Lab #4 Formal Report

PHY 203-01

Ballistic Projectile Formal Report

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Abstract

To test Galileo's Principle of Relativity, a projectile motion experiment was conducted, which was applied to the situation where a bullet is fired horizontally from the a ballistic gun with the intention to get directly into the cup on the floor. In the experiment, the main question was how far the ballistic gun should be placed for the fired bullet to land in the cup. To answer this question, measurements were acquired for the vertical and horizontal components of a bullet being shot from a ballistic gun. A meter ruler was used for measuring the distance of the traveled bullet between two Photogates. Two standard Photogates and a Digital Timer were used to get the time it took the bullet to travel through them. Using the known definition of velocity, distance over time, the horizontal velocity was calculated. The velocity of the sphere in the horizontal direction and vertical direction were acquired with the measuring devices and calculated from the definition of average velocity and the equation of displacement under constant acceleration, respectively. The time it took the bullet to travel vertically was applied to the horizontal motion as well. The calculated time was then used to find the total displacement in the horizontal direction. The horizontal distance or total displacement of the bullet was calculated to be 258.1cm ±7.8cm if it shot from a height of 85.8cm. To verify this projectile motion a medium size plastic cup was placed with masking take on the floor. The ballistic gun was placed on the table 258.1 cm away from the cup and the bullet was fired. The bullet landed about 10 cm away from the cup, not reaching it. To account for the miss, the ballistic gun was pushed 8cm closer to the cup and the fired bullet travelled directly into the plastic cup. From the experiment, it was evident that the calculated displacement was not the exactly correct. Based on the calculated uncertainty, the bullet should have been placed 7.8cm closer than the calculated displacement value. The correct displacement of the bullet should be 250.3cm away from the cup.

Introduction

According to the Galileo's Principle of Relativity, it is a requirement that the laws of physics remained the same in all inert frames of reference. This is because velocity is a relationship and not a property, it is dependent on the perspective; therefore no experiment can be devised for a solitary object. Galileo also explained that if objects in free-fall will fall at the same time when dropped from the same height. Therefore the time became a shared relationship of two motions in the objects. For example, a bullet falling from the same height as a bullet shot in a horizontal direction will both fall at the same time. Logically, the horizontal and vertical displacement of the bullet shot happened at the same time therefore the same time could be used for displacement of both vertical and horizontal displacements when using the definition of average velocity. In this experiment, we used the predictive powers from the theory of relativity to determine where to place a ballistic gun to shoot a bullet into a white wax coated cup. The ability to predicting where the bullet would land was used to determine where the bullet came from because velocity is a relationship (Vab)=-(Vba).

Research Questions

Based on the principles of projectile motion and mathematical calculations, how far from a plastic cup, which is on the floor, should a ballistic gun be placed on the table in order for the brass sphere (a bullet) to be fired directly into the cup?

Data Collection

For this experiment, the research team used a meter ruler to measure length and height, and two photogates and Digital timer to measure time. The units for length and height were in centimeters, and the unit for time was in seconds.. To find the velocity the team placed two photogates on the ballistic pendulum gun. The photogates were placed approximately 18.5 cm apart. The ball was fired through the Photogates and the time was measured with the Digital Timer. Five trials were conducted to measure the time the bullet goes through both Photogates. When the ball travels across the two photogates, four different times would appear on the computer. The first time was considered when the signal in the photogates is broken and the second time value was when the signal in the second photogate was broken by the travelling bullet. For this experiment, the time that broke the laser was closed the first time indicated the starting time and the time when the laser was closed the second time indicated the ending travelling time. Before starting the trials some test runs were performed, to make sure the photogates were working. The first trial had four sets of numbers: 2.499396s, 2.502983s 2.529192s, and 2.532983s. In the first and all trails, the first and third values were used during calculation. So 2.499396s and 2.529192s were used was the time traveled in 18.5 cm for the first trial. The second trial set of times were 5.525060s, 5.528560s, 5.554560s, and 5.558076s. The third trial was 3.128099s, 3.131584s, 3.157984s, and 3.160784s. The fourth trial was 4.247483s, 4.250983s, 4.277183s, and 4.480386s. The fifth trial was 0.963784s, 0.967186s, 0.993228s, and 0.996501s. After all the trials were done the height from the bullet in the muzzle to the floor was measured using a meter ruler. The height was measured in parts: the distance between the floor and the top of the table (78cm), the distance between the table and the top of surface of the ballistic gun (3.3 cm) and the distance between the surface of the gun and the bottom of the bullet in the muzzle (4.5cm). The total distance came to 85.8 cm.

