

****Most of the data from this sheet should also be entered (without units) into the “Sheet 1: Companion to Water Rocket Modeling”**

Video Work on The Phone:

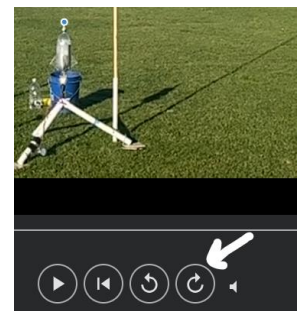
1. Check your video frame rate. If your video is on an iphone click the “i” in a circle. Record the frame rate here.
Video Frame Rate = _____ fps
2. Use your video to determine your rocket’s total time aloft. Here’s one method:
 - a. Edit your video so that the rocket’s entire flight is in slow motion.
 - b. Play the video in slow motion. As you watch the video, use another timer to time the rocket’s entire flight. Then multiply that slow motion time by $(30/frame\ rate)$ to get the actual flight time.

Time aloft = _____ seconds

3. Edit your video to create a fully-slow motion version that starts just before water comes out of the rocket and ends just after the rocket leaves the field of view. Email this video clip to yourself and to your partner(s).

Thrust Phase Data Collection in The Vernier Video Analysis App:

4. On your Chromebook (or just about any device), download the video that you emailed to yourself. Pay attention to where it goes, so that you can open it in the app.
5. Open the Vernier Video Analysis App. The link is in the “general” folder in our Google Classroom.
6. “Import” your video.
7. Click on the settings wheel and set the frames per second to the correct frame rate (the one you wrote down above).
8. Click “system” and “scale,” and stretch the two dots to span the entire 10ft pole next to the launcher. Type in the distance as 3.05m.
9. Still in the “system” settings, click “origin,” and move the origin to a point on the ground directly below the rocket.
10. Click “add.” Then move the slider until you see the rocket just begin to move. There should be a little bit of water coming out of the bottom.
11. One data point should appear (see screenshot), and its x and y position should be visible in the growing “data set.” Record the starting height (initial y position) of your rocket’s tip, above the ground. Also record the time. This is the initial time (t_0). If you followed my steps, the initial time from the table *should* be 0.00s.
12. Also record the frame number at which you clicked “add.”



$t_0 =$ _____ s $y_0 =$ _____ m frame₀ = _____

13. Continue adding points at the rocket’s tip until you see the first puff of air. This is the approximate end of water thrust. [In the beginning, you can use the single frame advance button (see screenshot) to skip frames if the dots are too close to one another.] Record the time and y velocity. For some reason, the table time isn’t precise, so use the number of elapsed frames and the frame rate to get time.

Frame #_{end of water thrust} = _____ Number of elapsed frames ($\Delta frames$) = _____

$t_{end\ of\ water\ thrust} = Frames / frame\ rate =$ _____ s $V_{y\ end\ of\ water\ thrust} =$ _____ m

14. Continue adding points until your rocket leaves the screen. Search the data table for the fastest y velocity. Record that velocity and the height and time at which the rocket reaches that velocity. Again, use the frame number to determine this.

$V_{y\ max} =$ _____ m/s Frame #_{max velocity} = _____ $\Delta frames =$ _____ $t_{max\ velocity} =$ _____ s

15. Do you feel like your rocket reached its maximum velocity during your video (or was it still accelerating)? Check one.

- Yes, it reached max velocity No, it seemed to still be accelerating

Thrust Calculations: As you complete these calculations, enter their values into the provided spreadsheet, so that I can check them quickly. ****For this part of the calculations, we are going to ignore air resistance.****

1. Use your video data to calculate your rocket's average acceleration during the water thrust phase.

$a_{\text{water thrust}} = \underline{\hspace{2cm}} \text{ m/s}^2$

2. What was your rocket's dry mass, in kg? $\underline{\hspace{2cm}}$ kg

3. What mass of water was added to your rocket? $\underline{\hspace{2cm}}$ kg

4. What was your rocket's total mass at the beginning of the water thrust phase? (include both dry mass and water mass) $\underline{\hspace{2cm}}$ kg

5. Assuming that water left your rocket at a constant rate (which we know is wrong, but it makes the calculations easier), calculate the rocket's average mass during the water thrust phase $((m_0+m)/2)$. $\underline{\hspace{2cm}}$ kg

6. According to your previous answers, what average net force was acting on your rocket during the water thrust phase? $\underline{\hspace{2cm}}$ N

7. Calculate your rocket's average weight during the water thrust phase. $\underline{\hspace{2cm}}$ N

8. What average thrust was provided by your rocket's expulsion of water? $\underline{\hspace{2cm}}$ N

9. Based on your previous answers, how many of these bottles (to the nearest 1/10 of a bottle) would you have to strap together to "lift" a 140 pound human plus an extra 20 pounds of straps, fixtures, and safety gear? Don't forget to account for the mass of the bottles themselves, including the water in the bottles. For the bottle mass, simply use the average water mass in each bottle during the thrust phase. Provide an answer that is precise to the nearest 10th of a bottle. [Instead of "lift," the word *suspend* may be better here; this problem is not about actually accelerating a person upward.]

$\underline{\hspace{2cm}}$ = Bottles needed to "lift" a 140 pound human

10. Based on some brief scrutiny of the *Game Show Water Bottle Launch*, the crew used around 30 bottles to launch the participant. The participant's mass plus the non-bottle mass seemed to be about 86kg (roughly 190 pounds). Those bottles look bigger than ours, so let's imagine that we strapped twice as many (60) of your rockets to the lucky game show contestant. What height would the participant reach due to the thrust during the "water thrust phase?" Be aware that the participant will keep flying upward after the thrust stops. You must calculate the full maximum height reached. Assume that the bottles have the exact same average mass, thrust, and thrust time as those you calculated for your bottle on the previous page.

Maximum Height Reached, using 60 of your rockets: $\underline{\hspace{4cm}}$

[Note: this will be a slight under-estimate, because you are only including the thrust during the "water thrust stage." In reality, the bottles would push a tiny bit more as their air escapes. Also, **ignore air resistance.**]