

Water Rocket – Trajectory Analysis

You will set up a numerical simulation to predict your rocket trajectory in this activity.

You will need:

- ❑ Rocket and engine thrust specifications (a computer connected to the internet is useful)
- ❑ Spreadsheet
- ❑ Sharp mind and pencil

Flight Simulations

You need to have some general specifications prior to setting up your numerical simulation.

- ❑ Rocket mass, water mass, pressure (typically 90 PSI) and nozzle size.
 - Comprehensive thrust vs time curve data can be found online. Assume a simple model for the force applied to the rocket. You can always add complexity.
 - General information from NASA can be found at the BottleRocketSim site:
<http://www.grc.nasa.gov/WWW/k-12/bottlerocket/index.htm>

You will use the basic laws of motion and a spreadsheet to calculate height as a function of time. Each column in your spreadsheet will be a different quantity:

- ❑ Time (pick a small increment – you can always change it if it is not small enough or too small)
- ❑ Distance: $y_{\text{new}} = y_{\text{old}} + v_{\text{avg}} \Delta t$
- ❑ Velocity: $v_{\text{new}} = v_{\text{old}} + a \Delta t$
- ❑ Acceleration: $a = \Sigma F/m(t)$
- ❑ Forces: F_{thrust} , F_{gravity} and F_{drag}
- ❑ Mass: $m = m_{\text{rocket}} + m_{\text{fuel}}(t)$
 - Let m_{fuel} be used up linearly over the time it takes the water to be ejected – typically 0.7 seconds so you could say $m_f = m_o(0.7 - t_i)/0.7$ where m_o is the initial mass of the fuel.
- ❑ Drag: $F_{\text{drag}} = 0.5 C_v \rho A v^2$
 - C_v , the drag coefficient, is typically 0.7 to 1.4
 - ρ is the density of air 1.29 kg/m^3
 - A is the cross section of your rocket (make sure to get the units correct)
 - : F_{drag} is opposite the velocity so use “ $\text{abs}(v) \cdot v$ ” to preserve the sign of the velocity

On-line Flight Simulation Tools

Feel free to use on-line tools to compare to your own calculations.

- ❑ NASA: <http://exploration.grc.nasa.gov/education/rocket/BottleRocket/sim.htm>
 - 3D: <http://exploration.grc.nasa.gov/education/rocket/BottleRocket/WRSimApplet/BRocket.html>
 - 1D: <http://exploration.grc.nasa.gov/education/rocket/BottleRocket/OldBottle.html>
 - 2D: <http://exploration.grc.nasa.gov/education/rocket/BottleRocket/RM2.html>
- ❑ Water rocket simulator: <http://www.sciencebits.com/RocketCalculator>
- ❑ Model Rocket Index - <http://www.grc.nasa.gov/WWW/K-12/airplane/shortr.html>
- ❑ OSU Rocket Simulator http://extension.osu.edu/rockets/cgi-bin/design_zone.cgi
- ❑ Complete information about rockets at NASA site:
<http://exploration.grc.nasa.gov/education/rocket/rktbot.html>
- ❑ Rocket Simulation (how to write a numerical simulation) <http://my.execpc.com/~culp/rockets>