Analysis

In order to find how far the ballistic gun should be placed from the cup for the bullet to be fired directly into the cup, the principle behind projectile motions should be considered. A projectile is an object which is launched with some initial velocity and which feels only the effect of gravity (Halliday and Resnick, 2014). Problems involving projectiles are essentially two-dimensional problems, in which an object is travelling horizontally and vertically at the same time. Therefore, projectile problems can be broken down to two one-dimensional problems, which occur independently from each other (Lecture, March 4, 2015). Similarly, the bullet in the experiment behaves like a projectile, since it is launched from the ballistic gun and has a horizontal velocity and, because it is fired from the height, it experiences acceleration due to gravity. Since there is only gravity affecting the bullet, the bullet only accelerates in downward direction. Therefore, bullet should be fired or the horizontal displacement of the bullet, the initial velocity of the bullet and the time the bullet stayed in the air were needed. The bullet is fired perfectly horizontally from the ballistic gun, which means the velocity is constant at every point in time. Consequently, the initial velocity when the bullet leaves the muzzle should be the same at any moment in horizontal direction. The initial velocity was calculated from the definition of average velocity under constant velocity conditions, when initial and average velocities are the same. The definition of average velocity is displacement over time. The displacement was obtained by measuring the distance between two photogates and the time was measured by Digital Timer when the bullet travelled from one photogate to another. Based on the average of average velocities of five trials, the horizontal velocity of the bullet was found to be 623.5403523 cm/s (Calculations are given in Appendix A). Vertical velocity of the bullet was used to calculate how much time it took the bullet to fall to the floor due to gravity. Since the height from which the bullet was fired did not change, the time in the vertical direction could be used in the horizontal direction as well. Essentially, time is what connects vertical and horizontal motions. Because motions in horizontal and vertical directions do not affect each other, the vertical motion is not affected by the bullet's initial velocity in the horizontal direction. So, the bullet can be assumed to be dropped from rest, meaning it has initial velocity of zero. The equation of displacement under constant acceleration was used to find the time in the vertical direction. The displacement equals the addition of the product of acceleration and time squared and the product of initial velocity and time. As all the variables except the time variable are known, the equation can be rearranged to solve for time. As a result, the time was calculated to be 0.414 s. The obtained time was then used to calculate the displacement of the bullet from the muzzle of the gun, which was placed on the table, to the cup, which was found on the floor. The equation for displacement under constant acceleration was used again. As acceleration is zero in horizontal direction, the equation took form of only the product of the initial velocity in the horizontal direction and time in the vertical direction. The obtained displacement was found to be 258.1 cm. The calculations are provided in Appendices B and C.

Uncertainty

Uncertainty arises from the fact that actual measurements of objects cannot be obtained no matter how perfect the measuring devices are. The measurements could only be as good as the gradations of the measuring tools allow them to be. Therefore, measurements always come in ranges. Any measurements that are taken during any experiment must be recorded to the one half of the smallest measuring unit ("About Uncertainty", www.yaverbaum.org). For this experiment, the method of Fractional Uncertainty was used to find the uncertainty ranges. Two measuring devices were used during this experiment,: a meter ruler and Photogate with Digital Timer. Therefore, there were two sources of uncertainty. There were two measurements of length made: one measurement was made of the distance between photogates to calculate the initial velocity of the bullet and another one was taken in the vertical component to measure the distance from where the bullet was to the floor. To calculate Fractional Uncertainty, the uncertainty range should be divided by the number it corresponds to. If several measurements are made with the same measuring device, only the largest Fractional Uncertainty is used among the measurements. The largest Fractional Uncertainty in this experiment was the one that was obtained from calculating the FU (Fractional Uncertainty) from the length between the surface of the table and the top of the ballistic gun (3.3cm±0.05cm). The FU for this measurement came to be

0.015151515. Because there were five measurements of time from five trials, the average among these measurements was calculated and the Fractional Uncertainty from the average value was obtained. It came to be 0.000016852. The calculations are provided in Appendix D. Because Fractional Uncertainties have no units, they can be added when calculating the total displacement of the bullet. The equation used to calculate total horizontal displacement had only the initial velocity and time. The initial velocity was found by dividing the displacement between photogates measured with a ruler (cm) by the time measured with photogates (s). Then, this initial velocity was multiplied by the time that found by dividing the measurement in centimeters by acceleration. Overall, multiplication and division were performed, in which measurement of length was used twice and the measurement of time once. Three Fractional Uncertainties were added together for the overall FU of ±0.030319882, which was later converted back to the units by multiplying overall uncertainty by the total displacement. The final answer was 258.1 cm ±7.8cm. The answer was rounded due to the fact that the meter ruler that was used to measure the distance from the cup to the bullet can only show gradations to one decimal place.

