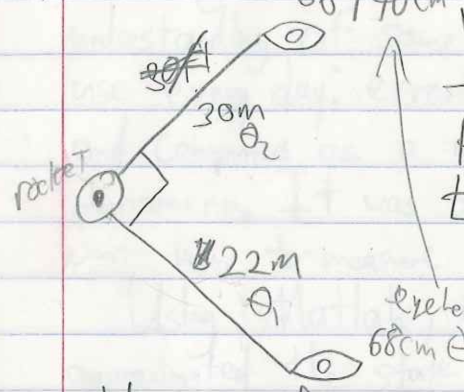
* +20m

Rocket Launch

Using trig, we est. max height



$V_{water} = 1L$

~~V = 3rd...~~

P read on gauge: 3 barr

$t_{hang} = 4.39$ sec

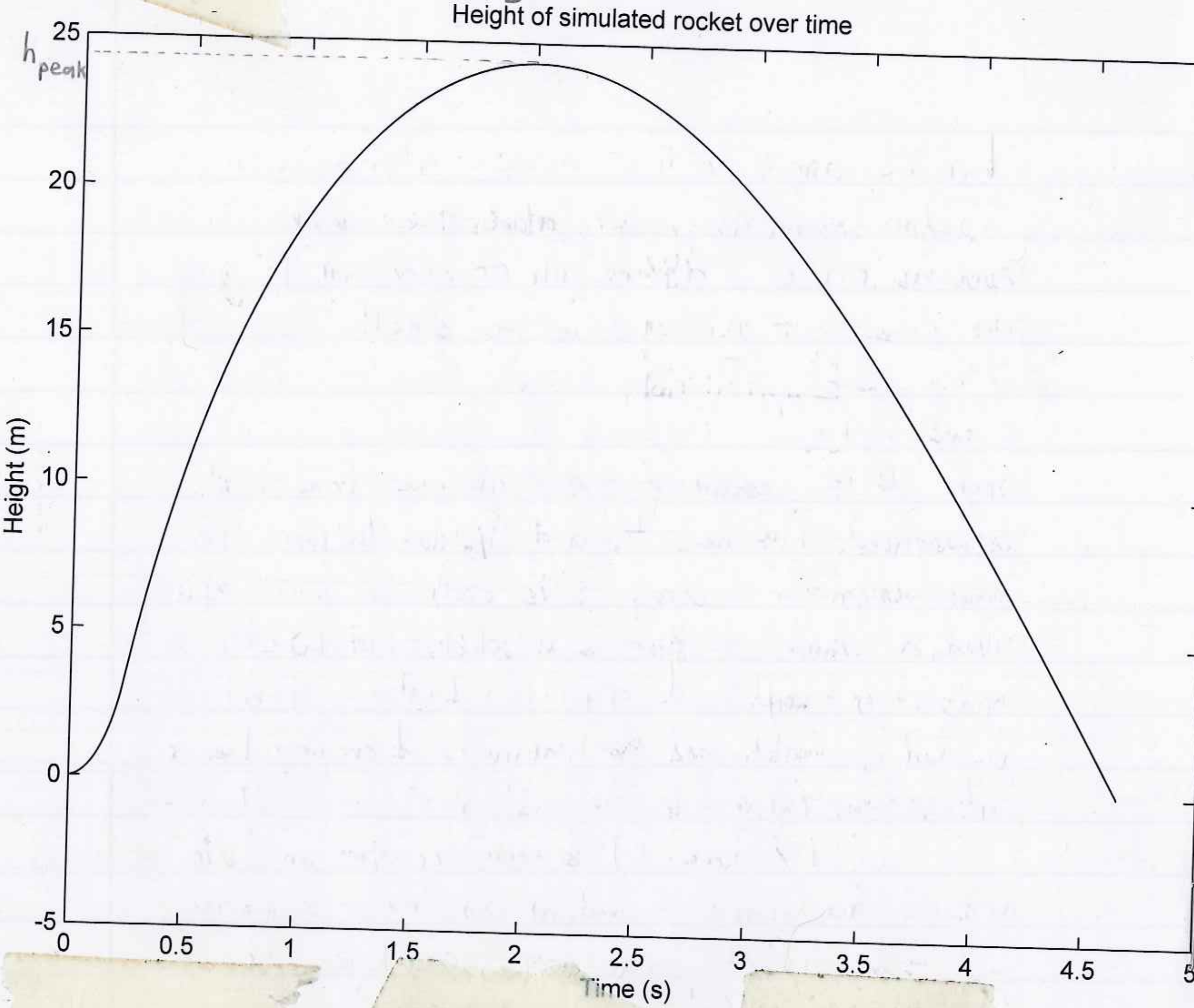
run	V_{water}	P_{gauge}	θ_1	θ_2	~~t_{hang}~~	t_{tor}
1	1L	3 barr	61	59/61	~~4.39~~	1.63
2	0.5L	3barr	46	60/56	~~4.69, 4.51~~	1.34
3	0.75L	3 barr	55*	64/61		
4	0.75	3 barr	53.5	59/58		1.86

