ASEN 2012- 002 Project 2

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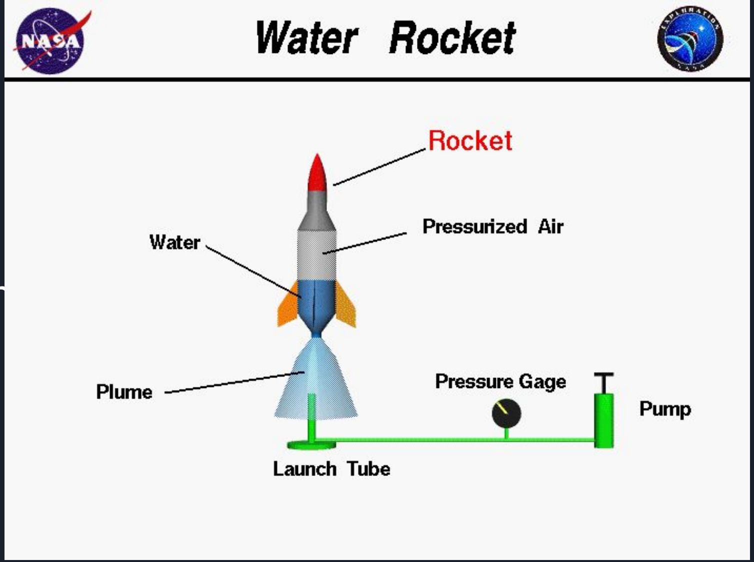
Introduction



The goal of project two was to model the trajectory of a bottle rocket, with the goals of understanding how a rocket's design parameters relate to functional performance. Through the modeling of the bottle rocket's trajectory, we specifically visualized how changes in the initial pressure of air inside the bottle, the drag of the bottle rocket, the volumetric fraction of water in the bottle, and the rocket's launch angle. Additionally, this project required understanding of matlab's built-in ODE45 function in order to successfully simulate the rocket's flight path. I assumed that the rocket maintained a constant flight path, and that there were no low flying birds at the time of launch that might come into contact with the bottle rocket.

Free Body Diagram

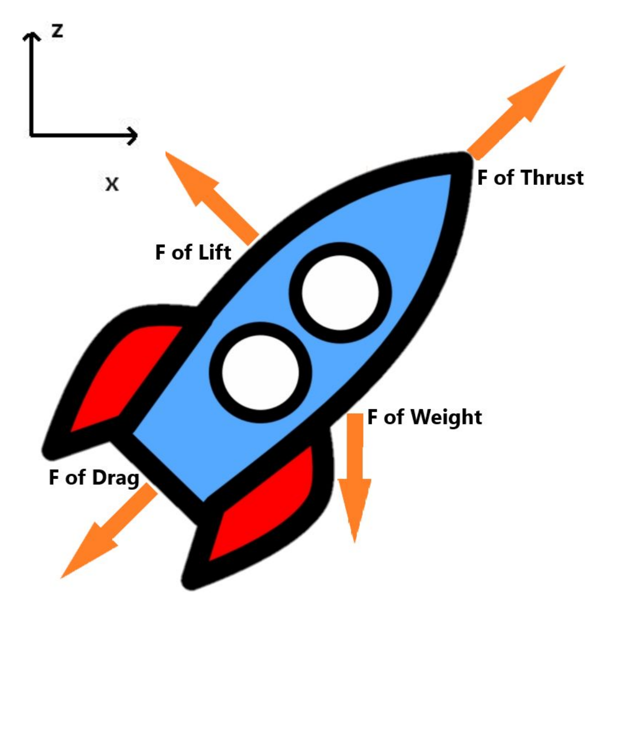
Forces acting on bottle rocket (during flight):

Drag: The force of the surrounding air on the body of the rocket, opposing and parallel to the thrust force

Lift: The force of the surrounding air on the body of the rocket, opposing the weight force and perpendicular to the drag force

Thrust: The force of the propellant system on the rocket (pressurized water)

Weight: The force of gravity (g) on the rocket



Three Phases of Flight

Three phases of flight:

Phase 1 - Lift-off

The bottle rocket shoots into the sky!