Excellent

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Conclusion

This goes in Intro.

Ballistics involve the motions of projectiles, from the instant a bullet leaves the gun to the moment it impacts an object. In today's society, law enforcement specialist's uses the motion of projectiles to determine how high the suspect shot or where the suspect was located based on the position of the wounded/deceased victim. The purpose of the ballistics lab is to predict the position of the gun (used pendulum gun) based on calculations and Galileo's Principle of Relativity for the bullet to hit/ fall into a cup. In order to calculate the distance of the gun, one must understand how a bullet move, in other words the motion of projectiles. All projectiles move along a curved path with gravitational forces affecting the downward vertical pathway. The gravitational forces are applied downward that causes downward acceleration in the vertical

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pathway. This concept is consistent with the concept of free falling objects, free falling objects contains a constant acceleration known as the acceleration of gravity. Gravity does not affect the horizontal motion of a projectile because it only acts on the vertical motion. Another concept for understanding the motion of projectile, in Galileo's Principle of Relativity, the horizontal velocity of the bullet is constant. In other words, the initial, instantaneous, and average velocity are equal to each other (the velocities are the same).

The research team calculated the position of the ballistic gun based on obtaining the horizontal average velocity of the five trials using the photogate and calculating the time an object from rest would take to free-fall based on the vertical displacement of 85.8 cm. The research team calculated the initial horizontal velocity (623.54 cm/s) and time in the vertical direction (0.414 s) that were required for calculation of the total displacement the fired bullet would travel if shot from 85.8cm height. Since the horizontal and vertical motions act on the bullet, 0.414 s can be used for the horizontal time. The total displacement was calculated to 258.1+/-7.8cm. When the result for the displacement was obtained, the ballistic gun was placed 258.1 cm away from the cup. As a result, the bullet missed. Although, the bullet hit the cup from 250.1cm, when the ballistic gun was pushed forward by the research team based on the approximate point of landing (8 cm), the calculated uncertainty was almost the same as and came to be +/- 7.8cm. The difference of 0.2 cm was due to the error that were introduced during the set-up. The research group determined that the gun should be placed, including the uncertainty, approximately 258.1 +/- 7.8 cm away from the cup.

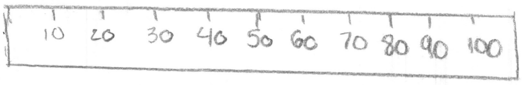
Reference:

Walker, J., Halliday, D. & Resnick, R. (2014). 2. In *Fundamentals of Physics* (10th ed.). Hoboken: John Wiley & Sons.