18m dist now 230

~~5~~	~~1.2L~~	~~3~~		~~73+30~~	
6	0.75L	5 barr	49	58/54 +15	1.12
7	1.2L	5.25barr	58+10	55/65	1.32

↑ These are notes ↑
Write-up starts next page

Figure 1

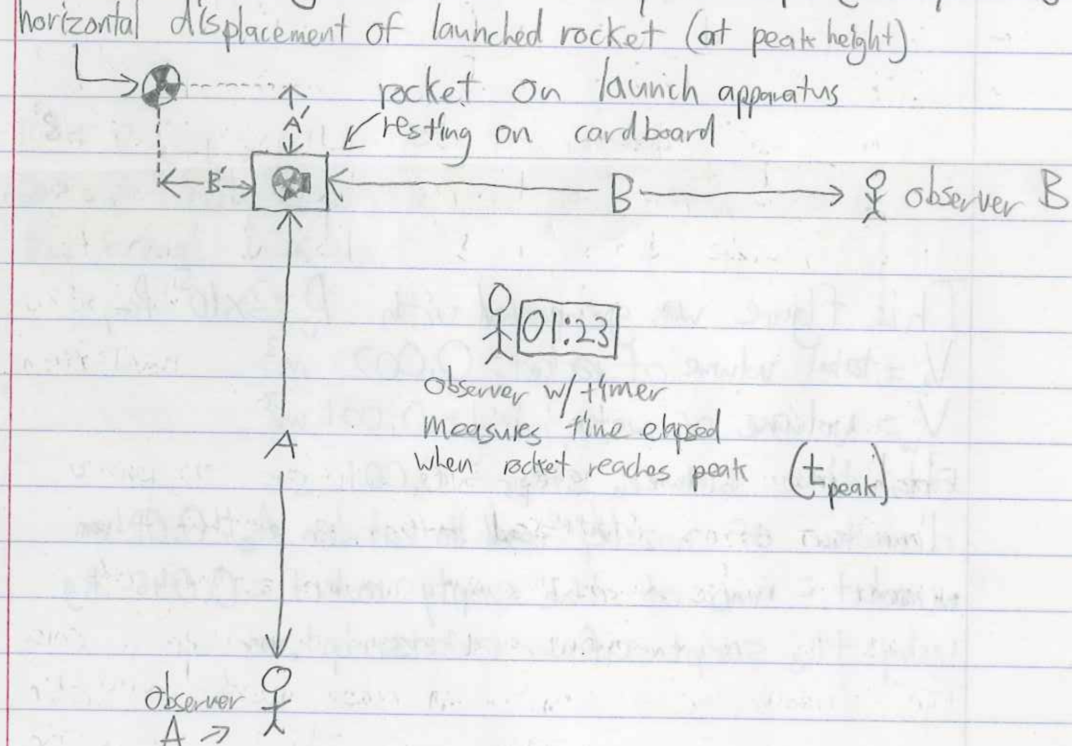


This figure was generated with $P_0 = 3\times10^5$ Pa,
V_t = total volume of rocket = 0.002 m^3
V_w = volume of water, initial = 0.001 m^3
dt = time between steps = 0.001 s
diameter of nozzle, used to calculate A_e = 0.02 m
mrocket = mass of the empty rocket = 0.045 kg
using the script afraser rocketscript.m

