Lab #5
2D Projectile motion

1. Objective

- To examine the motion of a projectile in 2 dimensions, and compare the experimental results to the equations derived in kinematics.

2. Material

- Luctor air table
- Heavy steel puck
- Flat wooden blocks
- Meter stick

3. Experimental Procedure

- Level the air table.
- Create an incline plane by raising the one-legged end of the table, ***using three (3) blocks***. Measure all quantities needed to calculate the angle θ of the incline plane and its uncertainty.
- Practice launching the puck from the lower left corner, so it describes a complete parabola, and reaches the lower right corner.
- When you feel confident about the direction and speed of the launch, ***set the spark-timer interval to 50 ms*** and proceed to record the trajectory of the puck as it follows a 2D projectile motion. You should get a trajectory consisting of 20 to 30 points.

4. Analysis

You are going to mark a lot of things on the experimental sheet. Please use a pencil with a hard point, keep your handwriting small, and traces as light as possible.

A. Determining the system of coordinates

- You have the trajectory of the projectile. You must first determine a set of axes with respect to which the position of each spark point will be measured. The vertical motion of the projectile is of course the direction in which the acceleration due to gravity is oriented. This direction may or may not be parallel to the edge of the data sheet.
- To determine the orientation of the axes, first identify the top of the trajectory. Starting from the top of the trajectory count ***approximately*** 10 to 15 points on either side, then draw a straight line between the two selected points. This line will be parallel to the x-axis.
- Now choose a point closer to the lower left corner as the origin of your system of axes, ***leaving one or two points below it***. From that origin, draw a line parallel to the line found in step 2. This line represents the x-axis of your system of coordinates, or the true horizontal of your projectile motion. ***Identify this axis clearly***.

- Again, from the origin, draw a line perpendicular to the *x*-axis. This represents the *y*-axis, or the true vertical of your projectile motion. ***Identify this axis clearly***. You know have everything needed to measure position of each point, with respect to this set of axes.

B. Point identification

- Setting the point at the origin of your coordinate system at $t = 0$ s, mark the proper time coordinate (***in seconds***) next to ***each data point right of the origin***.
- Draw a vertical line from each point to the *x*-axis. Make sure these lines are parallel to the y-axis. These lines are called the projections of each point on the *x*-axis. The distance between the origin and each projection, represents the *x*-coordinate of each point. Mark, next to each point, the value of its *x*-coordinate, ***in meters***.
- Draw the projections on the *y*-axis for each point, and mark the value of their *y*-coordinate, ***in meters***. Notice that some coordinates may be negative as the points go below the *x*-axis.

C. Determination of initial velocity directly from the data points

- Determine the initial velocity, at $t = 0$ s, using the point just before and just after the origin.
- Evaluate the uncertainty on the magnitude of this velocity, using the uncertainties on the positions, and the rules of propagation of uncertainties.
- Using the magnitude and orientation of the initial velocity, find the components of the velocity along either axes, v_{xi} and v_{yi}.

D. Graph of the horizontal position versus time

- For each point right of the origin on your data sheet, plot the horizontal position of the puck against time.
- Using the "trendline" option in Excel, draw the trendline for your data points and ***display the equation on the graph***.
- What is the horizontal velocity of the projectile? How does it compare to the *x*-component of the initial velocity found in the section C. ***Explain***.

E. Graph of the vertical position versus time

- For each point right of the origin on your data sheet, plot the vertical position of the puck against time.
- Using the "trendline" option in Excel, draw the trendline for your data points and ***display the equation on the graph***.
- What are the initial vertical velocity and the vertical acceleration of the projectile, found using the trendline?
- How does the initial vertical velocity found using this method compare to the one found in section C?

F. Graph of the vertical velocity versus time

- From the graph in section E, calculate the instantaneous velocity in the center of each time interval between the data points (remember that the average velocity between two points is the instantaneous velocity exactly in the middle of the time interval between the points, when the acceleration is a constant).

- Plot these velocities versus the corresponding time.
- Using the "trendline" option in Excel, draw the trendline for your data points and ***display the equation on the graph***. Watch-out for significant figures.
- What is the vertical acceleration, found using this trendline?

G. Determination of the acceleration due to gravity

- The magnitude of the acceleration due to gravity along the vertical direction of the incline plane, can be determined using the formula: $a_y = g \sin\theta$.
- Compare this value for the vertical acceleration to the values found in section E and F. Do they agree?

5. Lab Report

- You have two weeks to submit your report.
- Follow the instructions found at ***http://www.remi.poirier.com/Labs/Report.html***.
- All the points in the analysis section should be found in the final report.
- The graphs must be done using Excel and printed no smaller than ½ a page.
- The data on your graphs should use 80% or more of the graph area.
- Number and identify each table and graph clearly.
- In your introduction, the hypothesis should describe what you expect the graphs to look like and exactly what information will be extracted from it. A good hypothesis here should describe the characteristics of projectile motion.