www. yaverbaum.org, viewed on 24 March, 2015

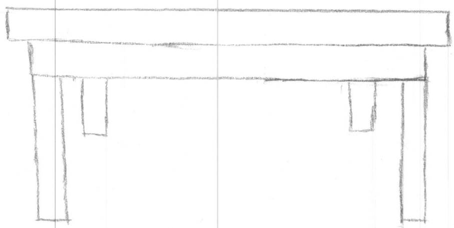
Diagram

Equipment

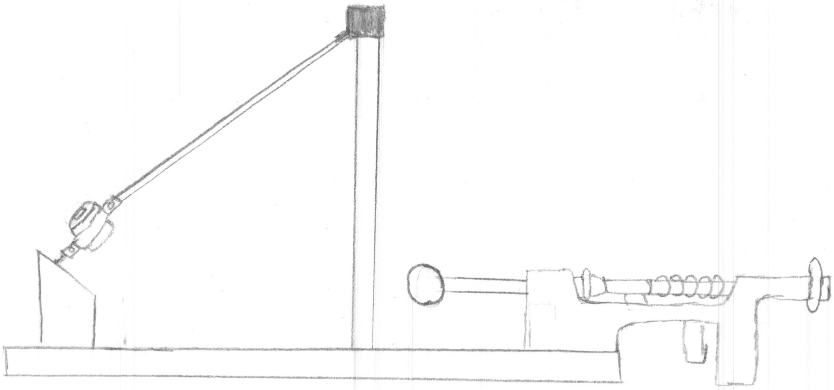


Meter Ruler

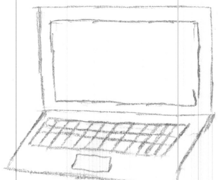
Cup



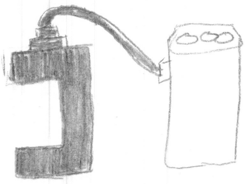