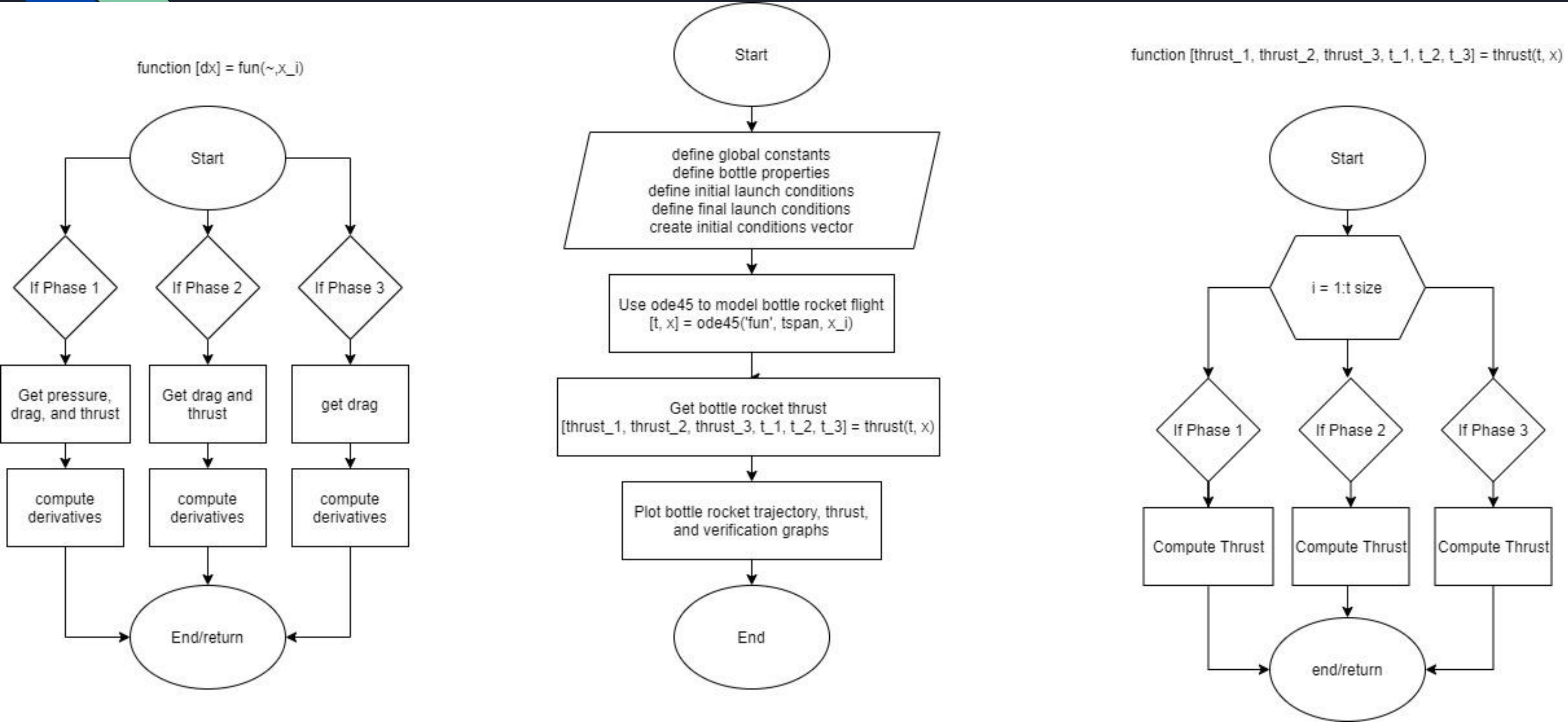
Phase 2 - Apogee

The bottle rocket has reached its peak altitude of approximately 18.7 meters, and has 0 velocity in the Z axis

