Constructing and Deploying a Water Rocket

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Problem Statement

Building and launching water rockets allows for experimentation with different designs and parameters like fin placement, water levels, and air pressure. This fosters critical thinking and problem-solving skills as you optimize your rocket's performance.

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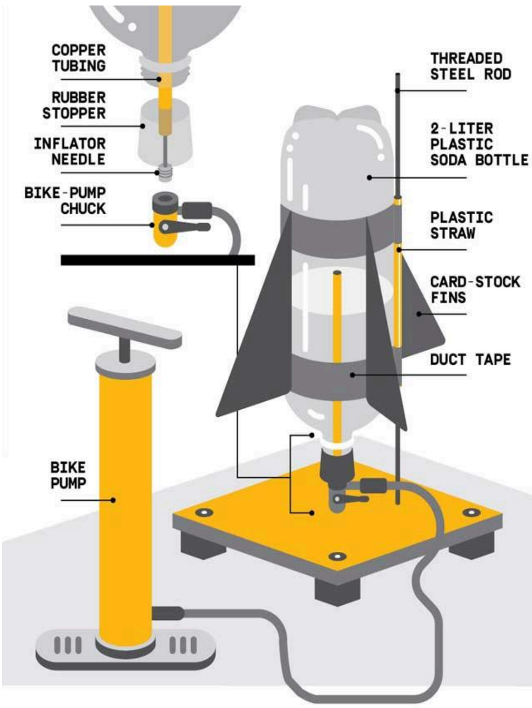
1.Understanding water rocket



What is a water rocket?

A water rocket is a simple yet fascinating device that harnesses the power of water and air pressure to propel itself into the air. This document aims to provide a clear and concise definition of what a water rocket is, its components, and how it functions.

Fairing : Fairings are used in two quite different ways. A section of a bottle is excised and utilized as a shroud to encapsulate the joint between two or more body tubes. This provides structural reinforcement to the connection point, preventing potential failure under pressure. The second technique adds whole bottles or parts of bottles onto the water rocket ‘engine’ to produce a longer rocket.

Nose Cone: A pointed structure attached to the forward end of the fairing. Its primary function is to optimize aerodynamic efficiency by minimizing air resistance, thereby maximizing flight distance.

Fins: These are thin, flat pieces attached to the back of the body tube that provide stability during flight. They help the rocket stay upright and prevent it from wobbling.

Launch Pad/Launcher: A vertical structure designed to securely position and stabilize the water rocket prior to launch. Typically constructed from PVC pipes or commercially available models. Includes a vertical launch tube that aligns with the rocket's nozzle. Provides a controlled environment for pressurization and launch.

Air Pump: A pneumatic pump used to introduce compressed air into the water rocket's body tube. Common options include bicycle pumps or dedicated foot pumps. The compressed air exerts pressure on the water, propelling it out of the nozzle and generating thrust.

Launch Tube: A cylindrical tube that extends from the base of the launch pad and inserts into the water rocket's nozzle. Functions as a guide channel for the initial phase of the launch, preventing premature water expulsion. Enables the rocket to gain initial velocity before transitioning to free flight.

Rocket Launch: Initiating water rocket launch commences with a predetermined quantity of water being loaded into the body tube. Securely attaching the rocket to the launch tube ensures proper alignment and connection. Pressurization follows, with the air pump connected to the launch tube's valve. For bicycle pumps, manual pressurization involves steadily adding air while monitoring the number of pump strokes. Foot pumps utilize pressure gauges, requiring the operator to stop pumping when the desired pressure level is achieved. Prior to launch, it's crucial to verify a clear and safe launch area. Finally, the launch mechanism is activated, typically by pulling a string to sever a restraining system cable ties. This triggers the rapid expulsion of pressurized air through the nozzle, propelling the water out and launching the rocket skyward.

2. Launcher

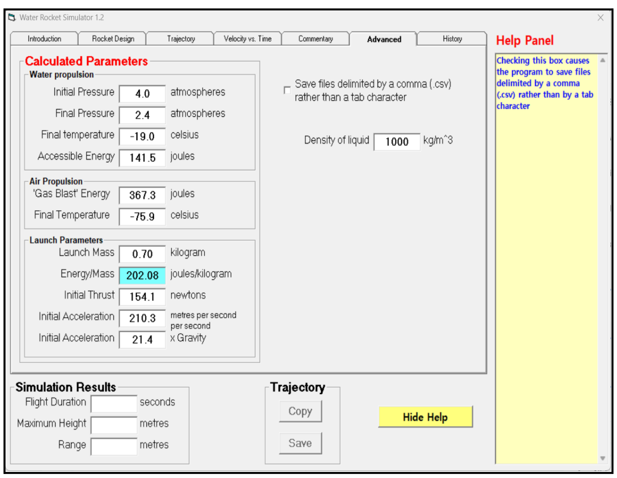
A water rocket launcher is a rigid structure designed to securely hold and guide a water rocket during its launch phase. It functions as a controlled pathway for channeling pressurized air from an external pump into the rocket's body tube. This pressurization process occurs safely within the launcher, preventing premature water expulsion and ensuring a stable and directed launch upon release.