Table



Ballistic Pendulum Gun



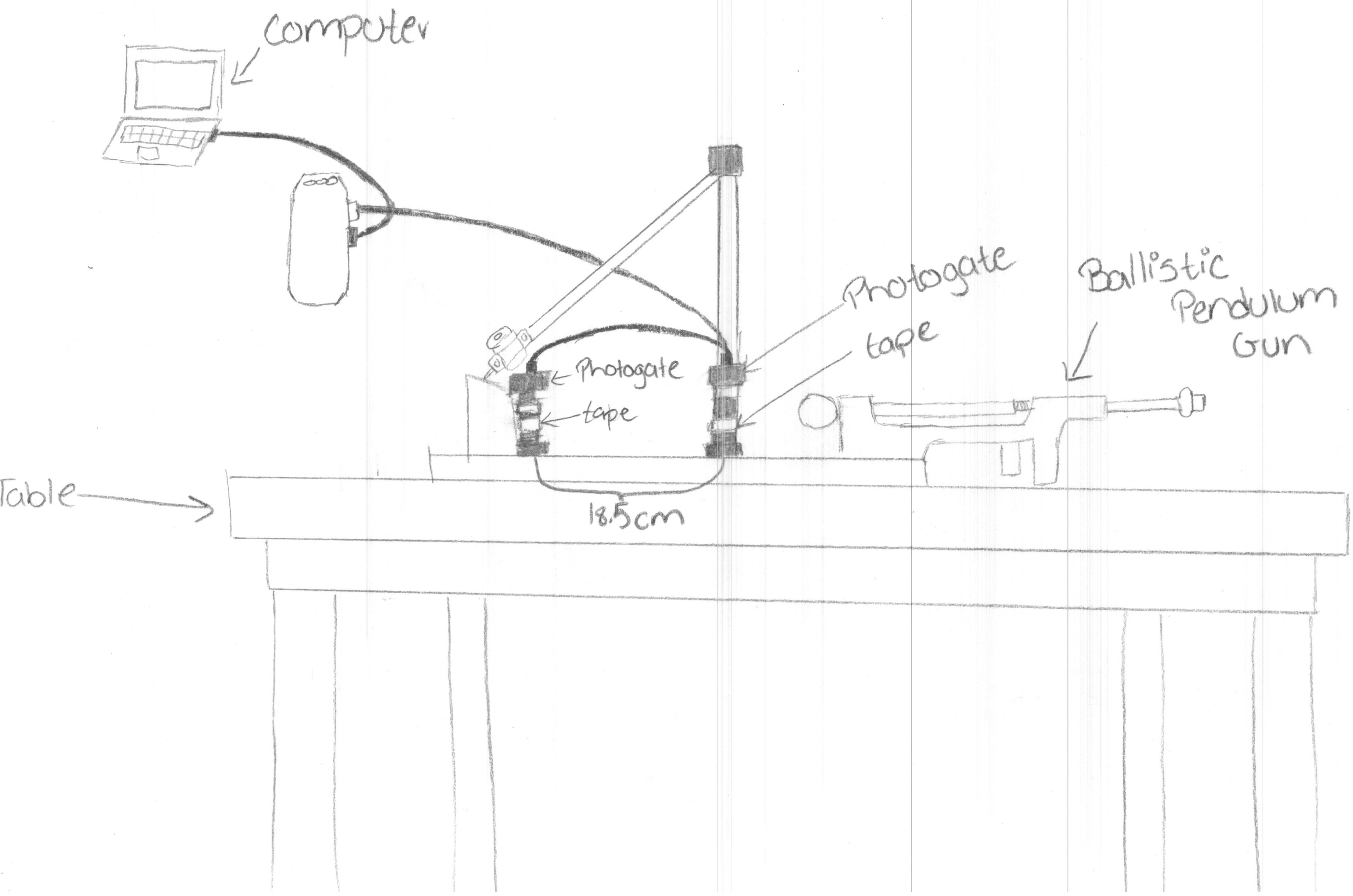
Computer



Photogate

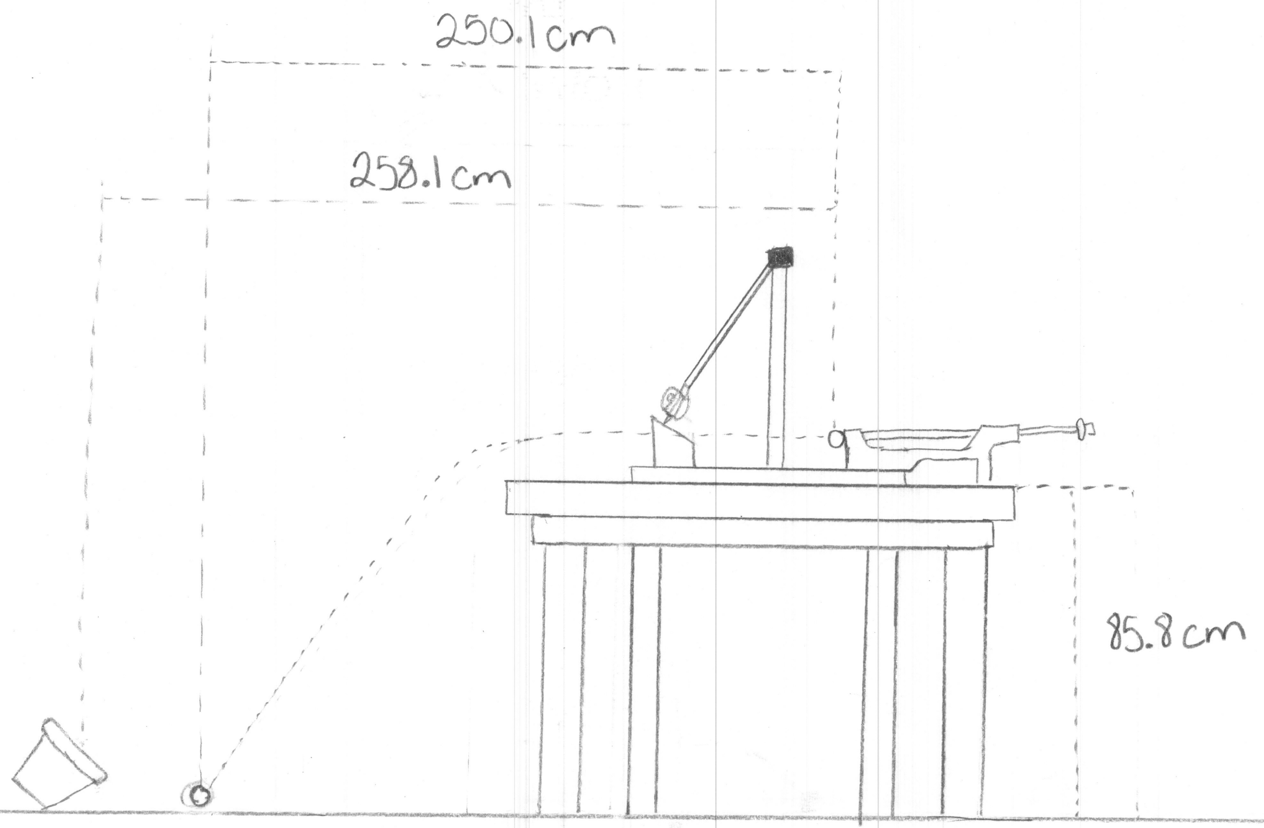
Setup: Calculate Velocity

wow!



Diagram

Setup 1: Ball into cup



Setup 2: Ball into cup

Gorgeous!