Phase 3 - Landed

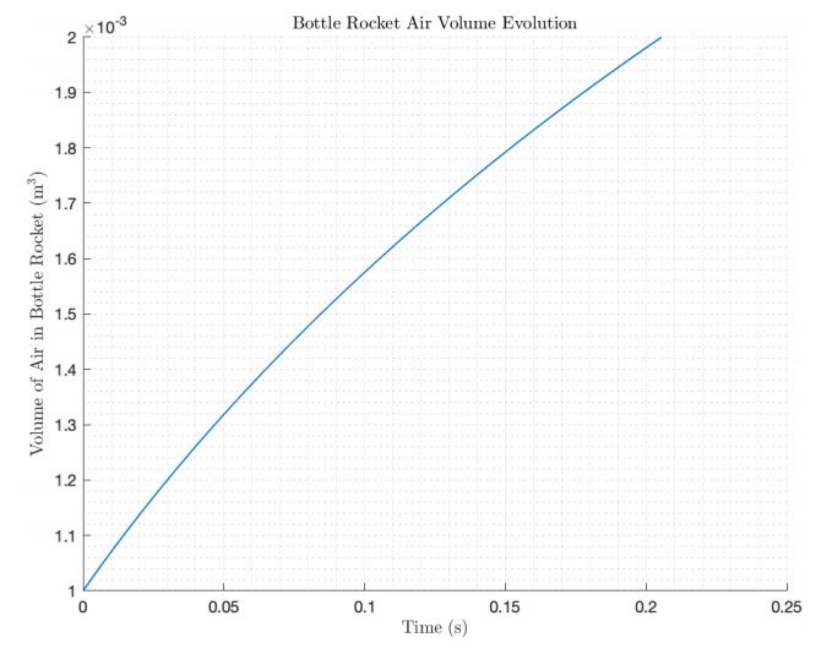
The bottle rocket has landed and is now no longer in motion. The trajectory graph shows that it traveled 66.6 meters away from the launch site in the X direction, and -6.5 meters in the Y direction

