Projectile Motions Lab

Investigating if the initial height would change the x displacement

Terry Tong, Victor Jeung, Cathy Liu, Jason Feng

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Abstract

This lab for projectile motions will be investigating the properties of the x displacement of a projectile. The change of the x displacement can be changed dramatically by any type of variable such as initial angle, initial speed, initial height, and air resistance but it is negligible. Our lab will be focused on changing the initial height and seeing the changes in the X displacement.

Introduction

Hypothesis

Our hypothesis for the displacement of the ball is that it will increase with the initial height changes.

Variables within the experiment

The variables within our experiment will be the Displacement of Y which we will control as an independent variable. While all other except the displacement of x and time will be set to one state and will not change, such as initial velocity and initial angle (set to zero to eliminate this variable).

Theory

\[(\text{equation 1}) \quad \Delta D_x = \Delta V_x \Delta t \quad \text{Uniform motion equation to find X displacement} \]

\[(\text{equation 2}) \quad \Delta D_y = \Delta V_y \Delta t + \frac{1}{2} g \Delta t^2 \quad \text{Uniform accelerated motion to find fly time(reject negative value) because the fly time is shared among its x component, we use this time to find the x displacement after find its velocity.} \]

\[(\text{equation 3}) \quad v_{fy}^2 = v_{fy}^2 + 2 gh \quad \text{Uniform accelerated motion, used for find out the initial velocity of the projectile from when it begins its free-fall.} \]

\[v_{fy}^2 = 0 + 2 gh \quad \text{Initial velocity is zero from top of ramp} \]

\[(\text{equation 4}) \quad v_{fy} = \sqrt{2 gh} \quad \text{The final velocity is found, which the initial velocity for the actual freefalling motion is.} \]

\[
\Delta D_x = \sqrt{2 gh} \pm \frac{-4 \frac{1}{2} g \Delta d_y}{2 \frac{1}{2} g} \quad \text{This equation combines all of 2 and 4 in to equation 1 which results in a direct calculation of the displacement of X} \]
Linearizing the equation by combining 1, 2, and 4.

\[ \Delta D_x = \Delta V_x \Delta t \] then substituting equations 2 and 4 in to initial velocity and time we get

\[ \Delta D_x = \sqrt{2gh} \pm \sqrt{\frac{-4g^2 \Delta d_y}{2^2 g}} \]

\[ \Delta D_x = \frac{2g(\pm \sqrt{\Delta h})}{g} \]

\[ \Delta D_x = \pm 4\sqrt{h} \sqrt{\Delta y} \]

\[ \log \Delta D_x = \log 2\sqrt{\Delta h} + \log 2\sqrt{\Delta y} \] Taking the log of both sides will show it is a linear relationship which log has a coefficient of 1.
**Experiment**

**Apparatus**

- 2 retort stands
- 1 hot wheel tracks
- 1 clamp
- Pieces of Carbon Paper and a sheet of line paper
- Tape, clear tape
- Projectile (Metal Ball Bearings)

**Setup of Apparatus**

Our set up for this lab was to use two retort stands placed one in front of the other. Then using clamps to clamp on to the end of a hot wheels race track approximately 28 cm above the base of the retort stand. Then using clear tape (which minimizes the friction when the ball goes over it) and tape the race track down on to the first rhetoric stand. The base length of our stand was 51.2 cm. Then Lay down the Piece of carbon paper to approximately where you think the steel balls would land, we placed a meter stick from the edge of where the balls are launched so we can quickly get the measurements.

![Figure 1: Apparatus setup of our lab.](image-url)
Conducting the Lab

Our lab was conducted by letting steel balls go at the top of the ramp, which basically is almost zero velocity at the top of the ramp. From the ramp's top we count down and release, which at the same time we start counting time and stop at the time when I hear the ball hit the floor. For each trial there would be 6 runs (3 runs with the heavy ball, 3 runs with light ball). After each trial we raise the entire height of the apparatus by placing a wooden plank under the two retort stands.

Data

<table>
<thead>
<tr>
<th>Small Balls:</th>
<th>Big Balls:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement X (cm)</td>
<td>Height(cm)</td>
</tr>
<tr>
<td>75.4</td>
<td>93.3</td>
</tr>
<tr>
<td>75.0</td>
<td>93.3</td>
</tr>
<tr>
<td>74.3</td>
<td>93.3</td>
</tr>
<tr>
<td>76.5</td>
<td>96</td>
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<td>78.9</td>
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</tr>
<tr>
<td>85.0</td>
<td>114</td>
</tr>
<tr>
<td>83.1</td>
<td>114</td>
</tr>
</tbody>
</table>

Figure 2: Raw data for small and big ball comparing displacement in x(cm) and height (cm) in tabular form.

The data we collected seems to take a linear form and that the distance in x is changing linearly according to the increase in the initial height. From the data we had also concluded that the weight of the ball also may apply a change in the X displacement also, but there is no evidence to conclude why it is so.

The graph as you see shows our collected data, the red plots represent the heavier (61 gram) steel balls while the blue shows the lighter (8 grams) steel balls. And there is a clear difference in how much difference there is between the heavier ball and the lighter ball.

The correlation ship between the initial height and the distance it yielded is shown quite clearly that it is a linear relationship. Slope of the graph is $H = 0.5956x + 19.746$ for big balls and $h = 0.4304x + 34.435$
both of which are a linear relationship, and does not show any signs of being an exponential or log characteristics. This of which proves that our theoretical calculations are correct.

![Displacement in x (cm) vs. Initial Height (cm) for Small and Big Ball Rolling Down Hot Wheels Ramp](image)

**Conclusion**

In conclusion, our hypothesis was correct because a direct relationship exists between the initial height and x displacement. As the initial height increased, x displacement also increased, this was due to the fact the extended height created more flight time for the ball, which means the velocity at x component is able to travel further and further. This created a linear relationship as we hypothesized. There were some random and systematic errors though that caused discrepancies in the data. These were:

- The systematic error of $\theta$ not being equal to zero since the ramp was curved and taped down at the end of the counter. This resulted in the ramp not being straight causing the x displacement to change.
- The systematic error of friction on the ramp, which caused the distance projected to be off by approximately 10cm.
• The systematic error of the ramp being uneven, due to the use of one retort stand. The random error caused the ramp to shake and wobble while the ball was in motion resulting in a change of the x displacement.

If we were to repeat this lab, we would propose the following changes:

• Use a ramp that is straight and does not curve with little friction to ensure that $\theta$ is zero. This also ensures the ramp does not shake or wobble while the ball is in motion.
• Verify the relationship between initial velocity and height.

**Acknowledgements**

Mr. Murzaku’s notes and assistance with the projectile motion lab.