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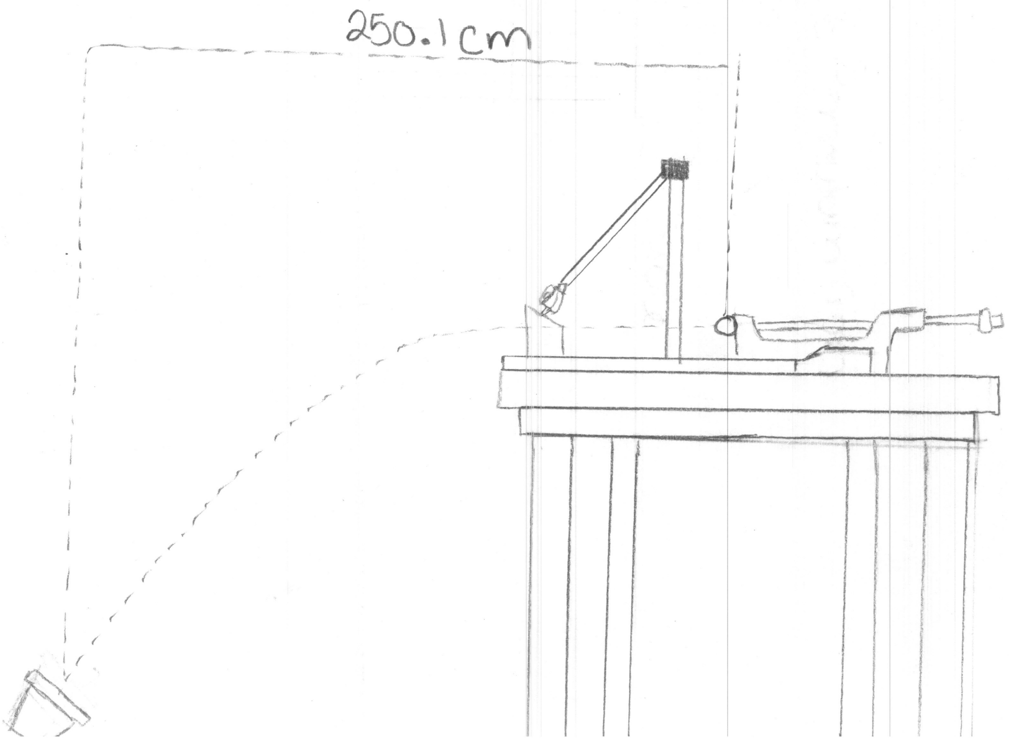


Appendix A

Data Table for Horizontal Velocity:

Trial	Horizontal Displacement (cm)	Time (s)	Horizontal Velocity (cm/s)
1	18.5cm	0.029796 s	620.8887cm/s
2		0.029526 s	626.566416cm/s
3		0.029885 s	619.039652cm/s
4		0.0297 s	622.8956229cm/s
5		0.029444 s	628.3113707cm/s

$$V_{avg} \equiv \frac{\text{displacement}}{\text{time}}$$

$$V_{trial\ 1} = \frac{18.5\text{cm}}{0.029796\text{s}} = 620.8887\text{cm/s}$$

$$V_{trial\ 2} = \frac{18.5\text{cm}}{0.029526\text{s}} = 626.566416\text{cm/s}$$

$$V_{trial\ 3} = \frac{18.5\text{cm}}{0.029885\text{s}} = 619.039652\text{cm/s}$$

$$V_{trial\ 4} = \frac{18.5\text{cm}}{0.0297\text{s}} = 622.8956229\text{cm/s}$$

$$V_{trial\ 5} = \frac{18.5\text{cm}}{0.029444\text{s}} = 628.3113707\text{cm/s}$$