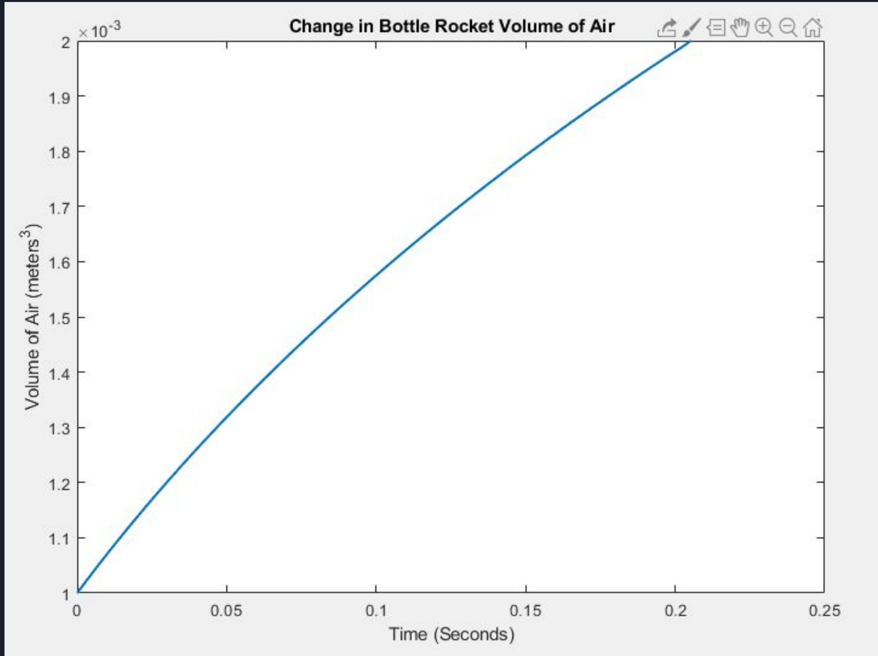
Main Flowchart



Verification Cases

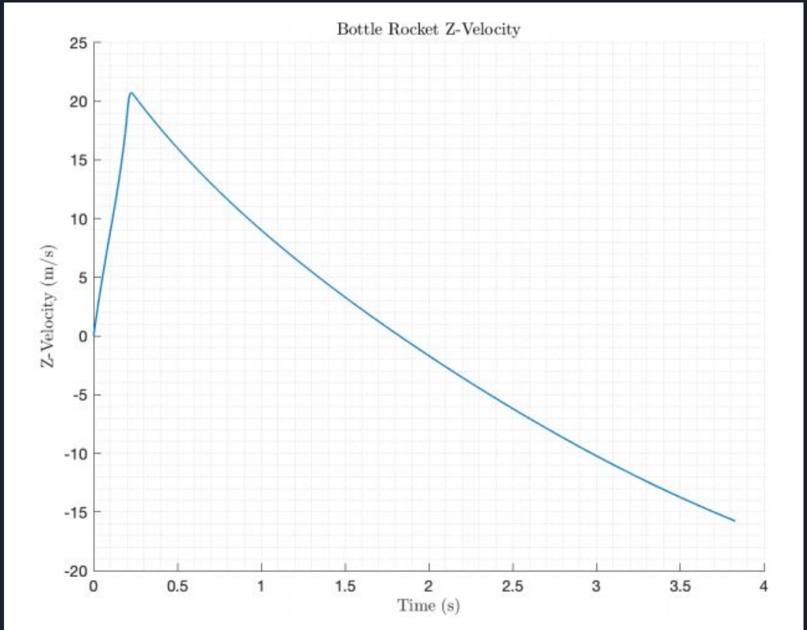
As shown below, the provided verification case for the change in the bottle rocket's volume of air over time (left) matches with graph I plotted using my own matlab code (right).