The launch tube itself is equipped with cable ties positioned strategically below it. These cable ties function as a restraining mechanism, holding the rocket's nozzle in place during the pressurization phase. A string mechanism is employed to trigger their release. Pulling the string severs the cable ties, enabling the pressurized air to propel the rocket upwards. To guarantee a leak-proof seal, Teflon tape is meticulously applied around the rear section of the launch tube.

The launch tube serves as a controlled conduit for the pressurized air, acting as the primary propellant delivery system for the rocket. Around the rocket's nozzle, where it connects to the launch tube, cable ties are strategically secured. These cable ties function as a restraining mechanism, holding the rocket in place during the pressurization phase. A coupler serves as the anchor point for the cable ties, and a string is attached to this coupler. Once the desired pressure level is attained within the launch tube, a pull on the string initiates the release mechanism. As the string is pulled, the coupler undergoes a downward movement, effectively loosening the cable ties. This sudden release allows the pressurized air to forcefully expel water out of the rocket's nozzle, generating thrust that propels the rocket upwards.

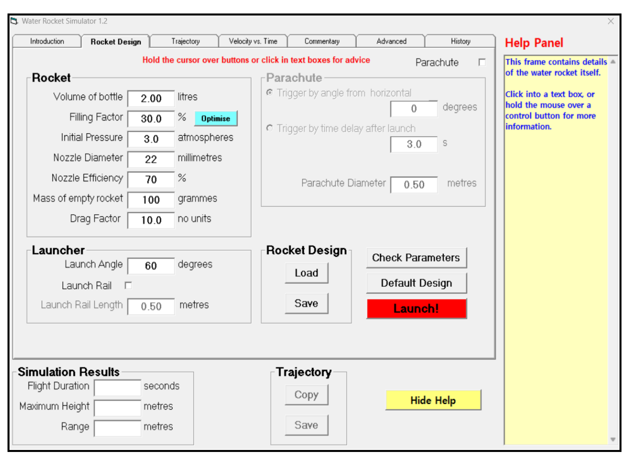
Launcher Description: The launch pad is a robust T-shaped structure constructed from PVC pipes for enhanced stability. The pipes are securely joined using M-seal sealant to ensure structural integrity. Two of the pipe ends are capped, while the third features a valve attached with M-seal. This valve serves as the entry point for pressurized air from the pump, allowing it to flow into the launch tube and subsequently pressurize the water rocket

3. Rocket design & Computer Simulation



For the computational analysis of water rocket performance, we employed Rocket Simulator 1.2, a virtual rocketry software designed for user-driven rocket design and launch simulation. This software offers extensive customization capabilities, allowing users to define various rocket components and parameters. It employs a physics-based simulation engine that considers factors like thrust and drag to accurately model the rocket's trajectory.

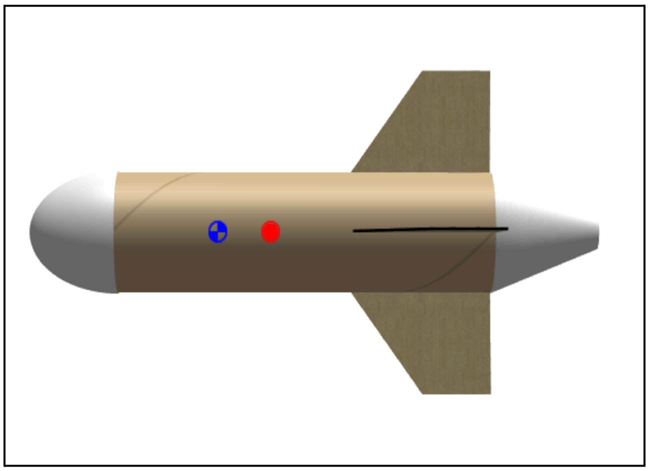
Additionally, the software provides detailed post-flight analysis of key parameters like altitude and velocity, offering valuable insights into the rocket's performance. This educational tool serves as a valuable platform for understanding the fundamental principles of rocketry and optimizing water rocket designs prior to physical launch, thereby reducing the need for iterative testing and increasing the efficiency of the design process.



3D MODELING To optimize the design and performance of our water rocket, we utilized OpenRocket software. This free software program boasts a comprehensive suite of features for model rocketry. It allowed us to virtually design our rocket in 3D, incorporating components like the Nose cone, fairing, fins.

