# Methods

The construction of the bottle rocket began with the development of the nose cone and fins. The nose cone was constructed with a crumpled sheet of paper covered with 137 g of clay. The fins were made into a general shape through the use of cardboard. After their design, each object’s mass was measured using a balance. Then, after attaching the nose cone and fins to the 2L Diet Coke bottle, the parametric design process began. The first design variable to be manipulated and optimized was the water volume. Through research, it was determined that the optimal amount of water should be between ⅓ to ¼ of the 2L bottle. A water amount little lower than the optimal range (400 mL) was chosen and first tested at 33 psi (which was kept constant). After making a successful attempt (distance, which was measured using an expanded self-retract ruler, determined a successful attempt), water amounts around 400 mL were explored (200 mL and 600 mL).

By creating a quadratic taylor series approximation of the relationship between water volume and distance as quadratic, the maximum theoretical distance traveled. can be calculated using only three data points. To do so, we first found the quadratic function describing the relationship. This equation took the form y=ax2+bx+c. By plugging in water volume for x and distance for y we were able to solve for the a, b, and c coefficients using *Equation 1*. Once we had the quadratic, we found the optimal volume using *Equation 2*. Through this process, we determined that the parametrically optimal water volume was 470mL.

*Equation 1:  Equation for coefficients of a quadratic function given three points*

https://lh4.googleusercontent.com/2OGZhzcjspFBq_WzHesHEXKCd8zw08aGhGVtM1DsAKusHeA8fZX7oPGf0FlCcBjsdxUTjxynkfn3_CExPApZc-laVxHKxU5BHqnA5PtbNHYXUfd98RZvp0-WcRHHC3wZsS4qTHGWeWrwfkfeckvsaZmc5qkC11QuulxRG_dF22kllwy6VVf6K3jG

*Equation 2: x-value of the vertex of a quadratic function*

Next, the fin design was manipulated and optimized. Different fin shapes were researched, leading to wide wings being tested first at 30 psi and 470 mL (this pressure and water volume were kept constant for the rest of the lab). Since the distance achieved was less than that of the primary fins, the fin design was manipulated again, resulting in a slimmer, longer fin shape (with cardboard reinforcements behind the fins for stability). The result was a distance similar to what was achieved with the wide wings, so the most optimal fin design was determined to be the original design.

Finally, nosecone design was manipulated and optimized. The first design that was tested was made of 124.7 g of clay and cardboard, and it yielded a distance of 160 ft. Since this was a lesser distance than that achieved with 137 g, the mass of clay was increased to 141 g and 165.3 g, both of which yielded distances less than that achieved with 137 g. It was determined that 137 g of clay with paper was the nosecone design.

Overall, the best bottle rocket determined from our experiment has 470 ml of water, a fin shape similar to our original, and a nosecone made of 137 g and cardboard.

# Mathematical Models

**W=PiViln(VfVi)=206,842.73 Pa(1.3L)ln(2L1.3L)=115,836J**

**m=PwVw2+mrocket+mclay=12(700g)+213.3g=563.3g**

**V=2(Wm-gh)=2(115,836563.3-(9.8)(0)=20.28m/s**

**d=20.282sin(90)9.8=41.97m**