Final Report - M1: Range

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PHSX 216 – Physics I Laboratory

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Lab Explanation

Brief Explanation

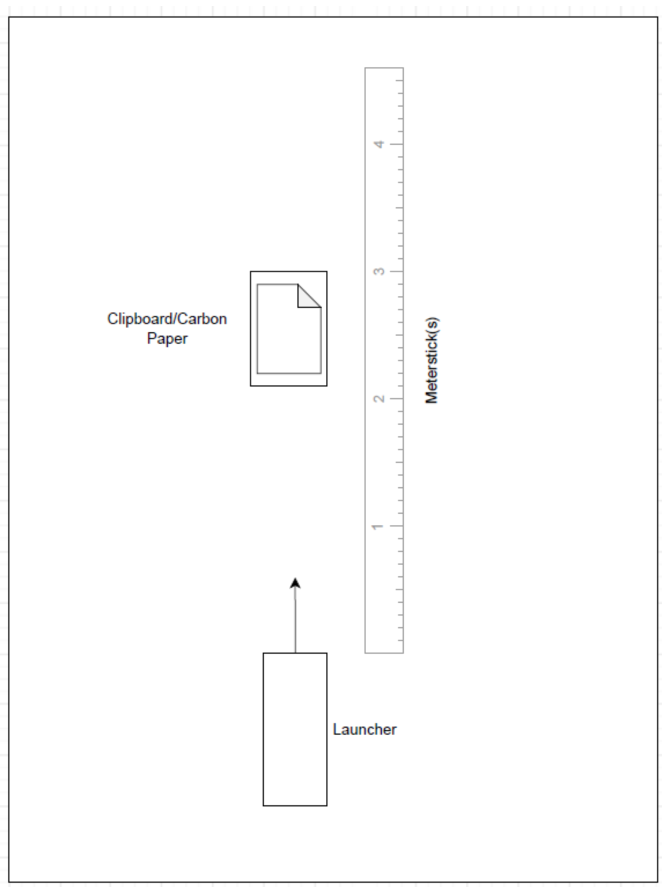
This lab utilizes a projectile launching kit. The projectile launcher that is being used is from the University of Kansas physics department for PHSX 216 Physics I Laboratory. The angle of the launch is measured from 0 degrees to 90 degrees directly on the launcher's body itself. The launcher also has 3 modes: low, medium, and high. The power of the launch is determined by these modes. The projectile that the launcher is using is a yellow 10 gram hollow plastic sphere that came with the kit. A metal 67g sphere is also provided which may provide more accurate short-distance results, and implementation of such may be added in the future. This report is organized as it was defined in the rubric.

Goal

Determine how to launch a projectile using the launchers provided. Determine what properties of your launcher and projectile affect its trajectory such that if given a particular location for your launcher and target by your TA, you could reach the target within the specified target size.

Methods

The way we set up our experiment can be depicted visually, as shown in the diagram on the right.



We placed the launcher at one end of the measuring device, aligning the end of the launcher barrel with the measurement device. In our case, our measurement device was multiple meter sticks on the centimeter side. We used the centimeter side to get the most accurate result we could. We faced the launcher in the positive x direction of the measuring device.

We decided to pick a set of set angles that we would run multiple trials on for each launcher power level. This would allow us to plot the relationship between the angle and the distance that it travels per power level.

Before collecting data for a specific angle, we would first launch the projectile from the targeted angle and power level with no carbon paper. We would observe where it landed, and would then place the clipboard with carbon paper on that spot.

When measuring points, we used a clipboard that had carbon paper and blank paper attached to it. We used carbon paper to show the impact points on the blank piece of paper. We attached them to a clipboard so that the papers would remain still when hit by the projectile. We used a straight object (in our case, a second ruler) to levelly connect the marked hit to the measuring device, ensuring an accurate reading. We also made sure to cross off already-measured marks that were on the blank paper.

We would record these readings into a Microsoft Excel spreadsheet, which automatically calculated things such as the averages, the standard deviation, the standard error, and the total propagation uncertainty. This excel spreadsheet is expanded upon and displayed in-text in the Results and Data section. We also created the graphs inside Microsoft Excel and used the trendline feature to create the prediction equation for each power level.

