

Jojo2Space CR01-072014

Rock Launch Summary Report (for English majors)

Charles HATHAWAY
Ranjani SARGUNARAJ

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1 Objective

The objective of this report is to summarize, in very basic terms, the process and related calculations that can go into a simple model rocket launch. Although there are some algorithms, the goal of this paper is to be understandable by people without a significant math background (for example, English majors).

The first section will talk about the procedure and process required to assemble and launch the rocket. The most important takeaway is the needed materials, which are not clearly stated on the rocket's product page.

The second section discusses the procedure that you should use when launching the rocket.

The third section will be an abstract discussion about the relationship between Newton's Laws and our rocket. It will conclude with a numerical analysis of the rocket launch, solving for a few pieces of data.

2 Procedure and Materials

2.1 Bill of Materials

To perform a simple rocket launch, we used the following commercial-over-the-shelf products:

- Estes 1469 Tandem-X Launch Set http://www.amazon.com/gp/product/B002VLP67S/ref=oh_aui_detailpage_o01_s00?ie=UTF8&psc=1

- This set includes 2 rockets; the second rocket requires much more assembly. We only used the first
- This set also contains the launch pad
- Estes B4-2 Engine Pack (3-Each) http://www.amazon.com/gp/product/B000QV08F0/ref=oh_aui_detailpage_o00_s00?ie=UTF8&psc=1
- Estes 2274 Recovery Wadding http://www.amazon.com/gp/product/B0006NAQ60/ref=oh_aui_detailpage_o02_s00?ie=UTF8&psc=1
- CVS Super Glue Gel 2-Pack <http://www.cvs.com/shop/product-detail/CVS-Super-Glue-Gel-2-Pack?skuId=904326>
 - This kind of glue isn't required, but it worked. You need a glue that can bond to both plastic and cardboard.
- 9V "Square" battery
- Philips head screwdriver
- Protractor <http://www.cvs.com/shop/product-detail/Caliber-Protractor?skuId=138038>
- 25' tape measure
- Stopwatch (we used a cell phone)
- 2-3 people
- Notebook, pencil
- (Optional) Acrylic-based paint and paint brushes
 - Although this wasn't perfect, it did stick to the surface of the rocket. Spray paint and stencils would probably work better

2.2 Procedure

Assemble the rocket and launch pad as per the instructions included with the rocket. When assembled and ready to launch (parachute in, engine in), weigh the rocket!

Find a large open field, and begin the fun!

Place the launch pad in the center of the field. Measure out from it (using the tape measure) about 100ft in a straight line (you can use 2 people for this!) This is where the person will stand while measure the angle the rocket goes to that we will use to determine the height.

Uncoil the launch button, insert the battery. When launching the rocket, you should have people doing the following things;

- Using the protractor, "follow" the rocket with the arm until it reaches its apex (the parachute will blow). Record this angle as θ_{rocket}
 - The protractor should be held at level angle; the arm rotates to track the rocket
 - Measure and record the height that the person is holding the rocket as d_1
- Using the stopwatch, measure to time it takes to reach its apex. Record this value as t_{rocket}
- Launch the rocket (requires countdown)
- Record video of the launch (optional)

Repeat this experiment until you run out of engines (or your rocket blows up)

3 Discussion

3.1 Newton's Laws

Everyone has heard the of Newton's three laws (if you haven't, don't fret! We will recap them here!). They are of interest to us because they help explain how the rocket works, without the need of calculus.

- "An object at rest stays at rest and an object in motion stays in motion unless acted upon by an outside force". This is paraphrased a bit, but still not too hard.
 - Something won't move unless it is pushed
 - Something won't stop unless something stops it. Most things stop because of friction
- The second law is more tricky, but basically means that an object's velocity (speed in a direction) is changed due to its acceleration
 - Wikipedia discusses this using calculus, which is a pain.
 - Think of it this way; if a car is moving forward and you press the gas, it starts to move forward faster. The velocity of the car increases every moment that you hold down the gas, as long as you keep it accelerating
 - Remember gravity? Gravity pulls things together, most notably it pulls things down to Earth. When you throw something (or launch it), you accelerate it very quickly and it goes up. Gravity pulls it

down, lowering it's velocity, until it reaches a velocity of 0, then it starts to fall back down (getting faster and faster!)

c. "For every action there is an equal and opposite reaction"

- This is not actually very important to us :). But it is cool! (when you launch the rocket, you push the Earth down... So why don't you feel the earth moving?)

