ASEN 2012 Project 2: Bottle Rocket Modeling

By Caleb Bristol

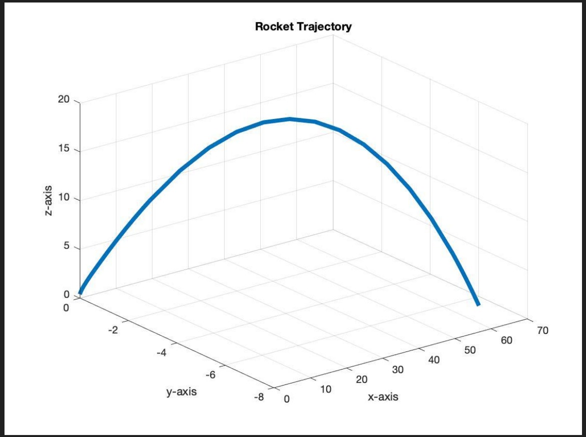
Assigned: 10/30/20

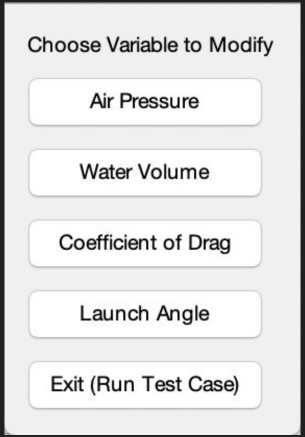
Due: 12/6/20

Introduction

Project Goals:

- Use numerical integration and ODE45 to model a bottle rocket
- Map the trajectory of a bottle rocket using only differential equations
- Modify initial conditions to reach target flight distance of 80 meters

