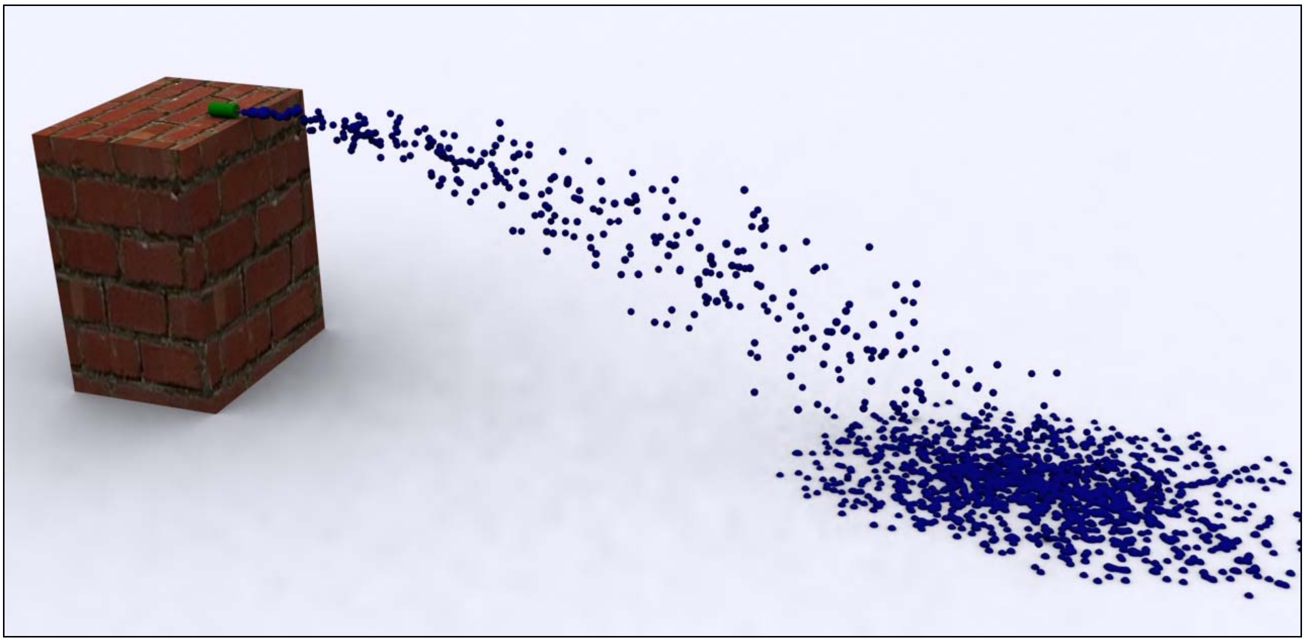
Determining the Average Muzzle Velocity of a Water Pistol



Andrew Harvey
12 PHYSICS

Title:

Determining the Average Muzzle Velocity of a Water Pistol

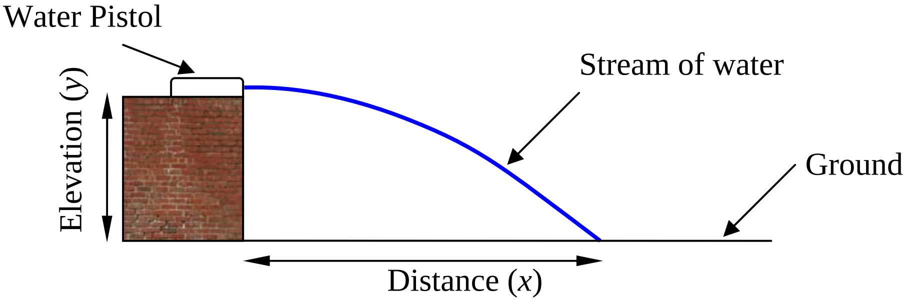
Aim:

To determine the average muzzle velocity of a water pistol.

