1 Introduction

This lab simulates the concept of projectile motion in two dimensions.

1.1 Tools

To run the simulation in browser navigate to `https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html` If your browser is having trouble running it, consider using Google Chrome.

You can find a youtube video for this lab here: `https://www.youtube.com/watch?v=8ZSiVGx3pFQ&t=3s` where a TA, Alec Lancaster, can help you with any problems you may encounter when trying to do the lab.

1.2 Relevant Equations

The basic kinematical equations for projectile motion in the x-direction are:

$$a_x = 0 \tag{1}$$

$$v_x = v_{x0} \tag{2}$$

$$x = x_0 + v_{x0}t \tag{3}$$

The basic kinematical equations for projectile motion in the y-direction are:

$$a_y = -g \tag{4}$$

$$v_y = v_{y0} - gt \tag{5}$$

$$y = y_0 + v_{y0}t - \frac{1}{2}gt^2 \tag{6}$$

$$y = y_0 + \frac{v_y^2 - v_{y0}^2}{2(-g)} \tag{7}$$

2 Procedure

1. Once running the simulation, click on the "intro" section.
2. In the top right, click on the dropdown menu and select "cannonball"
3. Ensure that all of "air resistance," "velocity vectors," and "acceleration vectors" are unchecked.
4. In the lower left hand corner, set the initial speed to 10 m/s.
5. Set the initial height to 1m.

2.1 Part I: Range versus Height

For this section, fix the angle of the cannon to 0 degrees.

For heights of 1m, 4m, 8m, 11m, and 15m, do the following and record each result in your Excel spreadsheet:

1. Calculate the horizontal distance (the Range) the object will travel, neglecting air resistance.
2. Fire the projectile.
3. Measure the horizontal distance (the Range) the projectile traveled.
4. Determine the difference (if any) between your measurement and the actual value.
5. Make a table of Range vs. height.
6. Make a graph of Range vs. height.

2.2 Part II: Range versus Angle

For this section, fix the height to 0m and leave the initial velocity at 10 m/s.

1. Use kinematics and physical reasoning to determine the angle at which the maximum Range will be achieved.
2. Using your prediction, determine the maximum possible Range.
3. For each angle of 25, 35, 45, 65, and 85 degrees, do the following:
   (a) Fire the projectile at each of those angles.
   (b) Measure the Range of the projectile for each angle.
   (c) Make a table of Range and angle.
4. Make a graph of Range vs. angle.

3 Data Analysis

1. Write a short paragraph summarizing your findings. Discuss any potential errors present in the process of taking the data.
2. For each height in Part I, compute the *percent error* in the Range between your calculated and measured values:

$$\%Error = \left| \frac{Measured - Calculated}{Calculated} \right| \times 100$$

noting that percent errors of 0.1% are excellent, 1%-5% are very good, 5%-15% are fairly good (expected in this lab course), and greater than 15% are poor measurements.

3. For each angle in Part II, compute the *percent error* in the Range between your predicted and measured values:

$$\%Error = \left| \frac{Measured - Calculated}{Calculated} \right| \times 100$$

noting that percent errors of 0.1% are excellent, 1%-5% are very good, 5%-15% are fairly good (expected in this lab course), and greater than 15% are poor measurements.

4. How closely did your Range predictions for each height line up with the actual distance the object traveled?

5. How closely did your Range predictions for each angle line up with the actual distance the object traveled?

6. Since this is a simulated lab, your Range predictions should be nearly exact. Had you performed the experiment in real life, explain how your predictions would have differed from the measured values. (*that is*, would the range have been generally smaller or larger for a given height or angle?)

7. For Part II, show that for a given initial velocity v_0 and angle θ, the Range is

$$R = \frac{v_0^2 sin(2\theta)}{g} \tag{8}$$

hint: Use the trigonometry identity $2sin\theta cos\theta = sin(2\theta)$

8. For an initial velocity of 10 m/sec and angle of 25° (height = 0), the projectile traveled a certain distance given by your measured Range. Using Equation (8) above, calculate the other angle that gives the same Range (carefully explain your calculations and how you arrived at your answer) [*hint*: sketch a simple plot of $\sin(2\theta)$].

9. Vary the angle in the Phet demo to see if your calculation is correct (*that is*, by varying the angle of the cannon, find another angle for which the projectile travels the same Range as that for an angle of 25°).