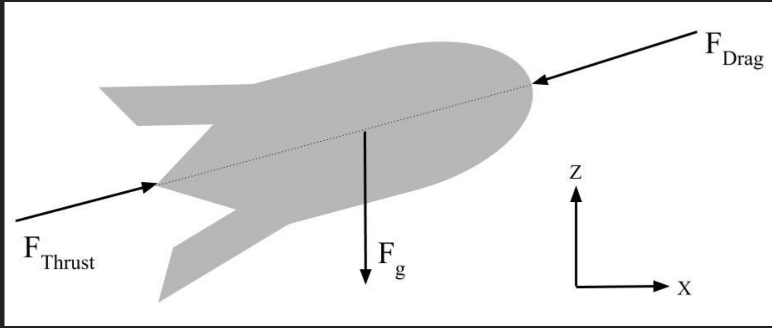




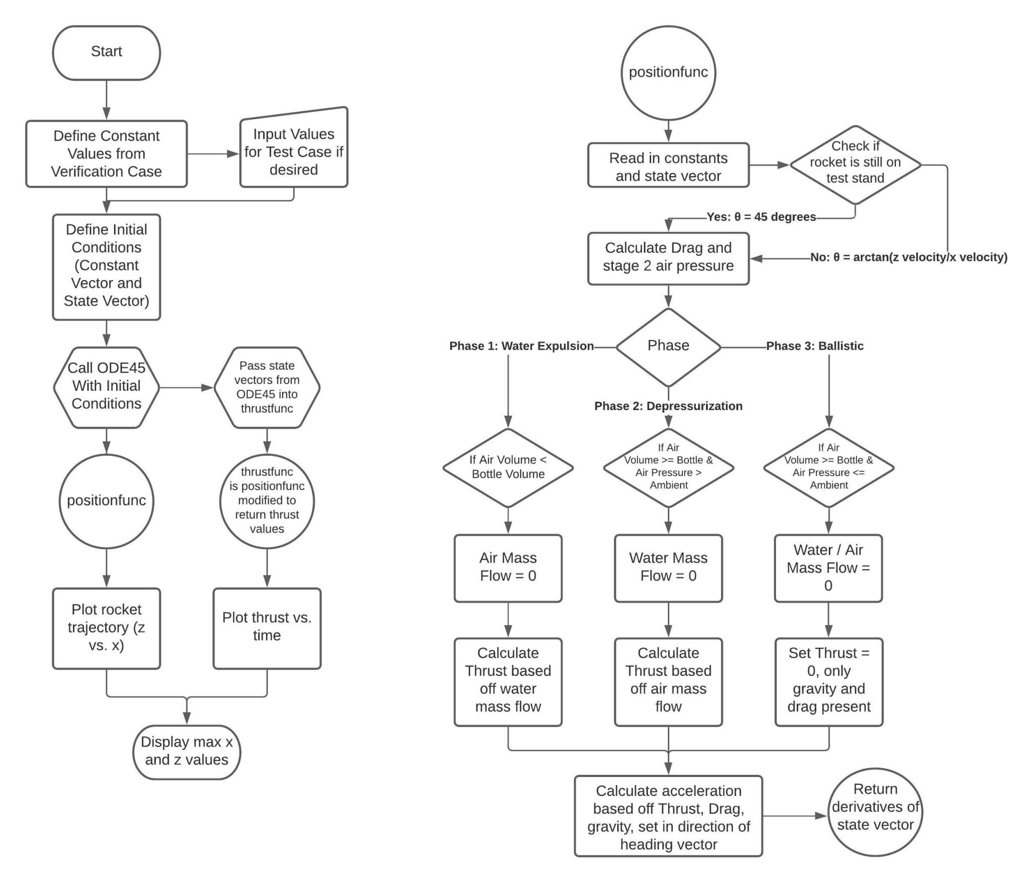
Introduction

Process:

- Model rocket in 2-D using 3 fundamental forces
  - Thrust: due to expulsion of air and water
  - Drag: due to dynamic air pressure on rocket nose
  - Gravity: gravitational attraction of rocket mass
- Convert force vectors into acceleration
- Use numerical integration to map trajectory



Code Flow Chart



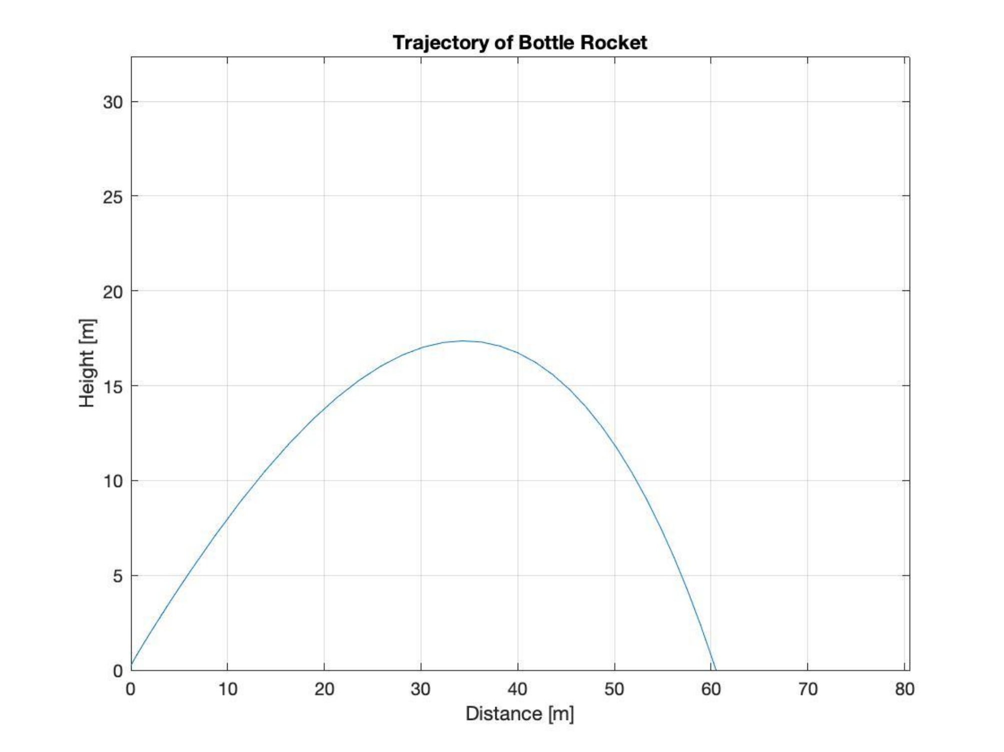
Verification Case - Results

Trajectory

- Max Distance: 60.5m
- Max Height: 17.4m

All numbers within 1m of case with:

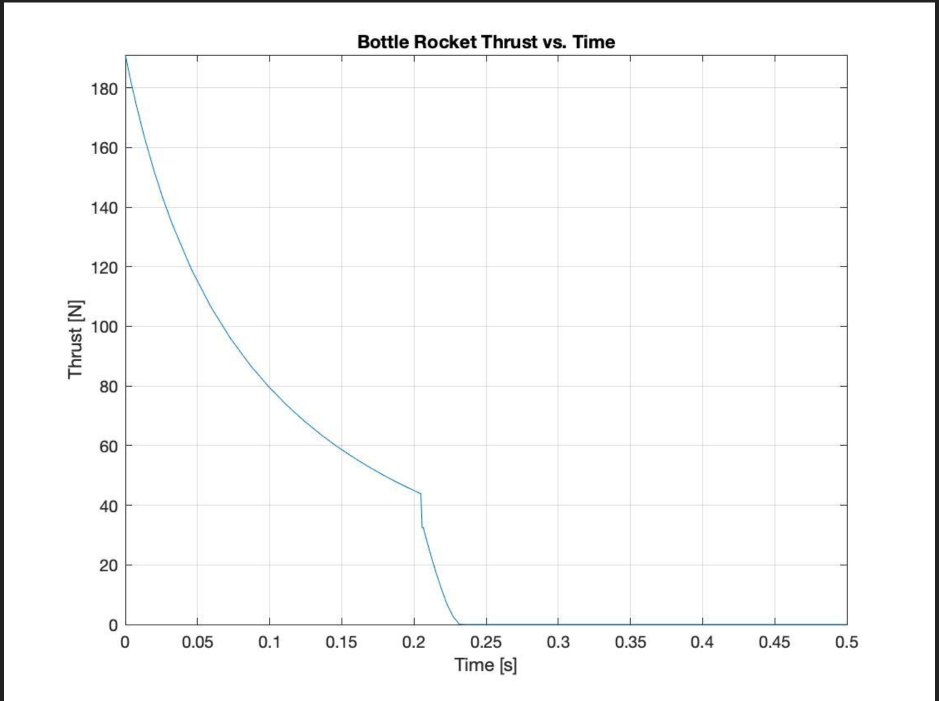
- Coefficient of Drag = 0.5
- Initial Air Pressure = 50 psi
- Initial Water Fraction = 0.5
- Initial Launch Angle = 45º



Verification Case - Results

Thrust

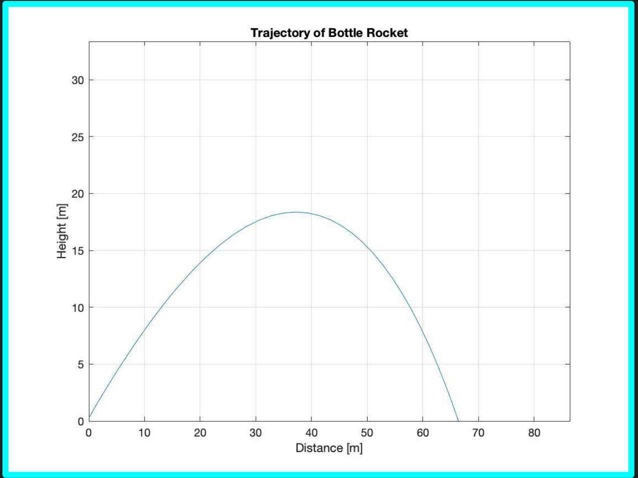
- Phase 1 finished in 0.2s
- Phase 2 finished in <0.05s
- Max Thrust 191.0 N