3.1.1 Take aways

Newton's first law is inertia. Inertia is the mass of an object times it's speed.

Newton's second law is about acceleration (which is just how the speed is changing by).

Newton's third law is about why perpetual energy machines can't exist.

3.2 How does this relate to the Rocket?

We start with the rocket sitting on the launch pad, moving at 0m/s. When we ignite the engine, it starts to accelerate (but how fast?? that is why we do math). Once the engine burns up, the rocket has a velocity of something, but now has a negative acceleration (gravity!). So the rocket slows down, eventually stops for a split moment, then starts falling back to earth.

The point where the rocket stops is how high it gets.

3.3 The Mathy Bit

Ok, so now we get to do the math things. Our goal is to figure out:

- How high the rocket went
- How high a different rocket would go with the same engine
 - For example, the second rocket in the pack

3.3.1 Measuring Height

In order to measure the height, we are going to take advantage of the properties of right triangles. Recall from the way-way-back machine the SOHCAHTOA rule (sin = opposite over hypotenuse, cos = adjacent over hypotenuse, tan = opposite over adjacent).

Figure 1 shows how we setup the launch. The observer with the protractor is recording the angle the rocket reaches at θ_{rocket} while standing 100ft (30.48

meters) away from the launch pad. Using this value, we calculate d_2 , add d_1 , and then we will know how the rocket went.

$$d_2 = 100ft * \tan(\theta_{rocket})$$

$$height\ of\ rocket = d_1 + d_2$$

Make sure you're using degrees in your calculator!

3.3.2 Predicting height of the next rocket

To predict the height of the next rocket, we need to know how much "force" the engine provided. Force is the total acceleration. Finding this value can be very hard, unless we cheat.

We know how high the rocket went, we know how much the rocket weighed, and we know how much force it took to get there (gravity!). To determine the force provided by the engine, we simply multiply the weight of the rocket by the height by the force of gravity here on Earth. Units are important! Convert all your measurements to the metric system;

- (m) Weight should be in kg
- (h) Height should be in meters
- (a) Acceleration (gravity) is $9.81 \frac{m}{s^2}$

To find the force (in Newtons... not important), simply multiply all your values together.

$$F = m * h * a$$

To determine how high the next rocket will go, we just change the mass, and solve for h. So...

$$h = \frac{F}{m*a}$$

4 Actual results

Unfortunately, we only got one good launch. One launch we just recorded with the camera, the other had too much wind.

$$m = 0.116kg$$

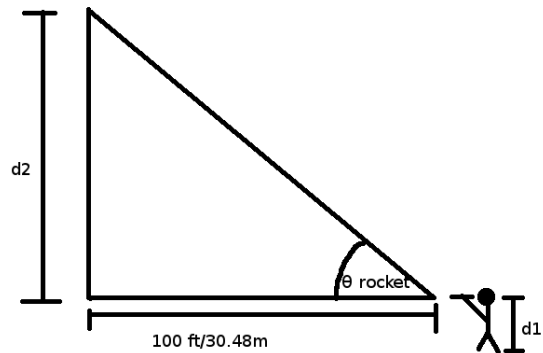


Figure 1: Diagram of rocket launch

$$\theta_{rocket} = 79degrees$$

$$d_1 = 70'' = 1.778m$$

So our results are...

$$d_2 = 100ft * \tan(\theta_{rocket}) = 30.48m * \tan(79degrees) = 156.81m$$

$$h = 156.81m + 1.778m = 158.59m = 520.308ft$$

$$F = m * g * h = 0.116kg * 9.81 \frac{m}{s^2} * 158.59m = 180.4690764N$$

4.0.3 Bonus credit!

You also recorded the time. Using this, you should be able to answer the following; when does the engine stop, and how fast is the rocket going at that time?

This problem is WAY more complicated. This short paper is not an appropriate forum for that discussion, but if you ask your nerdy friend, they would *love* to discuss it with you!