Variables:

Independent (Change)	**Dependent (Measure)**	**Control (Same/Constant)**
Nothing.	Distance (horizontal)	Value of *g* (ie. mass of earth and radius of earth + elevation) Water Pistol Amount of water in the water pistol Substance be fired from the water pistol (water) Elevation of water pistol Angle of water pistol Air density Flow of air around experiment (Do indoors where there is less wind) Velocity of frame of reference (earth) Altitude of ground (flat surface) Elevation of water pistol (vertical height) Force on trigger

Apparatus:



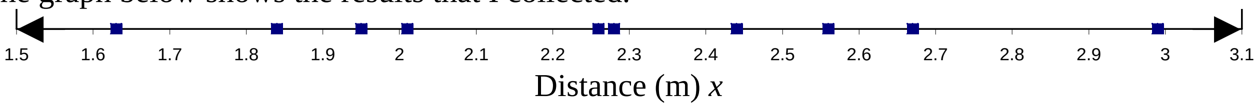
Procedure:

1. Fix the *water pistol* at an angle of 0° to the horizontal, at a constant elevation.
2. Place a ruler along the line of action of the *water pistol*, placing 0 directly below the *water pistol muzzle*, keeping the ruler horizontal.
3. Fire the *water pistol*, by slowly applying a constant force on the trigger.
4. Measure the approximate average distance (*x*) the water traveled.
5. Repeat step 3 and 4 multiple times. Each time keep the things in the same/constant column the same.
6. Record results.
7. Calculate average.

Data Recorded/Data:

Fire Number	Distance (m) x	Elevation (m) y	Initial Velocity (ms^{-1})
1	2.28	0.455	7.482
2	2.99	0.455	9.812
3	1.63	0.455	5.349
4	2.44	0.455	8.007
5	2.56	0.455	8.401
6	1.95	0.455	6.399
7	2.26	0.455	7.417
8	2.67	0.455	8.762
9	2.01	0.455	6.596
10	1.84	0.455	6.038

The graph below shows the results that I collected.



Calculations:

Process

Use $v_y{}^2 = u_y{}^2 + 2a_y\Delta y$ to find v_y ($u_y = 0$, $a = 9.8$, Δy = elevation)

Then use $v = u + at$ to find t ($v = v_y$, $u = 0$, $a = 9.8$)

Then use $\Delta x = u_x t$ to find u_x (Δx = horizontal distance)

u_x will equal $\left|\vec{u}\right|$ because the water is launched horizontally, thus there is no vertical motion at the beginning. The direction of u_x will always be along the line of action of the water pistol.

Actual Calculations

①

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.28 \times 9.8}{\sqrt{19.6 \times 0.455}} = 7.482ms^{-1}$$

②

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.99 \times 9.8}{\sqrt{19.6 \times 0.455}} = 9.812ms^{-1}$$

③

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{1.63 \times 9.8}{\sqrt{19.6 \times 0.455}} = 5.349ms^{-1}$$

④

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.44 \times 9.8}{\sqrt{19.6 \times 0.455}} = 8.007ms^{-1}$$

⑤

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.56 \times 9.8}{\sqrt{19.6 \times 0.455}} = 8.401ms^{-1}$$

⑥

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{1.95 \times 9.8}{\sqrt{19.6 \times 0.455}} = 6.399ms^{-1}$$

⑦

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.26 \times 9.8}{\sqrt{19.6 \times 0.455}} = 7.417ms^{-1}$$

⑧

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.67 \times 9.8}{\sqrt{19.6 \times 0.455}} = 8.762ms^{-1}$$

⑨

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{2.01 \times 9.8}{\sqrt{19.6 \times 0.455}} = 6.596ms^{-1}$$

⑩

$$u = \frac{x \times 9.8}{\sqrt{19.6 \times y}} = \frac{1.84 \times 9.8}{\sqrt{19.6 \times 0.455}} = 6.038ms^{-1}$$