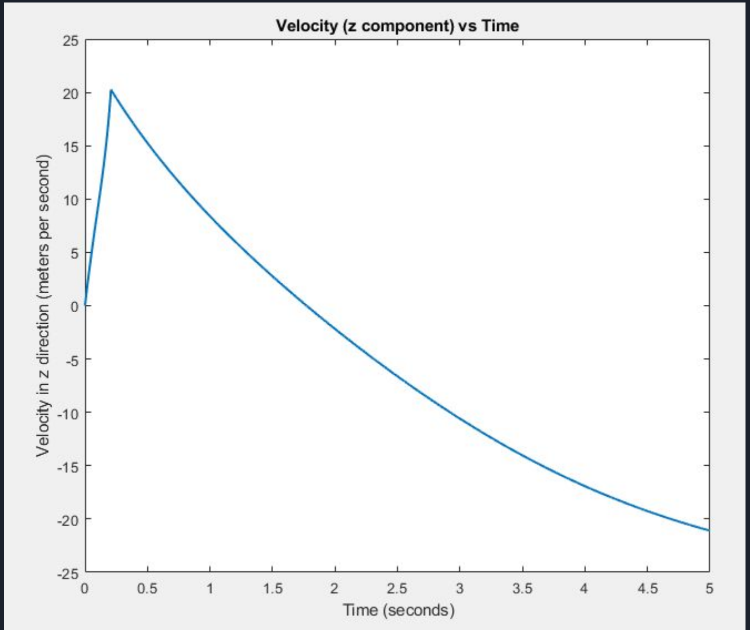




Verification Cases

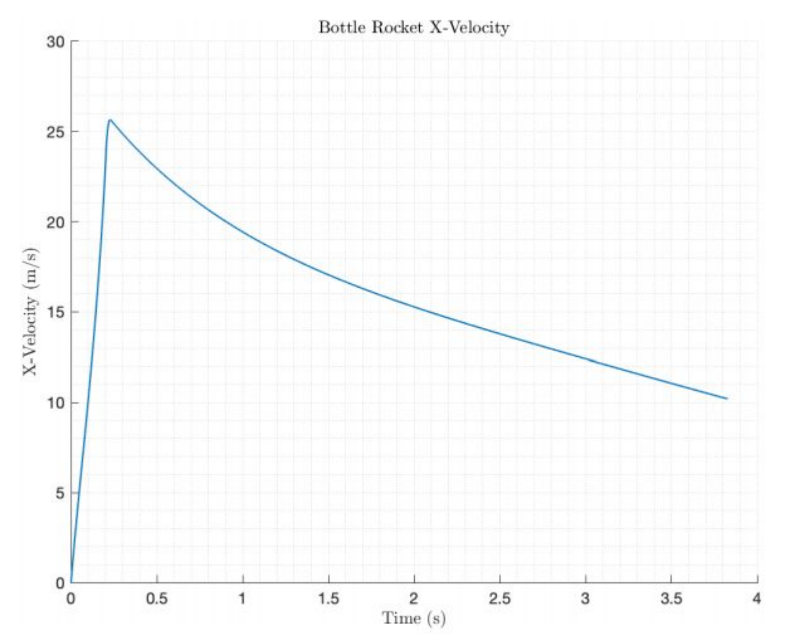
As shown below, the provided verification case for the bottle rocket's z-component velocity over time (left) matches with graph I plotted using my own matlab code (right).

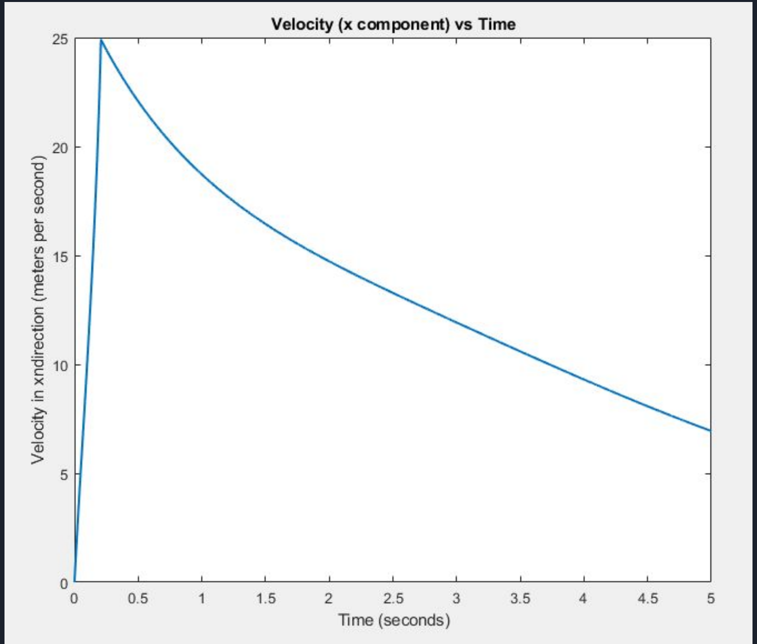




Verification Cases

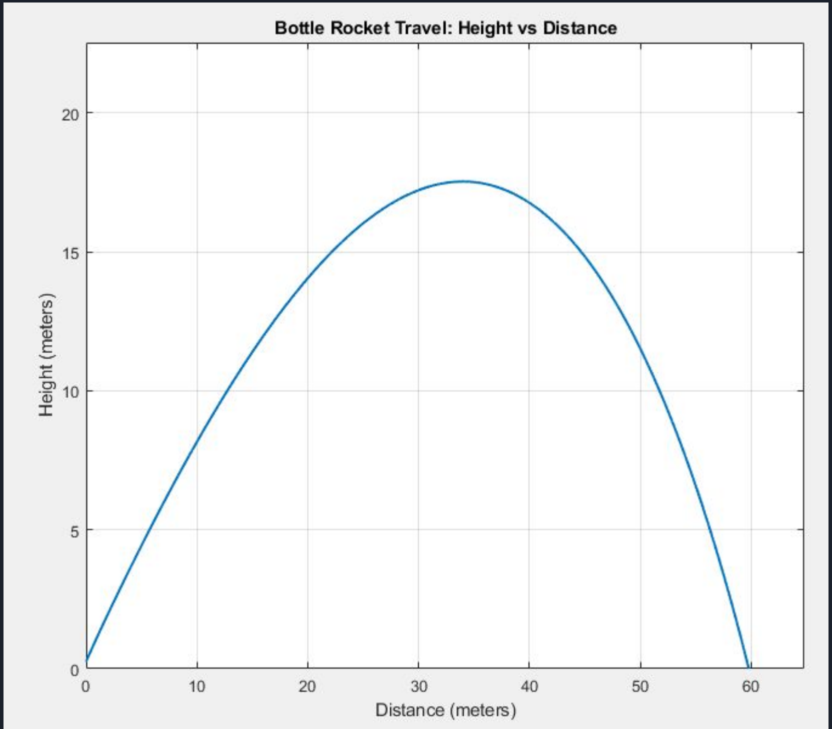
As shown below, the provided verification case for the bottle rocket's x-component velocity over time (left) matches with graph I plotted using my own matlab code (right).