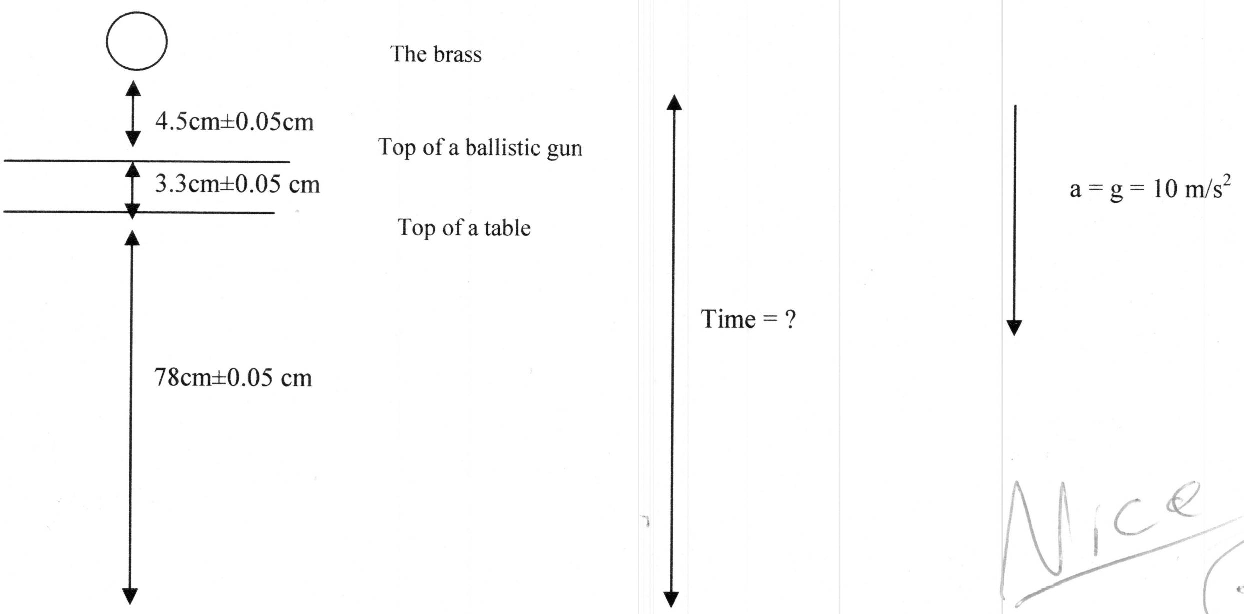
$$V_{avg} = \frac{V(\text{trial }1)+V(\text{trial }2)+V(\text{trial }3)+V(\text{trial }4)+V(\text{trial }5)}{5} = \mathbf{623.5403523cm/s}$$

$V_{avg} = V_0$, because the velocity is constant in horizontal direction.

$V_0 = \mathbf{623.5403523cm/s}$

Appendix B

Vertical Component:



Displacement = $\frac{1}{2}at^2 + V_0t$

Vertical Displacement = 4.5cm + 3.3cm + 78cm = 85.8cm

V_0 = 0cm/s (the brass is at rest at t=0)

a = 10 m/s^2 = 1000cm/s^2

Solution:

85.8cm = $\frac{1}{2} \times 1000\text{cm/s}^2 \times t^2$

$$t = \pm\sqrt{\frac{85.8cm}{500\text{cm/s}^2}}$$

t = 0.414 s (the time it takes for the bullet to fall to the floor from rest)

Nice +1

Appendix C: Horizontal Component:

$a = 0\ cm/s^2$ (based on Galileo's Principle of Relativity)

$V_{avg} = V_0 = 623.5403523 cm/s$

Displacement = ?

Time = 0.414 s

Displacement $= \frac{1}{2}at^2 + V_0 t$

Displacement $= 0 + 623.5403523 \frac{cm}{s} \times 0.414\ s$

Horizontal Displacement = 258.1457059 cm ≈ 258. 1cm

Appendix D: Uncertainty

Uncertainty from the meter ruler:

Horizontal Displacement = 18.5cm ±0.05cm

FU(Fractional Uncertainty) = 0.05cm/18.5cm = 0.002702703

Vertical Displacement = 4.5cm ±0.05cm + 3.3cm ±0.05cm + 78cm ±0.05cm

FU=0.05cm/4.5cm =0.01111111

FU=0.05cm/3.3cm=0.015151515

FU= 0.05cm/78cm=0.000641026

Since the uncertainty comes from the same tool (meter ruler), a largest Fractional Uncertainty is used.

FU = 0.015151515

Uncertainty from two Photogates and the Digital Timer:

Uncertainty for time = $\pm 5\times10^{-7}$s

$$t_{avg} = \frac{0.029796s+0.029526s+0.029885s+0.0297s+0.029444s}{5} = 0.0296702s$$

$$FU = \frac{5\times10^{-7}s}{0.0296702s} = 0.000016852$$

Final Uncertainty:

$$\text{Displacement} = V_0t = \frac{623.5403523cm(FU=0.015151515)}{s(FU=0.000016852)} \times 0.414\,s\,(FU = 0.015151515) = 258.1457059\text{ cm }(0.015151515 + 0.015151515 + 0.000016852) = 258.1457059\text{ cm }(\mathbf{FU = 0.030319882})$$

$$\text{Uncertainty} = 258.1457059\text{ cm} \times 0.030319882 = \pm\mathbf{7.826947cm}$$

Final Displacement is 258.1cm ±7.8cm (Rounded)