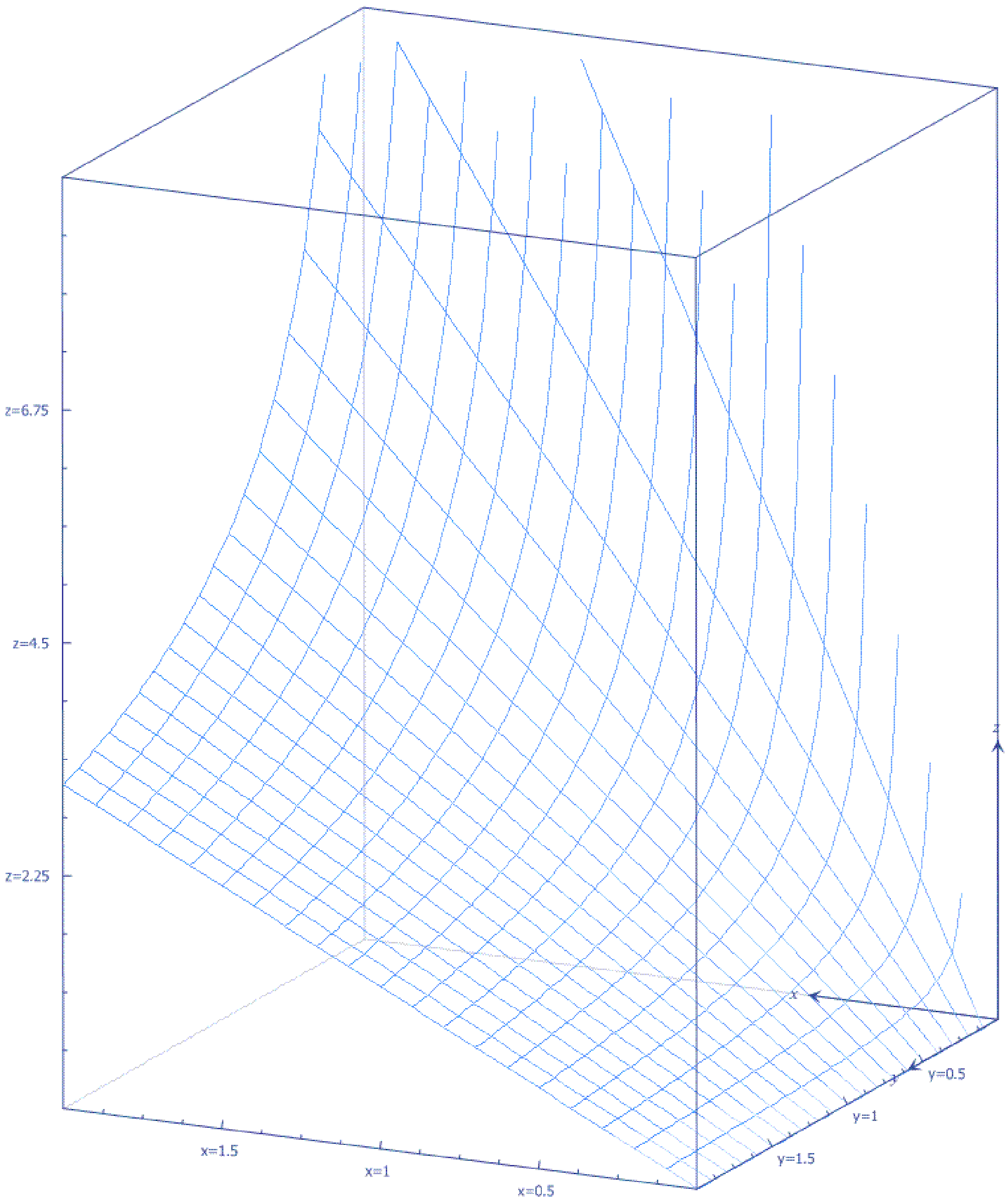
The Function

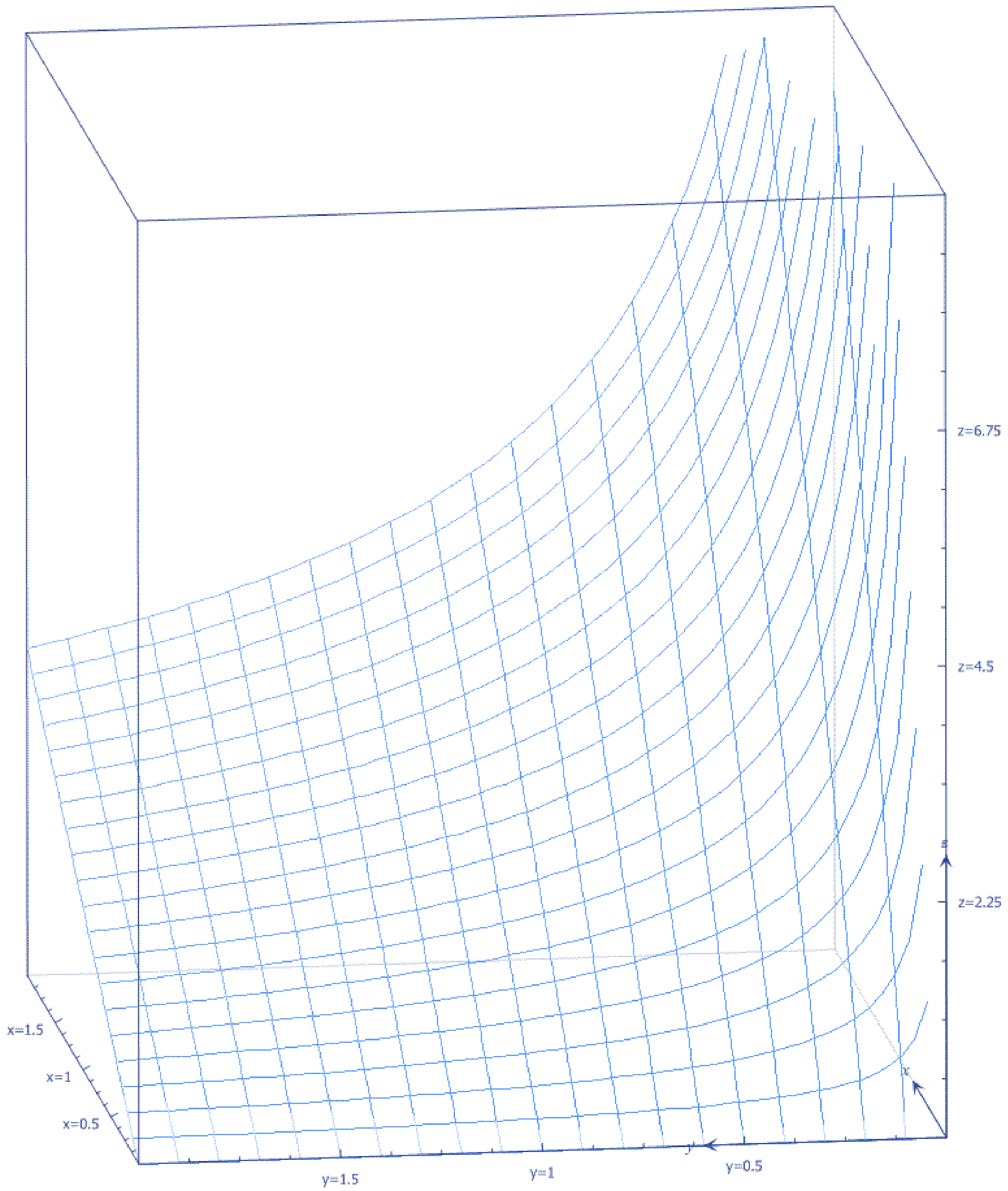
The relationship between horizontal distance, vertical height, and initial velocity can be determined, and is given by:

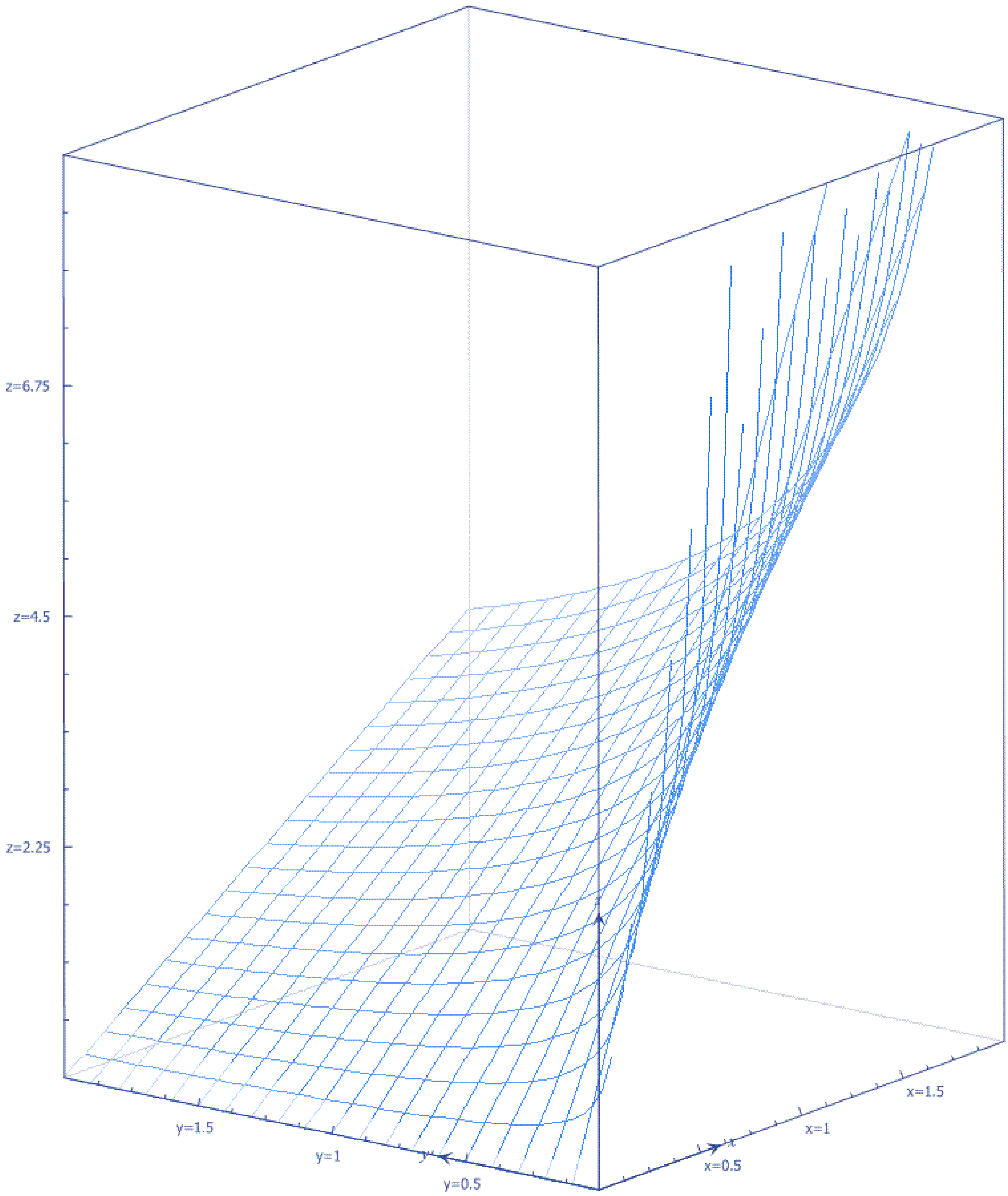
$$u = \frac{7x}{5} \cdot \sqrt{\frac{\left(\frac{5}{2}\right)}{y}} \quad \textbf{OR} \quad u = \frac{x \times 9.8}{\sqrt{19.6 \times y}}$$

Where,
u = initial velocity
x = horizontal distance
y = vertical height

The graph of this relationship is shown below from different points of view, (where *z* axis is *u*)




z=6.75
z=4.5
z=2.25
x=1.5
x=1
x=0.5
y=1.5
y=1
y=0.5



Statistical Analysis of Data
Average horizontal distance: 2.263 m
Range horizontal distance: 1.36 m

Average initial velocity: 7.4263ms^{-1}
Initial Velocity Standard Deviation: 1.294

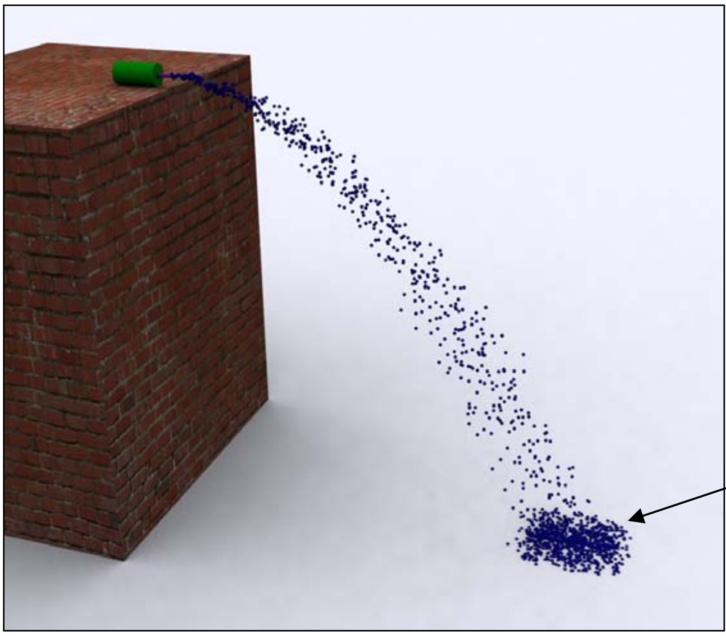
Discussion of Reliability and Conclusion:

Using this method and these calculations eliminates the need for measuring time, which would be impractical and unreliable, especially as it is a stream of water not a single object, and given that the time of flight is relatively short.

