° intervals.
3. Open the program "Graphical Analysis" and make a graph of the range (on the y-axis) versus the angle (on the x-axis). Use the "Analysis" feature to fit a function to the graph. When you find a function that fits well, print the graph and record the function (with the numbers) in your notebook. Try to explain why (physically, and from the equations of motion) this function should fit this data.
4. In "Graphical Analysis" make a graph of Time of Flight (on the vertical axis) versus Angle (on the horizontal axis).
5. Use the "Analysis" feature to try to fit a line to the data. How close is the fit? Can the data be fit better by some other function? Record the equation of the best fit line, and of the best function you can fit to the data. Print the graph and include it in your notebook.
6. Use the equation you found in step 5 to predict the time of flight for an angle of 75°. Perform the experiment and measure the actual time of flight. Calculate the percent difference.
7. Bonus: For extra credit, derive an expression for the time of flight \( \Delta t \) as a function of the angle \( \theta \). Use this expression with the measured angle, initial velocity and height of the table to predict the time of flight for a 75° angle. How does this compare to the measured value?