Shooting Star

Bottle Rocket Report

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**Abstract**

For this experiment, we were to create a water bottle rocket that could be launched to go the farthest horizontal distance possible. We used two 2-liter soda bottles to design our rocket. We use 800 milliliters of water as the fuel in our bottle rockets. Our bottle rockets also had a nose cone made from one empty soda bottle, which was connected to the other bottle. We used four wings that we evenly distributed in the back of our bottle rocket. We also used sand, which was used to increase the mass of the front of our rocket. When we launched our rocket, we set our rocket at an angle of 45 degrees. Throughout the process of testing our bottle rocket we changed many things. We decreased the amount of water to about 200 milliliters. We also added around 100 grams as well, to get our rocket at the right mass. We moved our wings, from the middle of our rocket, to the back of our rocket, to help the aerodynamics. With these changes, our rocket traveled a total of 53.8 meters.

**Table of Contents**

1. **Introduction** (pages 4-6)
2. **Description** **of Original Design** (pages 6-7)
3. **Results** (page7)
4. **Analysis** (page 7-8)
5. **Conclusion** (page 8-9)
6. **Appendices** (pages 9-10)
   1. **Materials and Methods** (pages 9-10)
   2. **Cost** (page 10)
   3. **Graphics** (after refrences)z
7. **References** (pages 10-11)

**Introduction**

A water bottle rocket is a type of rocket that is made with a 2 liter soda bottle and is fueled by water. To activate the bottle, one would fill the bottle with water and pump air into the rocket. The air pressure will cause the bottle to fly off the air pump base and into the air as a projectile. The angle at which the base is placed will be a large factor in how long and high the rocket flies. The wings that are attached to the rocket will help the aerodynamics of the rocket. Figuring out the fitting mass will also play a large role in the performance of the rocket.

Newton's Laws explain how the bottle rocket works. Newton's first law states that an object in motion stays in motion unless acted upon by an outside force. This stands true for the bottle rocket because the rocket will not accelerate until it has an extra force exerted on it, which in this case would be the pump. This law also applies to the slowing down of the rocket. If the rocket were in an open area without gravity, the rocket would never stop. However, the slowing of the rocket will be caused by an unbalanced force. While in flight, the rocket will have air resistance against it, which will cause the rocket to slow its velocity. Also while the rocket is in flight, gravity will be acting upon this object. Gravity will cause the rocket to fall downwards. If gravity were non-existent, the bottle would continue upwards forever at the angle which it was launched at. The ideas of unbalanced forces are very important to consider when building the rocket. Newton’s second law applies to the rockets as well. The equation f = m \* a must be considered by the builder of the rocket. This equation shows us that acceleration is directly proportional to force and indirectly proportional to mass. Therefore, the maker of the rocket aim for a lower mass of the rocket and a higher force in order to achieve a greater acceleration. However the mass cannot be too small or else it can be easily affected by air resistance, which relates back to Newton’s first law. The third law applies to the rocket as the force is exerted. This law states that every action has an opposite and equal reaction force. The bottle pushes some of its water downward and the water responds by pushing upward on the bottle.

A projectile is any object moving through the air in a curved path. Our bottle launches upward at an angle and will follow a curved path. Therefore, it is considered a projectile. The bottle rocket will be projected at an angle of 45 degrees. After the bottle is set into motion, it will be moving at a different horizontal rate than vertical rate. Since the force of gravity on earth is 9.81, the bottle will constantly be accelerating 9.81 m/s/s downward, even when it is moving in the upward direction. As the bottle rocket nears its peak, it will be slowing down to a vertical velocity of 0. Since the rocket is slowing down, this will make the acceleration negative. After the rocket reaches its peak, it will pick up speed and acceleration 9.81 m/s/s towards the ground. While all of the vertical motion is happening, the horizontal velocity acts independently of the vertical motion. The bottle’s velocity will start to slow horizontally as time goes on because of air resistance. To get the bottle to move the farthest, it should be launched at a 45 degree angle. As the launch angle nears 90 degrees, the object will increase its maximum height and decrease its total distance traveled. Therefore, to have the rocket in the air for as long as possible, but still have it travel as far as possible, it must be launched at a 90 degree angle.