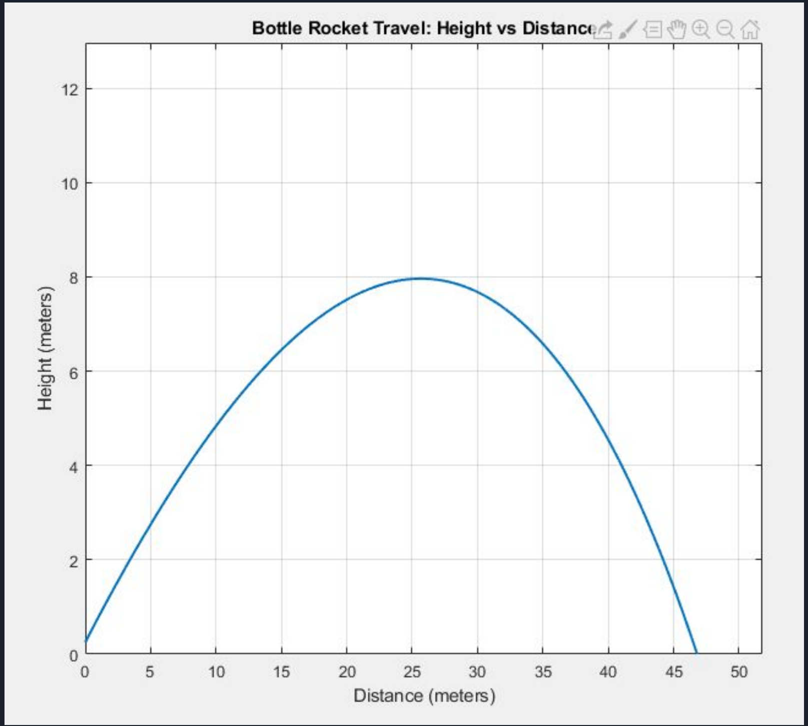


Test Cases - Trajectory

Base Case:

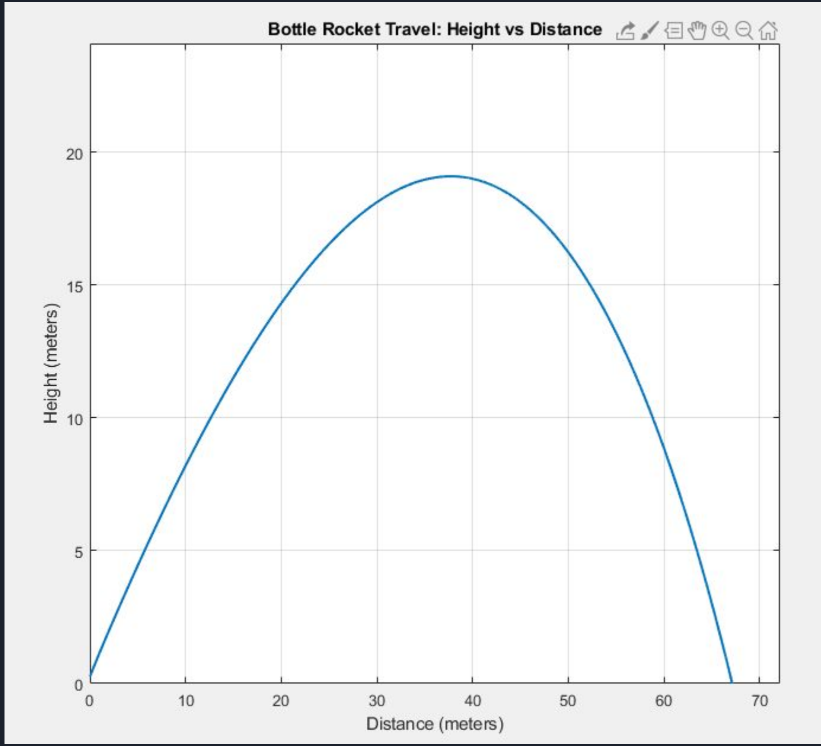


Test 1: Water Volume - 0.0005; Air Pressure - 300000
Drag Coefficient - 0.5; Launch Angle 30 degrees

