Lab M4 Projectile Motion

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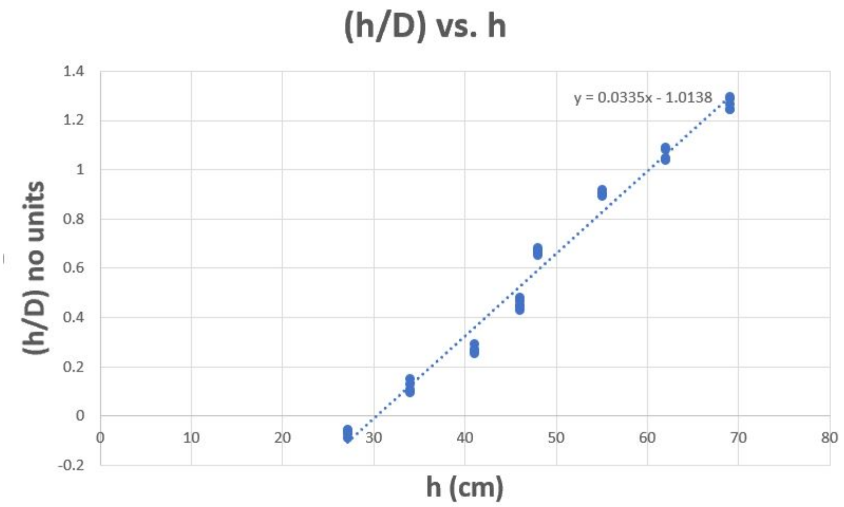
1 VI-1

Table 1: h and d values

h (cm)	D (cm)	h/D
-2.4		-0.08856
-1.5		-0.05535
-1.6	27.1	-0.05904
-1.8		-0.06642
-1.9		-0.07011
3.2		0.094118
3.4		0.1
3.7	34	0.108824
4.5		0.132353
5.1		0.15
10.5		0.256098
10.9		0.265854
11	41	0.268293
11.1		0.270732
12.1		0.295122
19.8		0.430435
20.4		0.443478
20.8	46	0.452174
21.6		0.469565
22.1		0.480435
31.3		0.652083
31.7		0.660417
32.2	48	0.670833
32.4		0.675
32.9		0.685417
49.2		0.894545
49.4		0.898182
49.7	55	0.903636
49.8		0.905455
50.5		0.918182
64.5		1.040323
64.7		1.043548
64.9	62	1.046774
67		1.080645
67.7		1.091935
85.9		1.244928
86		1.246377
87.5	69	1.268116
88.8		1.286957
89.4		1.295652

2 VI-2



3 VI-3

3.1 Linest

Using Linest, Excel returns the slope, y-intercept, and the uncertainties in both of these values for the above graph.

$$s = 0.033467305$$

$$\sigma_s = 0.000742608$$

$$b = -1.013807177$$

$$\sigma_b = 0.036777313$$

3.2 Calculating θ_e

From the equation in the book,

$$b = -\tan(\theta_e)$$

we can rearrange to solve for θ_e.

$$\tan^{-1}(-b) = \theta_e\,, \quad \tan^{-1}(-\sigma_b) = \sigma_{\theta_e}$$

$$\tan^{-1}(-(-1.013807177)) = 45^\circ\,, \quad \tan^{-1}(-(0.036777313)) = 2^\circ$$

Finally,

$$\theta_e \pm \sigma_{\theta_e} = \mathbf{45 \pm 2^\circ}$$

3.3 Calculating θ_m

To calculate θ_m, I can take the average of all 3 measured values.

$$\theta_m = \frac{\theta_1 + \theta_2 + \theta_3}{3} = \frac{37^\circ + 35^\circ + 35^\circ}{3}$$

$$\theta_m = 36^\circ$$

To calculate σ_{θ_m}, I'll take one half of the difference between the largest measured θ value and the smallest.

$$\sigma_{\theta_m} = \frac{|\theta_{larger} - \theta_{smaller}|}{2} = \frac{|37^\circ - 35^\circ|}{2}$$

$$\sigma_{\theta_m} = 1^\circ$$

Finally,

$$\theta_m \pm \sigma_{\theta_m} = \mathbf{36 \pm 1}^\circ$$

3.4 Compare the θ Values

Unfortunately, the values that were returned for each θ do not agree with each other, even when accounting for their uncertainties.

I do believe that the measured value of θ is actually a more reliable number because even though the other one was calculated, it depended on 48 other measured values that can be seen in the table in section: VI-1. So while measuring θ flat out may not be perfectly accurate, each data point in the table can hold it's own uncertainty, contributing to an even more uncertain calculation for θ_e.

4 VI-4

4.1 Calculating v_0

Using the slope returned by Excel, $g = 980\text{cm/s}^2$, and both of the calculated θ values, v_0 can be calculated by using,

$$s = \frac{g}{2v_0^2 \cos^2(\theta)}$$

Rearranging for v_0,

$$v_0 = \sqrt{\frac{g}{2s\cos^2(\theta)}}$$

Since we have two different θ values, we'll end up with two different initial velocities: v_{0_e} and v_{0_m}.

$$v_{0_e} = \sqrt{\frac{980cm/s^2}{2(0.033467305)\cos^2(45^\circ)}} = \mathbf{170cm/s}$$

$$v_{0_m} = \sqrt{\frac{980cm/s^2}{2(0.033467305)\cos^2(36)}} = \mathbf{150cm/s}$$

4.2 Calculating σ_{v_0}

To calculate the uncertainties in the above initial velocities, we can use the formula found in the lab manual. The partial derivatives are already solved for us.

$$\sigma_{v_0} = v_0\sqrt{\left(\frac{b\sigma_b}{1+b^2}\right)^2 + \left(\frac{\sigma_s}{2s}\right)^2}$$

For $\sigma_{v_{0_e}}$,

$$\sigma_{v_{0_e}} = (170cm/s)\sqrt{\left(\frac{(-1.013807177)(0.036777313)}{1+(-1.013807177)^2}\right)^2 + \left(\frac{(0.000742608)}{2(0.033467305)}\right)^2}$$

$$\sigma_{v_{0_e}} = \mathbf{4cm/s}$$

For $\sigma_{v_{0_m}}$,

$$\sigma_{v_{0_m}} = (170cm/s)\sqrt{\left(\frac{(-1.013807177)(0.036777313)}{1+(-1.013807177)^2}\right)^2 + \left(\frac{(0.000742608)}{2(0.033467305)}\right)^2}$$

$$\sigma_{v_{0_m}} = \mathbf{3cm/s}$$

4.3 $v_0 \pm \sigma_{v_0}$

For both velocities:

$$v_{0_e} \pm \sigma_{v_{0_e}} = \mathbf{170 \pm 4cm/s}$$
$$v_{0_m} \pm \sigma_{v_{0_m}} = \mathbf{150 \pm 3cm/s}$$

5 VI-5

From the book, the initial velocity can be found using the following formula:

$$v_0 = \sqrt{\frac{10gs}{9}}$$

Plugging in the values this becomes:

$$v_0 = \sqrt{\frac{10(980cm/s)(30.3)}{9}} = \mathbf{180cm/s}$$

6 VI-6

Unfortunately, my result from Section VI-5 does not fall into the ranges determined in Section VI-4. The reason for this discrepancy is most likely due to sloppy measurements averaging out to a value to far off from what it should be.