Results

Data

Our method of data collection was extremely accurate, thanks to our ability to

Equipment

Metal Ball Mass: 67g

Plastic Ball Mass: 10g

Instrumental Uncertainties

Ruler Instrumental Uncertainty: $\pm$ 0.1 cm

Angle Instrumental Uncertainty: $\pm$ 1 degree

Total Measurement Error: $\pm$ 1.00499

Projectile-Barrel Offset

Angle is measured in degrees, Y-Offset measured in centimeters

Projectile Barrel Offset	
Angle	Y-Offset from the ground
0	26.3
20	26.7
40	27
60	27.5
80	28

Low-Power Data

Angle is measured in degree, and distance is measured in centimeters.

Low Power						Instrumental Uncertainty
Angle	0	20	40	60	80	1
Distance Trial 1	68.2	102.5	106.0	95.5	34.4	0.1
Distance Trial 2	68.8	102.9	106.8	95.6	34.5	0.1
Distance Trial 3	68.0	103.0	107.0	96.2	34.8	0.1
Distance Trial 4	68.0	101.0	107.3	96.9	35.0	0.1
Distance Trial 5	68.0	102.0	107.2	95.5	35.0	0.1

Residual

Low Power Residual			
Angle	Average Distance	Predicted Distance	Residual
0	68.2	67.0	-1.2
20	102.3	103.4	1.1
40	106.9	110.5	3.6
60	95.9	88.4	-7.5
80	34.7	37.0	2.3

Uncertainties and Error

Low Uncertainty and Error					
Angle	0	20	40	60	80
Average	68.2	102.3	106.9	95.9	34.7
Standard Deviation	0.34641	0.816701	0.517687	0.610737	0.279285
Standard Error	0.154919	0.36524	0.231517	0.27313	0.1249

Medium-Power Data

Angle is measured in degree, and distance is measured in centimeters.

Medium Power						Instrumental Uncertainty
Angle	0	20	40	60	80	1
Distance Trial 1	108.6	208.3	270.1	220.7	99.0	0.1
Distance Trial 2	108.1	208.5	271.9	225.5	95.9	0.1
Distance Trial 3	108.5	210.5	272.1	227.3	95.6	0.1
Distance Trial 4	109.5	211.1	270.9	220.6	100.9	0.1
Distance Trial 5	111.5	212.7	270.4	224.6	98.7	0.1

Residual

Medium Power Residual			
Angle	Average Distance	Predicted Distance	Residual
0	109.2	103.6	-5.6
20	210.2	221.6	11.4
40	271.1	260.5	-10.6
60	223.7	220.3	-3.4
80	98.0	101.0	3.0

Uncertainties and Error

Medium Uncertainty and Error					
Angle	0	20	40	60	80
Average	109.2	210.2	271.1	223.7	98.0
Standard Deviation	1.363085	1.84716	0.889944	2.98379	2.239866
Standard Error	0.60959	0.826075	0.397995	1.334391	1.001699

High-Power Data

Angle is measured in degree, and distance is measured in centimeters. The reason that there are so many missing data points from trials here comes down to a few main things:

1. For 0 degrees, medium power already has data that can reach such distances. We found it redundant to spend more than necessary time recording trials for it.
2. For 80 degrees, the projectile hits the ceiling of the testing area, automatically corrupting the final distance data. We found it best not to measure this angle.
3. Other factors that this lab did not relate to, such as air resistance, became much more visible. We also noted that while the metal ball is more accurate when it comes to the air resistance issue, it would never be able to travel the distances measured for high power with the plastic ball. Because of these discussions, we concluded that it is highly unlikely that we would be tested for distances greater than 300, and thus decided against capturing more data than we needed to for high-power.