The impulse momentum theorem also applies to bottle rocketry. Impulse is a force acting upon an object for a specific amount of time and it causes a change in momentum. We want our rocket to have a larger impulse, or a larger change in momentum, so we can have our rocket farther. Water Rockets, as well as any rockets need fuel and energy.  Chemical reactions in the fuel release energy, which allow the rocket to push the fuel backward. Water is used as fuel rather than air alone because the water will apply an extended force to the rocket rather than a short force. Water is also a good fuel because it is dense and provides a lot of inertia for the rocket to push against. Since time and force a directly proportional to impulse, the impulse will increase as time increases, because by adding water to the rocket, the time that the force is exerted can be extended. We cannot determine the force for this experiment, therefore we must rely on the amount of time the force is applied so that the bottle can have the greatest impulse possible without making the bottle too heavy at the launching.

There is currently an existing design that will work for a water bottle rocket. This design uses 4 wings and a nose cone with extra mass. It also suggests to use 1 liter of water when launching the rocket. This existing design can be improved by altering the amount of mass and or water used. Since the rocket will not be used with the same exact amount or kind of tape and the wings will be made of slightly different materials, this design should be altered where it can be. Meaning the amount of mass should be changed if the mass is not in the center of the bottle rocket and the water amount should be altered if the rocket is not reaching the desired distance. You can alter the mass in the front of the rocket by adding sand or clay. This will make the front heavier, and will help the rocket from crashing. Also, instead of adding 1 full liter of water, you may want to add more around 800 milliliters, because having too much water will negatively affect how the rocket accelerates. Lastly, you can alter the type of material for the four wings. Instead of using plastic for it, it would be a better to use a more sturdy material, like cardboard, because it is more durable.

**Description of Original Design**

For the original design, we chose to incorporate fins and a nose cone along with the main rocket. The main bottle, or the pressure chamber, is made with a 2-liter bottle. The top (the spout) of this bottle will act as the tail of the rocket. We added four fins to the rocket. We chose to add four fins instead of three so the aerodynamics can be further improved.  We attached the fins relatively close to rear. The closer they are to the rear the more effective they will be in changing the air resistance. However, we do not want the fins to extend below the spout of the bottle (where we insert the pump). If they extend too low, they will be in the way of the launcher and possibly make for an unbalanced flight. The fins were originally made of plastic folder to have them of a sturdy material. The nose cone is made from the top quarter of a second 2-liter bottle. The purpose of the nose cone is to shift the center of mass of the bottle rocket. The center of mass should not be close to the center of the rocket. This will cause the rocket to crash. The center of mass should be towards the top of the bottle. We added sand into our nose cone to help shift the balance towards the top and away from the pressure chamber. The shift of mass will help further stabilize the rocket in flight. The mass of our rocket is 88.6 grams. It is this weight because the added sand mass in the nose cone will help give the rocket better flight, but the added mass will not weigh the rocket down while in flight. We used 1000 ml of water to fuel our rocket because it is enough water to give our rocket a greater change of momentum, but not too much to weigh our rocket down in the launch. We used a 45 degree angle to launch our rocket because it will give the rocket good height, along with good distance.

**Results**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Trial** | **Mass of Rocket** | **Amount of Sand** | **Volume of Water** | **Launch Angle** | **Description of Flight** |
| 1 | 88.6 g | 30.65 g | 1000 ml | 45° | 26 meters |
| 2 | 224.7 g | 63.07 g | 1000 ml | 45° | 25 meters |
| 3 | 453.592 g | 100.34 g | 800 ml | 45° | 61 meters |
| 4 | 453.592 g | 100.34 g | 1000 ml | 45° | 58 meters |
| 5 | 580.432 g | 126.84 g | 800 ml | 45° | 32 meters |
| Final Launch | 580.432 g | 126.84 | 800 ml | 45° | 53.8 meters |