4.Rocket Manufacturing

The water rocket was constructed utilizing readily available materials for efficient fabrication. The primary body was formed from a commercially available soda bottle, selected for its structural integrity and appropriate volume. Duct tape served as a versatile adhesive for securing the various components. Teflon tape provided enhanced sealing around the launch tube connection point to minimize air leaks. A small plastic ball was strategically placed and secured to form the nose cone, optimizing aerodynamic efficiency. Fins were crafted from cardboard, chosen for its lightweight properties while maintaining sufficient rigidity to stabilize the rocket during flight. The overall dimensions and component configurations were meticulously determined through prior calculations, ensuring optimal performance. Additionally, a 3D model served as a visual reference to guide the assembly process and ensure all components aligned with the intended design. We used OpenRocket software for 3D modeling.



4.Calculations

Achieving a stable and predictable flight path is paramount for a successful water rocket launch. To ensure this, we undertook some calculations, carefully considering the key factors that influence rocket stability. We'll see these calculations in detail. This section will delve into the specific calculations performed to optimize our water rocket's design. Following are the calculations that were done :

1. Fin calculations
2. Cg and Cp calculations
3. Stability calculations
4. Pressure calculations

1.Fin calculations

Root chord	14.3 cm
Tip chord	7 cm
Height	9 cm
Sweep length	7.32 cm
Sweep angle	39 deg
Area of single fin	103.2 cm sq.
Area of 4 fins	412.8 cm sq.

2. Cg and Cp calculations

Calculated Cg	23.1 cm
Calculated Cp	31.9 cm

Here other than the software we have used two methods to calculate Cg & Cp

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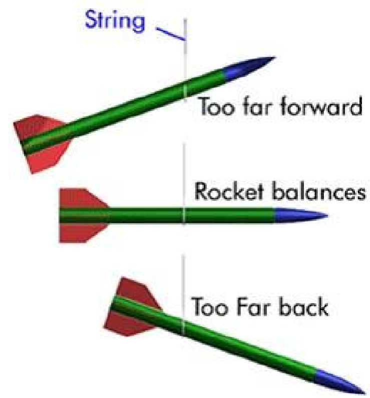
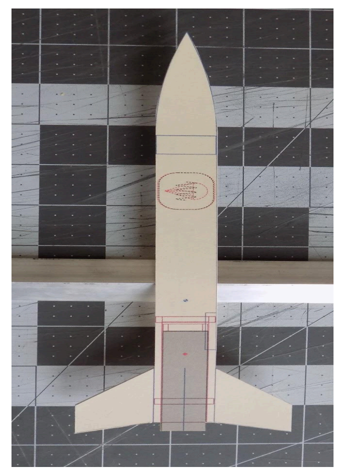


Step 1: Tie a string to rocket as shown in figure.

Step 2: Adjust the position of the knot in such a way that the rocket remains balanced and parallel to the ground.

Step 3: Note down the distance of the point from the nose cone tip or the aft end of the rocket.

To estimate Cp we have used cut-out method:



Step 1: Trace the outline of your rocket on a strong cardboard

Step 2: Carefully cut out the drawing

Step 3: Try to balance the cut out on a tip

Step 4: Measure the point of balance from the noose cone tip or the aft end of the rocket

3.Stability calculations

Cg = 23.1 cm

Cp = 31.9 cm

D = 10.6 cm

Stability = $Cg - Cp/D$

= 31.9-23.1 / 10.6

= 0.83

4. Pressure calculations

Volume of air	n*0.224
Volume of air	4.56
Volume of water bottle	0.002 m^3
Total volume	Volume air + Volume of water bottle
No. of moles of gas	Total volume / 0.0224 m^3/ mole = 4.562/0.0224 = 203.66
P = n*r*t / v	= 303.66*8.314*298/4.562 = 110605.5 pascal = 1.091 atm
Volume of air pump	$\Pi r^2 h$ R = 1.91 cm = 0.019 m H = 50 cm = 0.5 m = 3.14*(0.019)*0.5 = $5.67*(10)^{-4} m^3$ P = 203.66* 8.314 * 298 / $5.67*(10)^{-4}$ = 889, 915, 896.6067 Pa = 8.783 atm

6. Testing

The team embarked on a comprehensive testing phase, where they examined the launcher's functionality by pressurizing a 2.25-liter bottle through conventional means, utilizing a standard pump, and refining the seals to ensure optimal performance. This process allowed them to fine-tune the system for subsequent evaluations. In the next phase, the team conducted further tests using the same 2.25-liter bottle, this time filled with precisely 650 grams of water. This step aimed to assess the launcher's performance under specific payload conditions, providing valuable insights into its capabilities and potential areas for improvement. After the preliminary tests, the team proceeded to the pivotal stage of launching the rocket. Employing the 2.25-liter bottle based rocket with a fairing, the team executed the launch. The rocket was stable, demonstrating the effectiveness of the design enhancements and achieving the desired range of 40 meters. This successful flight validated the calculations behind the launch