Test Case - Coefficient of Drag

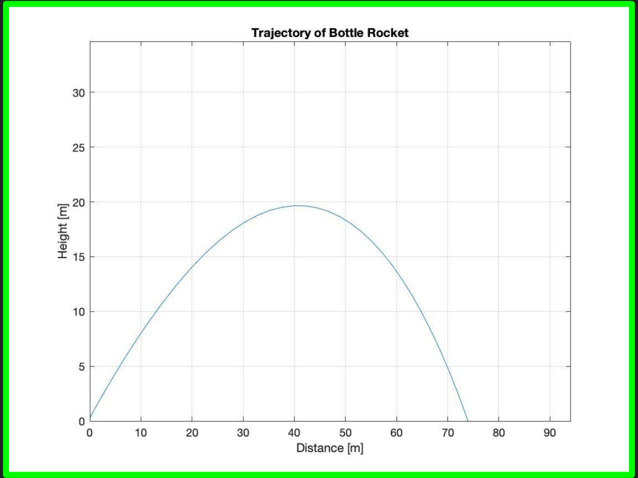
0.4 Coefficient of Drag

- Max Distance 66.4m
- Max Height 18.4m



0.3 Coefficient of Drag

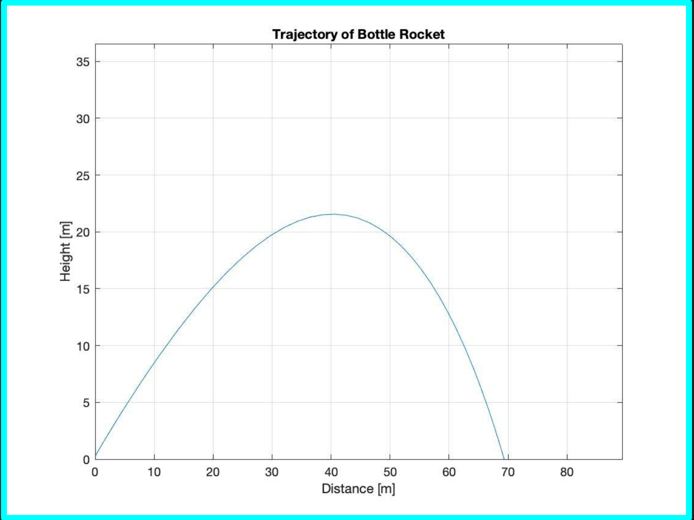
- Max Distance: 74.0m
- Max Height: 19.7m