**Analysis**

In our first two trials, our rocket was not very successful. It went 26 meters in the first trial and 25 meters in the second trial. This did not go quite as far as we hoped, and it also went crooked, to the left the first time, and then off to the right the second time. We added sand to the front of our rocket on the opposite side of the water, to increase the mass of that side. The front needs to be heavier so that the center of mass is forward. This allows the rocket to have a more forward acceleration and prevent it from crashing.  We added at first 30.65 grams of sand, which was not heavy enough, so we then added 63.07 grams. This still was not enough, so we added about 40 more grams for next trial. We needed to decrease our amount of water by a couple hundred milliliters, because we needed less weight. Too much water slows down the acceleration of the rocket, because it adds more mass to the rocket, because acceleration is inversely proportional to mass. We also added cardboard onto our fins that were previously plastic and made out of a folder. We changed this material because when the wings are stiffer, there will be less air resistance. With cardboard as the material, the fins will be able to help further stabilize the flight of the rocket instead of slow the rocket down.

The next two trials were much more successful. Our rocket traveled 60 meters. However, we still wanted to make our rocket go farther. The rocket currently holds 126.84 grams of sand in the nose cone, which is more than four times as much mass than we started with. We also moved the wings farther to the back of the rocket. This will help the rocket have better flight. We decided that 800 ml of water would be best to use for our rocket. We tested with 1000 ml and with 600 ml to make sure that this amount would work best. If there was more time to work on the rocket, we would have made a sturdier nose cone. Since the nose cone is in the front of the rocket, it is important to try and keep it from being dented.

On our final launch air resistance might have negatively affected our rocket. Our wings were not very tightly taped onto our rocket and most likely slowed in down in the air. Our rocket did not go as far as we hoped, but it still went 53.8 meters.

**Conclusion**

The following conclusions are supported by the results of this study. A bottle rocket built in the style of a pressure chamber and a nose cone will travel farthest with a launch angle of 45 degrees. The rocket will have the best aerodynamics when the fins are towards the back of the bottle rocket. The amount of water used in the launch is crucial to the initial acceleration of the rocket: 800 ml works best for our rocket because it does not add too much mass to the rocket, but it helps extend the time of force of the rocket to give a big enough change in momentum. Another essential part of the flight of the rocket is the amount of added mass in the nose cone of the rocket. About 125 grams of added mass works best for our rocket to help shift its center of mass towards the front of the rocket, and thus move it further. The properties used for this specific rocket design allowed the rocket to travel 53.8 meters.

**Appendices**

**Materials**:

* Two 2- liter bottles
* Masking tape
* Pocket folder (plastic)
* Cardboard
* Sand

**Methods**:

1. Wrap three strands of masking tape around the bottle. Make sure there is equal distance between each band of tape.
2. Mark 4 spots evenly throughout the bottle for the wings to be placed
3. Sketch a triangle on a scrap piece of paper that has 15 cm that attaches to the rocket, 17 centimeters on one side, and 15 centimeters closest to the bottom of the rocket.
4. Trace this design onto the pocket folder where the pocket is. Cut out four of these triangles for the fins of the rocket.
5. Repeat step 4 with card board material.
6. Use the masking tape, to tape each plastic wing (triangles) on each of the four marks on the bottle.
7. Tape the cardboard wings to the plastic wings.
8. Use the masking tape to go over the fins, to make them sturdier. (Tape around the triangle once)
9. Using a second 2-liter bottle, cut the top off (from the spout to about 21 centimeters down) and attach it with masking tape to the bottom of the first bottle. This second half-bottle will be used as the nose cone.
10. Fill the nose cone with 126.84 grams of sand.
11. Weigh the bottle rocket.
12. Add 800 ml of water to the main bottle.
13. Attach the bottle to launcher and launch your rocket!

**Cost:**

|  |  |
| --- | --- |
| **Object** | **Cost** |
| Bottles (2) | $0 |
| Folders (2) | $4 |
| Tape | $0 |
| Cardboard | $0 |

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