**IB Physics SL Laboratory #4 Projectile Motion**

In this experiment, we’ll use an online simulation to explore projectile motion.

Note: Special thanks to Sean Boston of Timberline High School who posted the activity *Lab Projectile Intro* on the PhET website, upon which much of the activities below are based!

 **Equipment:**

A computer or other device to run a projectile simulation on the PhET website.

**Procedure:**

Go to <https://phet.colorado.edu/en/simulation/projectile-motion> and open up the simulation.



Figure 1: Measuring Tool

Spend several minutes playing around with all of the features of the simulation, getting to know all of its capabilities. Be sure to check out the measuring tool (see Figure 1) and how you can use it along with the pause/play buttons. This lets you measure data anywhere along the projectile’s path.

**Part I: Vector Components of a Projectile**

In this part of the activity, we will explore how velocity and acceleration vectors behave during the flight of a projectile.



Figure 2: Vectors Tab

1. Click on the “Vectors” Tab (See Figure 2).
2. Cannon set up: Make sure the cannon is set at ground level (0 m mark) and at a 40° angle. Set initial speed to 16 m/s.



Figure 3: Vectors display options

1. Display options: Have the vector display options set such that they **show** components, velocity vectors, and acceleration vectors, but force vectors and air friction are turned **off**. (See Figure 3)
2. Now fire the cannon! Carefully observe the velocity and acceleration vectors. Re-fire the cannon as many times as you need to in order to answer Analysis Questions #1-3 below. Using slow motion and the pause/play buttons may help.
3. Now turn **on** air resistance and fire the cannon again! Re-fire the cannon as many times as you need to in order to answer Analysis Questions #4-5 below. Using slow motion and the pause/play buttons may help.

Analysis Questions for Part I:

1. When you neglect air resistance, what do you observe about the **acceleration** vector throughout the cannonball’s trajectory?
2. When you neglect air resistance, what do you observe about the **horizontal component of the velocity vector** throughout the cannonball’s trajectory?
3. When you neglect air resistance, what do you observe about the **vertical component of the velocity vector** throughout the cannonball’s trajectory?
4. When you include air resistance in the simulation, what additional vector is now present that was not before?
5. How do any of your answers for #1-3 change in the presence of air resistance?

**Part II: Determine Acceleration Due to Gravity**

In this part of the activity, we will explore the affect of launch angle on range, maximum height, and hang time.

1. Keep your cannon set at ground level with initial speed of 16 m/s.
2. Make sure air resistance is turned **off**.
3. Fire your cannon at the angles indicated in Table 1 below. Record the range, max height, and hang time for each launch.

Table 1: Data for launches with no air resistance

|  |  |  |  |
| --- | --- | --- | --- |
| Angle | Range (m) | Max Height (m) | Hang Time (s) |
| 30° |  |  |  |
| 40° |  |  |  |
| 45° |  |  |  |
| 50° |  |  |  |
| 60° |  |  |  |
| 90° |  |  |  |

1. Now turn air resistance **on**.
2. Fire your cannon at the angles indicated in Table 2 below. Record the range, max height, and hang time for each launch.

Table 2: Data for launches with air resistance

|  |  |  |  |
| --- | --- | --- | --- |
| Angle | Range (m) | Max Height (m) | Hang Time (s) |
| 30° |  |  |  |
| 40° |  |  |  |
| 45° |  |  |  |
| 50° |  |  |  |
| 60° |  |  |  |
| 90° |  |  |  |

Analysis Questions for Part II:

1. When you neglect air resistance, what launch angle optimizes range?
2. When you neglect air resistance, what launch angle optimizes maximum height?
3. When you neglect air resistance, what is the effect of launch angle on hang time?
4. What do you observe about your results for two launches whose angles happen to be compliments of each other?
5. How do your answers to #6-9 change when you include air resistance?

**Part III: Confirming Projectile Motion Calculations**

For each analysis question below, use 2-D kinematics calculations in order to answer the question. Be sure to show all work in your lab report. (Assume air resistance is negligible.) Then confirm each answer using the simulation. Please include a screenshot verifying each answer.

1. If the cannon is placed 10 meters above the ground and the cannonball is launched horizontally at 16 m/s, where should a bull’s eye be placed on the ground in order to be hit by the cannonball?
2. If the cannon is placed at ground level and fired with an initial velocity of 18 m/s at 60°,
	1. How high will it go?
	2. Where on the ground should a bull’s eye be placed in order to be hit by the cannonball?
3. If the cannon is placed 6 meters above the ground and fired an initial velocity of 14 m/s at 35°, where on the ground should a bull’s eye be placed in order to be hit by the cannonball?

**Part IV: Design Your Own Investigation**

In this activity we have explored the affect of launch angle on range, maximum height, and hang time, both neglecting and accounting for air resistance. But there are many more possible aspects of projectile motion that can be investigated using this simulation.

1. Click on the “Lab” tab. (Refer back to Figure 1)
2. Note that you now have the ability to control the mass and diameter of the cannonball as well as the strength of gravity.
3. Choose one of those properties and design and implement an experiment in order to investigate its effect (or lack thereof) on a measurable property of a projectile (e.g. range, maximum height, hang time, etc). You will be graded based on the thoroughness of your methodology as well as your success in communicating the details of this investigation in writing as part of your lab report.

Write a full lab report chronicling all parts of this projectile motion investigation. Be sure to follow and include a completed lab report checklist.