Test Case - Initial Air Pressure

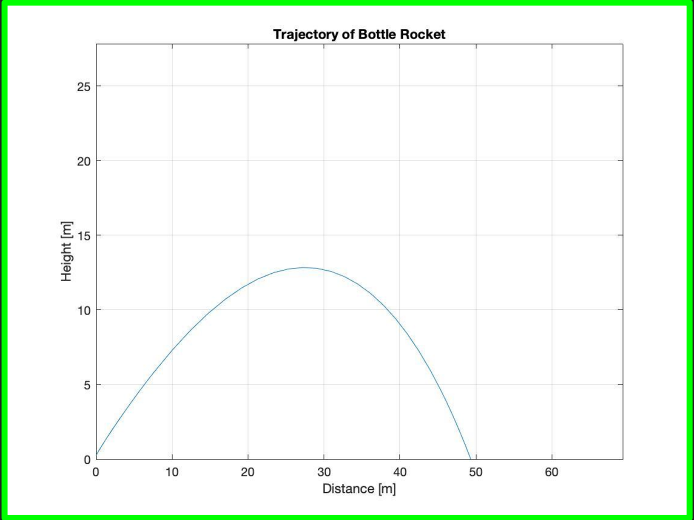
60 PSI

- Max Distance: 69.3m
- Max Height: 21.6m



40 PSI

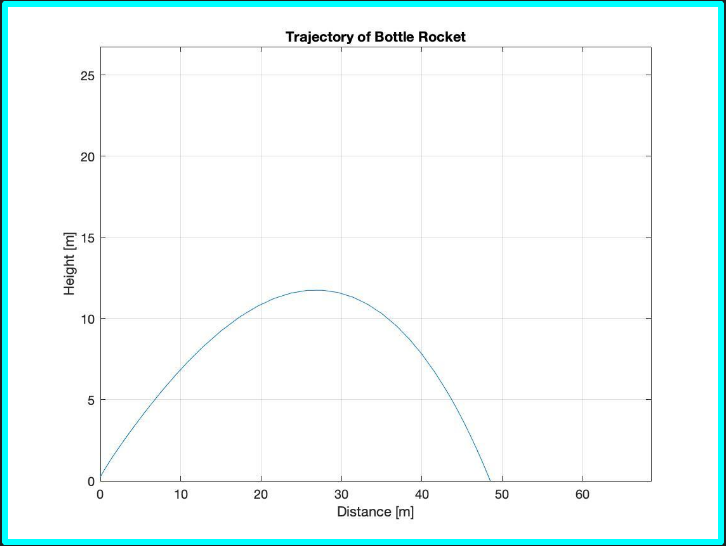
- Max Distance: 49.3m
- Max Height: 12.8m