Also the lower the height then the less horizontal distance traveled, and thus less affected by air resistance (as my formula used do not account for air resistance), and thus a more accurate velocity, however the greater the horizontal distance, the more accurate your measurements are. But also if the height is too high then the water will reach its terminal velocity and thus the results would be less reliable. Also different values of height result in different values of *g*. So this should be taken into account and *g* should be calculated. However even if you change your height 100m the value of *g* will only change by 0.0003.

The reliability of this experiment was also decreased because the trigger of the water pistol was controlled by a human, this leads to the problem that a human cannot apply the same amount of force on the trigger every time.

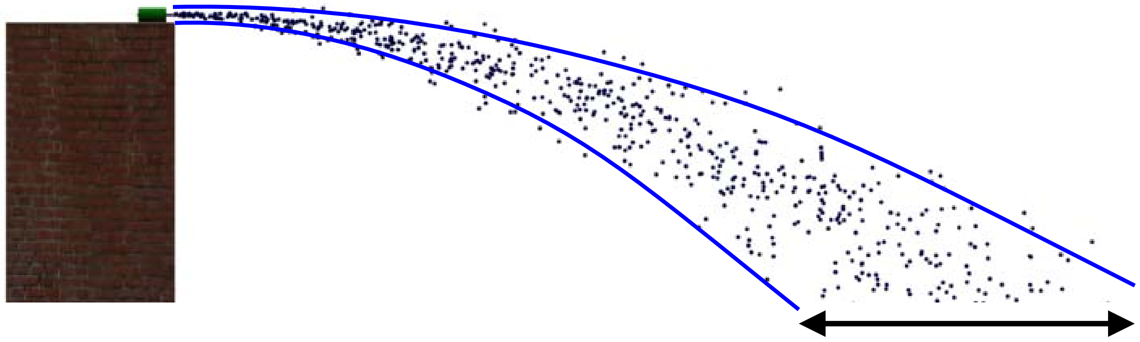
There are flaws in my method and thus this experiment is less reliable. This can be explained with the diagram below.

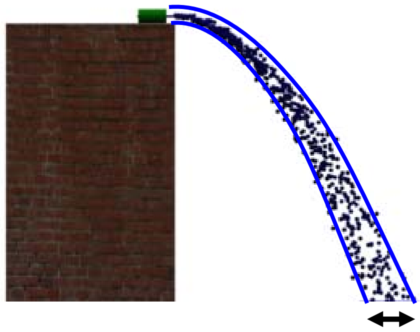


As you can see above, when the water pistol is fired, the water initially follows one line and stays stuck together, however after just falling slightly in height, the water disperses, and once it lands on the ground there are many different droplets in different places. In order to correctly fulfill the aim of the experiment, I would need to measure the distance from the position of every one of those droplets landed at, to the wall directly underneath the water pistol muzzle. Then take the *average* of all those distances. However there are far too many droplets for this to be done. Not to mention the problem of when 2 or more drops land on the same spot, as you wouldn't know if only one drop or if there were multiple drops that landed in that position, as this would affect the average.

The standard deviation of the data was quite high, so this means that the experiment is not very reliable.

The ratio of elevation to average distance was 455:2263. So the distance was quite long compared to the height. This is bad in terms of experiment reliability because the long distance means that there is more dispersion of the water droplets, and the water is more affected by air resistance. The reason for the dispersion error is shown in the figure below. As you can see the further the water went, the more it spread out.





The only way to compensate of this is to increase the height. However as mention previously, this also has adverse effects, unless in a vacuum.

As with any experiment, it could have repeated it more times to get a more accurate result.

Another factor that could have affected the reliability of my experiment was air currents (wind). This is a problem because non zero air currents are not taken into account in the formula that were used. This can be controlled to a certain extent by conducting the experiment indoors, without the fans on.

A problem also arose by trying to apply a constant force to the trigger, for the duration of the firing, and also each time the water pistol is fired. This could be controlled using a spring balance attached to the trigger. But this method has a factor of human error, so it could be automated with a robot.

Conclusion:

The average muzzle velocity of my water pistol was 7.4263ms^{-1}, in the direction that the water pistol was oriented.

PLEASE NOTE: This experiment was NOT based on a computer simulation, rather the computer simulation was based on the real world data. The computer simulation was only used an illustration, illustrating only particular aspects that were raised through the physical experiment. The illustrations do not depict a 100% real world replica.