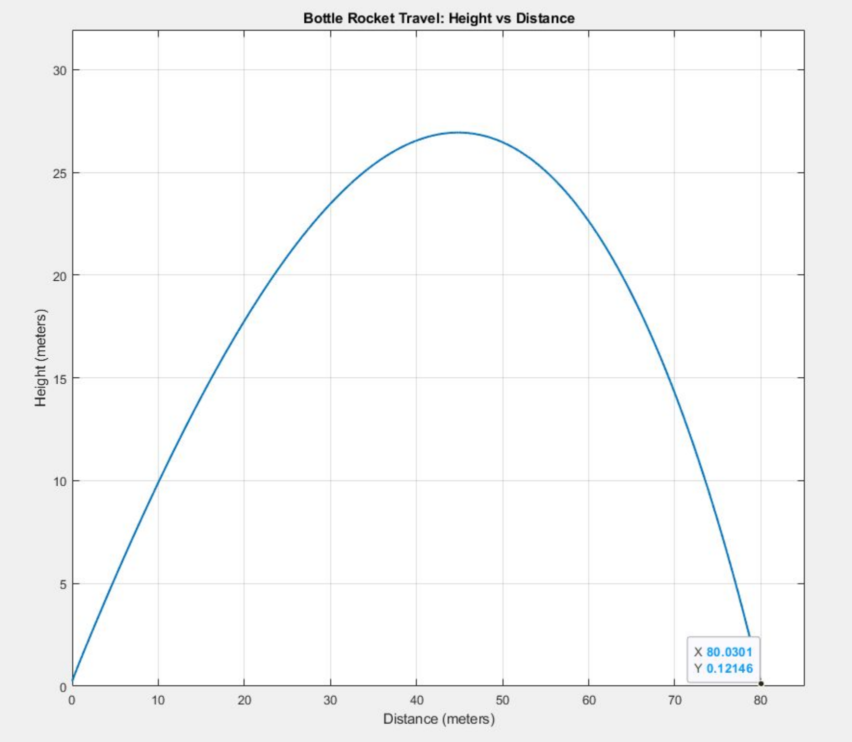


Test Cases - Trajectory

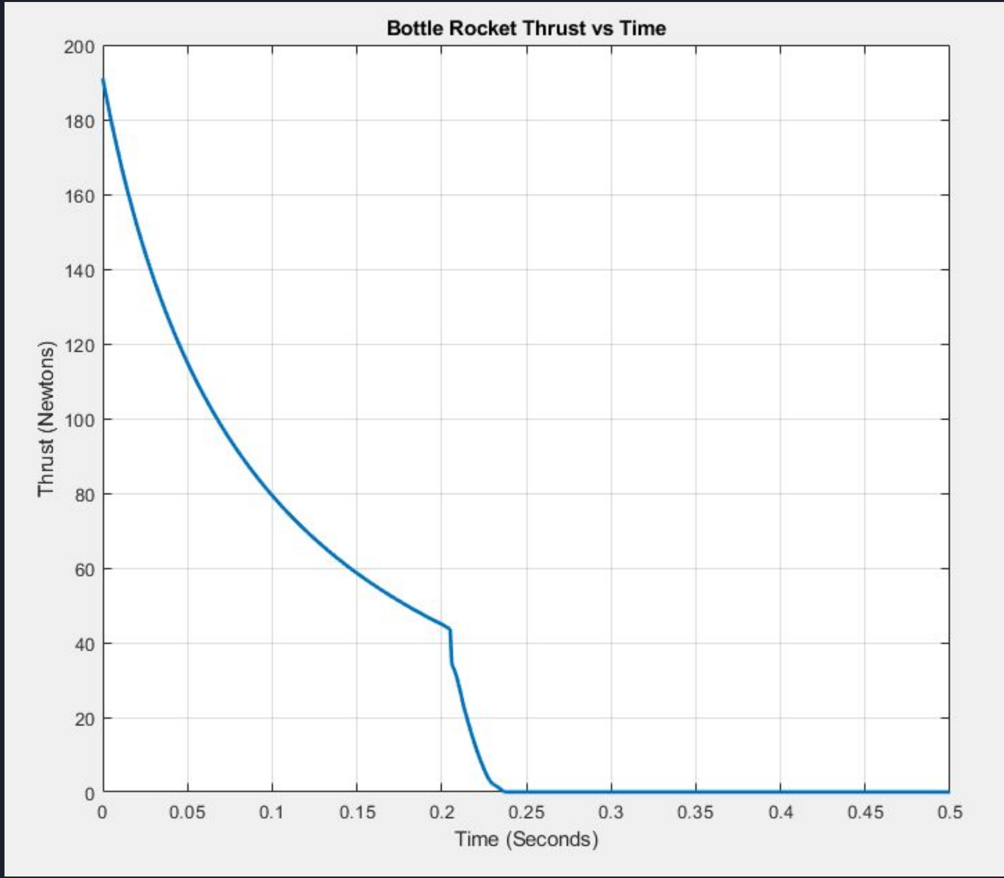
Test 2: Water Volume - 0.001; Air Pressure - 428164.4
Drag Coefficient - 0.4; Launch Angle 45 degrees



Test 3: Water Volume - 0.002; Air Pressure - 377000
Drag Coefficient - 0.3; Launch Angle 50 degrees



Test Cases - Thrust



As shown on the left, the thrust in phase 1 is decreasing, as the slope is negative, and subsequently drops sharply as phase 2 occurs. This masks sense, as the water in the rocket drains, and the air pressure in the bottle drops to ambient. Finally, in phase 3, there is no thrust, as the rocket is now in free fall.

Rocket Performance Analysis

Parameters			Change	Tradeoff
Volume of Water - Original: 0.001 (range: 0.000-0.002)				While increasing the amount of water does increase the thrust of the rocket to a certain extent, filling the bottle with too much water actually reduced it's distance traveled.
.0005	.001	.001	-;neutral;+	Direct relationship, unless overfilled
Initial Air Pressure - Original: 428164.4				Increasing the air pressure dramatically increased the overall travel distance of the bottle rocket, while decreasing it did the opposite.
300000	428164.4	377000	-;neutral;+	Direct relationship
Drag Coefficient - Original: 0.5 (range: 0.3-0.5)				Increasing the drag coefficient of the rocket decreased the overall travel distance of the rocket, while decreasing
.5	.4	.3	-;neutral;+	Inverse relationship
Launch Angle - Original: 45 degrees				Differing the launch angle from 45 degrees made the rocket travel less far
30	45	50	-;neutral;-	Launch angle optimal at approximately 45 degrees

Conclusion

In conclusion, I discovered that one of the most impactful variables to change was the rocket air pressure, as with higher air pressures the rocket achieved more thrust, therefore making it go higher while still maintaining the same target distance of 80 ± 1 meters from the launch site. Varying the angle of launch changed the amount of time the rocket was in the air, as a high angle of launch let it fly higher, whereas with a low launch angle it hit the ground faster. I found alsod that the launch angle was optimal at approximately 45 degrees, as this allowed for both ample vertical height and the farthest horizontal distance. The amount of water also changed the rocket’s flight trajectory. I computed a few ways to hit the 80 meter mark, with test case 3 showing my most accurate attempt.

References

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