Physics 200 Name (s): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Bottle Rocket Analysis

**\*\*\* Complete the data-collection steps first. Data collection steps are in bold.**

\*\*In an effort to simplify this process, ignore any motion or forces in the X dimension. On your spreadsheet, you can just enter zero for X0.

**Part 1. Water Thrust Phase Analysis: The water thrust phase begins when the first bit of water has just escaped from the rocket. The phase ends when air begins to leave the rocket, creating a *puff* as it hits the rocket’s trailing water column.**

**In Logger Pro:**

* **Make sure that the frame rate in Logger Pro matches your video file frame rate.**
* **Use the meter stick by the launcher to set the scale**
* **Click to record data from the time when the rocket first begins to accelerate until the puff of air (indicating the end of water thrust) appears.**
* **Right click and then choose the option that sets the time to zero at your first click.**

1. What was your rocket’s Δy during its *water thrust* phase? \_\_\_\_\_\_\_\_ m

2. What was the Δt during your rocket’s water thrust phase? \_\_\_\_\_\_\_\_s

3. Use Δy and Δt to calculate your rocket’s average acceleration during the water thrust phase. \_\_\_\_\_\_m/s2

4. What was your rocket’s total mass at the beginning of the water thrust phase? (include both dry mass and water mass) \_\_\_\_\_\_\_\_ kg

5. What was your rocket’s mass at the end of the water thrust phase? (dry mass only) \_\_\_\_\_\_\_\_ kg

6. 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 ((m0+m)/2). \_\_\_\_\_\_\_\_ kg

7. According to your previous answers, what average net force was acting on your rocket during the water thrust phase? \_\_\_\_\_\_\_\_ N

8. Calculate your rocket’s average weight during the water thrust phase. \_\_\_\_\_\_\_\_ N

9. What average thrust was provided by your rocket’s expulsion of water? \_\_\_\_\_\_\_\_ N

10. Based on your previous answers, how many of these rockets 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. [Instead of “lift,” the word *suspend* may be better here; this problem is not about actually accelerating a person upward.]

\_\_\_\_\_\_\_\_ = Bottles needed to “lift” a 140 pound human

11. Based on my brief scrutiny of the *Japanese Water Bottle Launch*, the crew used 20 bottles to launch the participant. Furthermore, I estimate that the participant’s mass, plus the non-bottle mass was about 86kg (roughly 190 pounds). Assuming that the water bottles in the video were the same as your water rocket, what height would the participant reach due to the thrust during the “water thrust phase?” Ignore air resistance for this. It would probably be negligible anyway.

Maximum Height Reached, using our rockets: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*[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.]*

**Part 2, Air Thrust Phase:** This is very brief and difficult to analyze. We will not analyze this phase, but we will try to find the endpoint, which will give us the starting time of the coasting phase.

12. You should have stopped collecting water thrust data when the puff of air appeared. Now continue collecting data until the y velocity is no longer increasing. This point in time may be unclear, but estimate it as well as you can. This time will be the starting point for the coasting phase analysis.

End of thrust phase = beginning of coasting phase (\*\*spreadsheet starting time\*\*) → t = \_\_\_\_\_\_\_\_\_\_

**Part 3, Coasting Phase Analysis :** This phase begins as soon as all initial acceleration has ended -- and the rocket has reached its maximum velocity. This is apparent when the logger pro Y velocities stop increasing. Coasting ends when the rocket hits the ground. There is no thrust during the coasting phase. The only forces acting on the rocket are drag and weight.

13. What was your rocket’s velocity at the beginning of the coasting phase?

\_\_\_\_\_\_\_\_ m/s = \_\_\_\_\_\_\_\_\_ mph

14. What is your rocket’s Y position at the beginning of the coasting phase? \_\_\_\_\_\_\_\_ m

15. Use Logger Pro to find your rocket’s “crashdown speed” (y velocity just before impact). This should be close to your rocket’s terminal velocity, but most rockets would need to fall farther to actually reach terminal velocity.

To do this, you will need to reset your scale using the person who is standing next to your rocket at the end of the video. Collect data for the last few meters of your rocket before it hits the ground. The Y velocity at this point is the negative of your rocket’s crashdown speed.

Crashdown speed = \_\_\_\_\_\_\_\_ m/s

16. Use Logger Pro or QuickTime to find your rocket’s total time aloft. Δt = \_\_\_\_\_\_\_\_\_\_ s

**Part 3: Spreadsheet Analysis.** Use recorded data, previous answers, and your spreadsheet for these questions. To make your spreadsheet more responsive, you may want to download it and open it in Excel.

17. What was your rocket’s mass after all of the water left the rocket (dry mass)? \_\_\_\_\_\_\_\_ kg

18. Your rocket’s cross-sectional area = \_\_\_\_\_\_\_\_m2

19. We will assume that the density of the surrounding air was = 1.22 kg/m3.

20. **Estimating Cd using time aloft:** In your spreadsheet, enter your rocket’s mass, cross-sectional area, starting y position, starting y velocity, and the air density for the coasting phase. Also enter the starting time for your rocket’s coasting phase (from #12). Then manipulate your rocket’s drag coefficient until the spreadsheet time aloft matches your rocket’s actual time aloft. According to this method, what is your rocket’s drag coefficient? Enter all of the following data for this method…

Time Aloft = \_\_\_\_\_\_\_\_\_\_\_\_

Cd = \_\_\_\_\_\_\_\_ Max Height = \_\_\_\_\_\_\_\_\_\_\_ Crashdown Speed = \_\_\_\_\_\_\_\_\_

21. **Estimating Cd using crashdown speed:** Now find your rocket’s drag coefficient another way. This time, manipulate Cd until your spreadsheet crashdown speed matches your rocket’s measured crashdown speed (from Logger pro). Enter all of the following data for this method…

Crashdown Speed = \_\_\_\_\_\_\_\_\_

Cd = \_\_\_\_\_\_\_\_ Max Height = \_\_\_\_\_\_\_\_\_\_\_ Time Aloft = \_\_\_\_\_\_\_\_\_\_\_\_

**Part 4: Comparison of rocket data and spreadsheet output with Clifford Heath’s rocket simulator (website).**

22. Use your Cd from either #20 or #21, along with your other rocket data, to run the online simulator. Record the simulator data in the first column below. Record your measured data, calculated data, and spreadsheet data in the second column.

|  |  |  |
| --- | --- | --- |
|  | Online Simulator Predictions | Our Measurements, Calculations, and Spreadsheet Results |
| Total Flight Time |  |  |
| Actual Apogee (highest point reached) |  |  |
|  |  |  |
| Average Acceleration (compare to our average water thrust acceleration) |  |  |
| Crashdown Speed |  |  |
| Average Thrust (estimate from the simulator thrust graph) |  |  |
|  |  |  |

23. The online simulator is pretty good. If anything in your column is radically different, from the online simulator predictions, propose a reason for the difference.