**Projectile Motion - Hands On**

**Background**

So far, we have primarily studied things that move in only one dimension, either horizontal or vertical. In reality, though, many things move in two dimensions, that is, both horizontally and vertically at the same time. One of the simplest examples of two-dimensional motion is a moving ball.

One of the most important things to remember is that while each dimension is separate (don’t mix your horizontal and vertical variables), they can both be written with the same set of equations. The equations for motion are

  

**Goal:** To examine projectile motion by using a projectile launcher to measure the muzzle velocity and hit a target.

***Warning!*** *Never look directly down the muzzle of the launcher. Always be sure to clear the area of classmates and lab partners before launching. Do not use your finger to compress the launcher, use the push rod instead.*

**Part I - Determining the Muzzle Velocity**

In this part of the lab, you will use the projectile launcher to shoot a small metal ball across the room at a horizontal angle - this will allow us to determine the muzzle velocity (the speed that the ball leaves the launcher).

* Clamp the Mini-launcher at the end of your lab bench. Adjust the angle of the launcher to 0.0 ̊ such that the ball will be fired horizontally. Measure the height of the ball above the floor and record it here.
* Now, place the piece of carbon paper (with white paper underneath) at an appropriate distance away such that the ball will hit it when fired. Keep the launcher set to the shortest range setting throughout the entire lab. Find the horizontal range of the ball (how far it goes in the *x­-*direction. Repeat for a total of five trials and record the values below.

|  |  |
| --- | --- |
|  | Horizontal range (m) |
| Trial #1 |  |
| Trial #2 |  |
| Trial #3 |  |
| Trial #4 |  |
| Trial #5 |  |
| Average: | |

* Now let’s use the equations of motion to calculate the muzzle velocity of the ball.
* Using the information you measured above and what you know about the acceleration, fill in the blanks below (looking for numbers)

|  |  |
| --- | --- |
| *x­*-direction | *y­*-direction |
| \_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_ |
| (what we’re solving for) | \_\_\_\_\_\_\_\_\_\_\_\_ |
| \_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_\_ |
| ? | ? |

* Looking at table that you just filled in, you should see that there are more known quantities in the *y*-direction. So, it makes sense to use the *y*-direction to solve for the only missing quantity - time! Use your equations of motion to solve for time in the *y­-*direction.
* Remember that time is the only variable that is necessarily the same in both the *x-*direction and the *y-*direction. So, that means that the only variable that you don’t know in the *x*-direction is the muzzle velocity,  Use the equations of motion to solve for the muzzle velocity.

**Part II - Predicting the Range for Any Angle**

* Now, we need to predict the range of the ball shot at an angle using kinematics. Though it may be tricky at first, let’s set up this problem using only variables. The best reason to do that is because it makes the final calculations much simpler and quicker! Let’s work through it step by step …
* For these tests, the projectile launcher will be at an angle. That means that you’ll need to resolve the velocity into the *x* and *y* components. Remember that the full velocity is the muzzle velocity that you solved for in Part I. Use the diagram below to help you write down the components of the initial velocity using the launch angle, , and the muzzle velocity,  (Looking for variables.)



* When we run each test, we will be able to measure the height. Remember that  Since the ball lands on the ground, . That means that we can write  or even more simply:  Use the information so far, along with your knowledge of acceleration, to fill in the blanks in the table below. **There should only be variables below**.

|  |  |
| --- | --- |
| *x­*-direction | *y­*-direction |
| What we’re solving | \_\_\_\_\_\_\_\_\_\_\_\_ |
| \_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_ |
| \_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_\_ |
| ? | ? |

* Now it’s time to put things together. As you can see, you know the most about the *y*-direction. And, we also know that the acceleration in the *x* direction is zero. That actually makes things a bit simpler because it removes a piece of our equation. So, use the equations of motion to solve for time in the *x*-direction.



* We also know that time is the only variable that is necessarily the same in both the *x* and *y* directions. So, use the equations of motion in the *y­*-direction and substitute the expression time that you found above. (Hint: you should have gotten  for the time.)
* It may feel like it’s getting messy, but it will be worth it! Compare your work to this equation to make sure you’re on the right track:



* Finishing the solution will not be nearly as ugly as it may seem. We want to solve for the range,  If you look carefully, you’ll see that what we have is a quadratic equation! Compare what you did above to the standard form of a quadratic,  In the space provided, write down the equation for each variable of the quadratic.







Success! You’ve now derived the most general equation for the range of the ball of any launch angle that you choose. When it’s time to take data and actually solve, feel free to use an online quadratic equation solver, like the one available from Math Warehouse or Wolfram.

<http://www.mathwarehouse.com/quadratic/quadratic-formula-calculator.php>

<http://www.wolframalpha.com/widgets/view.jsp?id=f7c358d46c9ccc355492bfb66d2c59b>

**Part III - Launching at an Angle**

* Choose any angle between 20 and 60 degrees. Complete the table below to measure the appropriate variables, calculate the predicted range, measure the actual range, and find the percent error.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Measured | | | Theory/Prediction | | | |  |
|  | for Quadratic Equation | | |  | %  Error |
|  |  |  |  | A | B | C |
| Trial #1 |  |  |  |  |  |  |  |  |
| Trial #2 |  |  |  |  |  |  |  |  |
| Trial #3 |  |  |  |  |  |  |  |  |

* Repeat for two more angles of your choosing.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Measured | | | Theory/Prediction | | | |  |
|  | for Quadratic Equation | | |  | %  Error |
|  |  |  |  | A | B | C |
| Trial #1 |  |  |  |  |  |  |  |  |
| Trial #2 |  |  |  |  |  |  |  |  |
| Trial #3 |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Measured | | | Theory/Prediction | | | |  |
|  | for Quadratic Equation | | |  | %  Error |
|  |  |  |  | A | B | C |
| Trial #1 |  |  |  |  |  |  |  |  |
| Trial #2 |  |  |  |  |  |  |  |  |
| Trial #3 |  |  |  |  |  |  |  |  |

**Part IV – Predicting Distance with a Launch of Known Angle**

Your instructor will give you an angle, you will predict the distance the projectile will travel, and place a bullseye target. You will be judged by how close your projectile falls from the center!

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Measured | | | Theory/Prediction | | | |  |
|  | for Quadratic Equation | | |  | %  Error |
|  |  |  |  | A | B | C |
| Trial #1 |  |  |  |  |  |  |  |  |