High Power						Instrumental Uncertainty
Angle	0	20	40	60	80	1
Distance Trial 1	154.3	369.0	480.6	410.4	N/A	0.1
Distance Trial 2	N/A	N/A	480.2	417.6	N/A	0.1
Distance Trial 3	N/A	N/A	482.5	418.7	N/A	0.1
Distance Trial 4	N/A	N/A	N/A	N/A	N/A	0.1
Distance Trial 5	N/A	N/A	N/A	N/A	N/A	0.1

Residual

High Power Residual			
Angle	Average Distance	Predicted Distance	Residual
0	154.3	150.4	-3.9
20	369.0	380.8	11.8
40	481.1	468.7	-12.4
60	415.6	414.2	-1.4
80	N/A	N/A	N/A

Uncertainties and Error

High Uncertainty and Error					
Angle	0	20	40	60	80
Average	154.3	369.0	481.1	415.6	N/A
Standard Deviation	N/A	N/A	1.228821	4.508141	N/A
Standard Error	N/A	N/A	0.549545	2.016102	N/A

Miscellaneous Data

Minimum Distance Measured: 34.4 cm

Maximum Distance Measured: 482.5 cm

Graphs

Data Plots

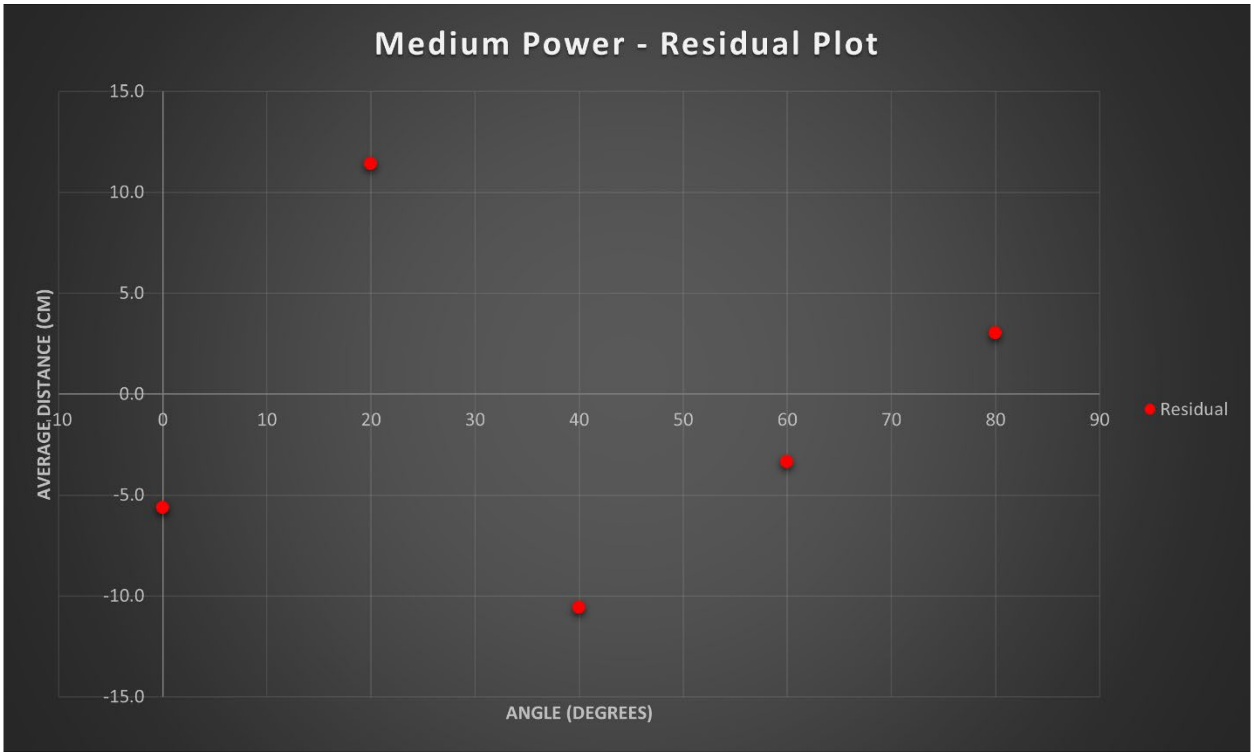
It should be noted that the degree for the lines of best fit is of degree 2, because it is nearly impossible to find the inverse of a polynomial of degree 3 or higher. Despite this, we believe that a 2nd degree polynomial, both equationally and visually, is sufficient to represent the data we have found. It should also be noted that error bars *are* present for the y-axis, but are simply too small to be shown on a graph without expanding it unnecessarily. The error/uncertainty has already been stated elsewhere in this report.