Test Case - Initial Fractional Water Volume

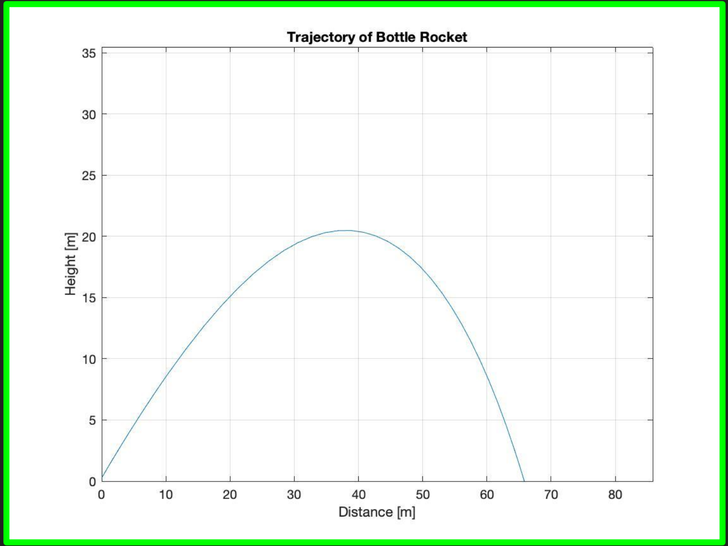
Water Volume 60% of Bottle

- Max Distance: 48.5m
- Max Height: 11.7m



Water Volume 40% of Bottle

- Max Distance: 65.8m
- Max Height: 20.5m



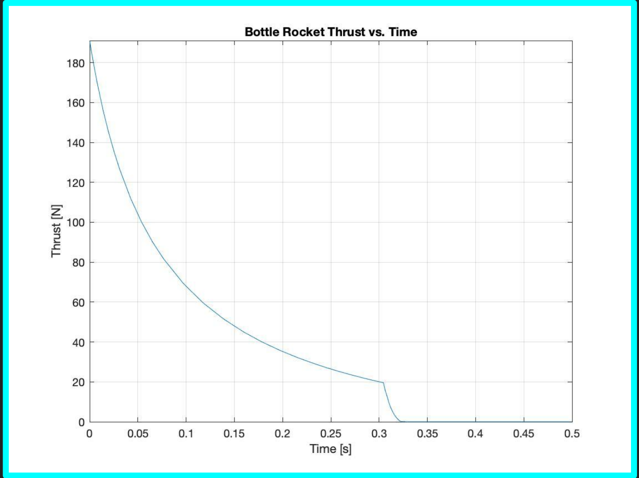
Water Volume - Thrust

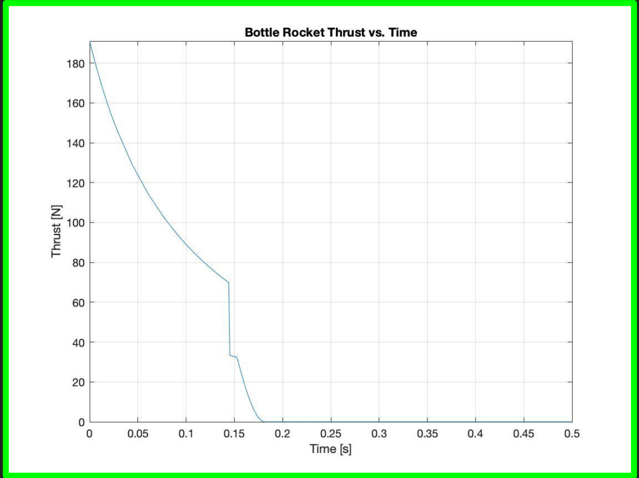
60% Water Volume

- Caused steeper drop off of thrust
- Stage one lasted longer
- Increases initial mass of rocket

40% Water Volume

- Shallow drop off of thrust
- Thrust and stage one much shorter
- Decreases initial mass of rocket