Launch day:

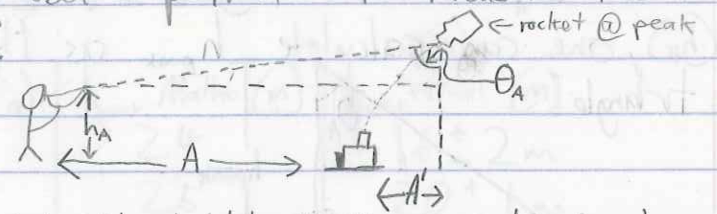
On launch day, we placed our launching apparatus on a flattened pile of cardboard to produce as close to a vertical launch as possible. Two* observers then stood 20-30 m away from the launch site, at roughly right angles to each other, and measured the angle of the peak of the trajectory from their perspectives. The time taken to reach the peak was measured with a simple stop-watch as well. Whenever wind or undesired horizontal thrust pushed the rocket horizontally away from the launch site, the distance pushed was estimated to produce more accurate peak calculations (A' and B' in Fig. 2).

Figure 2, Launch day set-up (birds-eye view)



*For some runs, there were two observers standing in one spot (B), one standing in another (A).

Each observer (besides the timer) used a protractor to measure the angle θ here:



h is the height off the ground of where they held the protractor

To launch the rocket, the empty 2L bottle was filled with a measured volume of water and placed on the apparatus, where a bicycle pump was used to increase the pressure in the rocket. The apparatus had its own pressure gauge to measure P_0.

Results: (from thursday's run only)

first observer, Second observer (Measured values of

	V_w (L)	P_0(bar)	$A+A'$(m)	θ_A (degrees)	$B+B'$ (m)	$\theta_B(1)$; $\theta_B(2)$	t_{peak} (s)
1	1.0	3	22+0	61	30+0	59°; 61°	1.64
2	0.5	3	22+0	46	30+0	60°; 56°	1.34
3	0.75	3	22+20	55	30+0	64°; 61°	1.61
4	0.75	3	22+0	53.5	30+0	59°; 58°	1.81
5	0.75	5	18+0	49	30+15	58°; 54°	1.12, 1.64
6	1.2	5.25	18+10	58	30+0	55°; 65°	1.32

$h_A = 68$cm

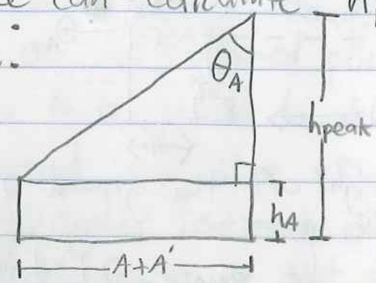
$h_B(1) = 66$ cm

$h_B(2) = 70$cm

Calculations:

Each measurement made was subject to pretty significant errors (addressed later), so rather than present a guise suggesting an accurate estimate of errors in measurement and error propagation, I calculate the trajectory peak, h_p, using each method available for a given launch, then use the mean and the RMS to analyze.

Given θ_A and $A+A'$ (or θ_B & $B+B'$), and h_A (h_B), one can calculate h_{peak} as the leg of a triangle:



Calculated this way, $h_{peak} = \frac{A+A'}{|\tan\theta_A|} + h_A$
(same thing for observers B1 & B2)

launch #	h_{peak} for A	h_{peak} for B1	h_{peak} for B2	Mean $\pm\ \sigma_{\bar{h}}$
1	13 m	19 m	17 m	16 ± 2 m
2	22 m	18 m	21 m	20 ± 1 m
3	30 m	15 m	17 m	21 ± 5 m
4	17 m	19 m	19 m	18 ± 1 m
5	16 m	29 m	33 m	26 ± 5 m
6	18 m	22 m	15 m	18 ± 2 m

I like this method more than error propagation because the equipment used on launch day was not rigorously callibrated, and each stage was not only subject to random, inconsistent human error, but could easily have been subject to systematic error that we don't know about. Additionally, due largely to the quickness of each launch, and the size of the bottle, and the distance from apparatus to observer, there was definition error — error caused by uncertainty in the point at which h_{peak} had been reached.