Low Power: Distance vs. Angle
DISTANCE (CM)
ANGLE (DEGREES)
Distance Trial 1
Distance Trial 2
Distance Trial 3
Distance Trial 4
Distance Trial 5
Combined
Poly. (Combined)
y = -0.0366x² + 2.5527x + 66.983
R² = 0.978


Medium Power: Distance vs. Angle
DISTANCE (CM)
ANGLE (DEGREES)
Distance Trial 1
Distance Trial 2
Distance Trial 3
Distance Trial 4
Distance Trial 5
Combined
Poly. (Combined)
y = -0.0989x² + 7.8803x + 103.56
R² = 0.9866

Residual Plots

Our residual plots show a very small average residual magnitude when it comes to our average distance and our predicted distance, with the residual magnitude increasing in tandem with the increasing power level.


Medium Power - Residual Plot
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-10
0
10
20
30
40
50
60
70
80
90
AVERAGE DISTANCE (CM)
ANGLE (DEGREES)
Residual


High Power - Residual Plot
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-10
0
10
20
30
40
50
60
70
80
90
AVERAGE DISTANCE (CM)
ANGLE (DEGREES)
Residual

Equations

Trendlines

Where y is distance in centimeters, and x is the angle in degrees:

Low Power Trendline Equations:

- $y = -0.0366x^2 + 2.5527x + 66.983$
- $x = -\frac{(-2.5527 \pm \sqrt{-0.1464y + 16.32258849})}{0.0732}$

Medium Power Trendline Equations:

- $y = -0.0989x^2 + 7.8803x + 103.56$
- $x = -\frac{-7.8803 \pm \sqrt{-0.3956y + 103.06746}}{0.1978}$

High Power Trendline Equations:

- $y = -0.1781x^2 + 15.083x + 150.37$
- $x = -\frac{-15.083 + \sqrt{-0.7124y + 334.620477}}{0.3562}$

Total Propagated Uncertainties

Where y is the distance in centimeters (trendline equation), x is the angle in degrees, and $\Delta y = \pm 0.1$ cm:

$$total\ propegated\ uncertainty = \sqrt{\left(\frac{\partial y}{\partial x} * \Delta y\right)^2}$$

Low Power Total Propagated Uncertainty:

$$= \pm\sqrt{(0.00732x + 0.25527)^2}$$

Medium Power Total Propagated Uncertainty:

$$= \pm\sqrt{(0.01978x + 0.78803)^2}$$

High Power Total Propagated Uncertainty:

$$= \pm\sqrt{(0.03562x + 1.5083)^2}$$

Conclusions

Qualitative Observations

We found that our highest source of instrumental uncertainty was the launcher. Not only did it only increment by ones, but it also relied on the use of a pendulous string-and-nut combination. It was quite difficult to make it stay still during the setup portion, and leaves a large magnitude of error when measuring the angle.

Furthermore, the launcher would also sometimes be moved from the force of it's spring/mechanisms during launch, leading to it needing to be readjusted and frustration.

Discussion of Results and Theories

Overall, we believe that our results are accurate and can be replicated quite easily. Our methods are straightforward and display proper accounting for error and uncertainty.

The equations we found from the trendline very closely align with the data that we had collected, forming a perfect arc.

I believe that we could have achieved more accurate results from a few ways:

1. Accounting for air resistance would allow us to take a lot of the uncertainty away from shooting longer distances.
2. Measuring the angle of launch with a more accurate tool would let us lower our instrumental uncertainty greatly.
3. Clamping the projectile launcher when testing would create less frustration every trial and allow much less room for human error.
4. Measuring the distance using lasers (or any more accurate measuring device) would bring with it near-perfect precision and reduce the instrumental uncertainty even more.
5. Running more trials (given a longer testing period) would allow a much more accurate reading of averages and margins for error.