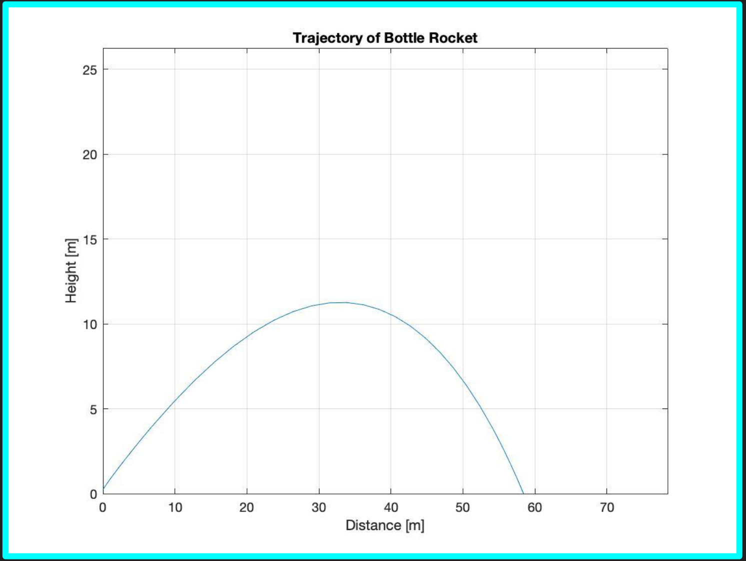
Test Case - Launch Angle

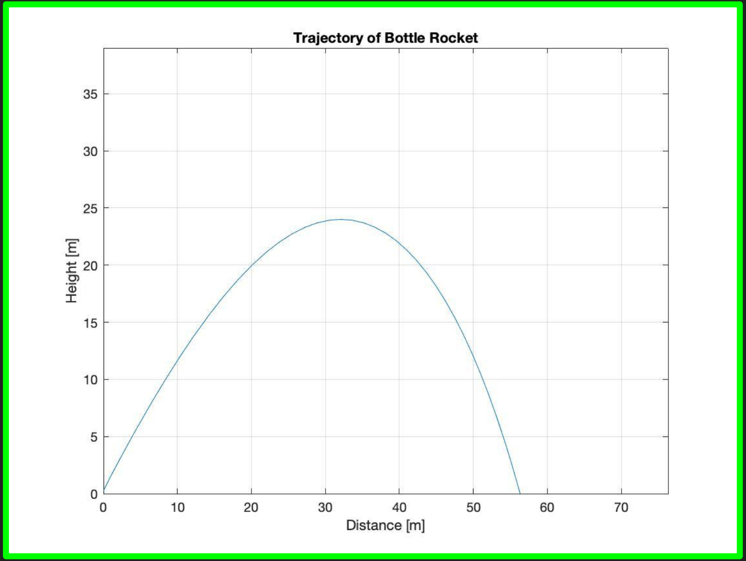
Initial Launch Angle $\theta = 35^o$

- Max Distance: 58.4m
- Max Height: 11.3m

Initial Launch Angle $\theta = 55^o$

- Max Distance: 56.3m
- Max Height: 24.0m

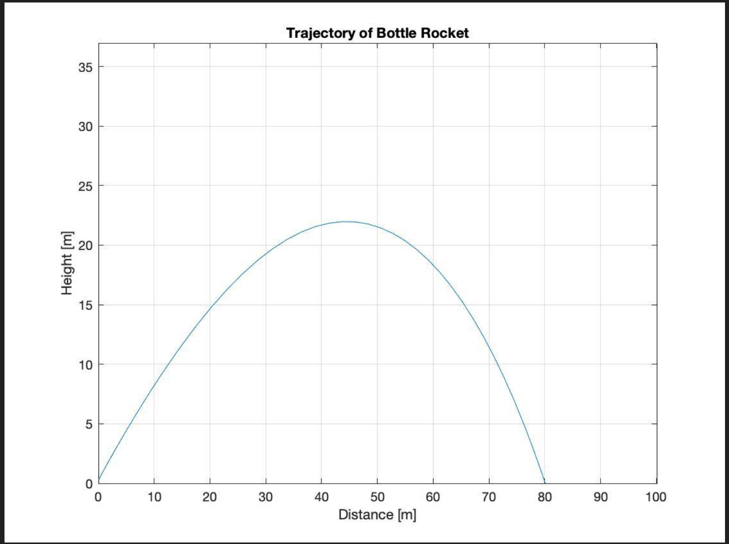


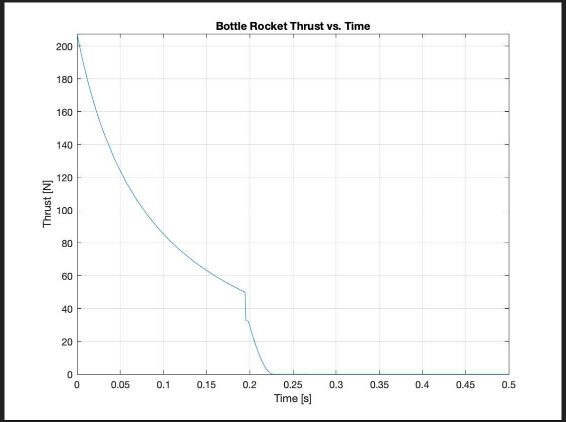


Test Case - Results

In order to reach the target of 80m, I settled on the final variables:

- Coefficient of Drag: 0.3
- Air Pressure [gage]: 54.3 psi
- Water Volume: 0.5 Bottle Volume
- Launch Angle: 45º





Final Max Distance: 80.1m

Final Max Height: 22.0m

Test Case - Discussion

Some variables relied on others to produce positive results

- Coefficient of Drag
  - Produced objectively higher distance and height at lower values
  - If we **can** reduce drag, we **should**
- Air Pressure
  - Produced higher thrust at higher pressures
  - Higher thrust means more velocity but more drag
- Water Volume
  - Caused thrust to have sharper curve at higher values
  - Resulted in greater distance travelled at lower values (up to a limit)
- Launch Angle
  - Higher angle resulted in greater max height and lower max distance
  - Lower angle resulted in lower max height and distance
  - 45^{o} produced consistently high distances

Conclusion

My ode45 function matched the verification case

- This allowed for modifying variables

Most variable altercations were expected, except water volume

- Increase Pressure = Increase Thrust = Increase Distance
- Decreasing water volume increased travel distance

We were able to reach our goal of 80m flight distance

- There are many more configurations to explore
- My test case isn’t the only way to reach 80m

References

Anderson, J. D., Jr., **Introduction to Flight, 7th Ed.**, McGraw-Hill (2009).

Sutton, G. and Biblarz, O., **Rocket Propulsion Elements, 8th Ed.**, Wiley (2010).