Montemorelos University

Engineering and Technology Faculty

Differential Calculus

Water Rocket Challenge

ALEX L. MONTIEL P.

Content:

Abstract:

Water rockets, as their name implies is a rocket that obtains its push by the pressure from the bottle´s pumped air and the water that works as the fuel (for the purpose of this event we used PET bottles). In order to control it we used a ramp (that could change its angle for direction) and differential calculus to have the needed amount to propel the rocket. We had a competition against many of our peers which decides the winner depending in the amount of points they obtained when the rocket falls in certain spots.

Introduction:

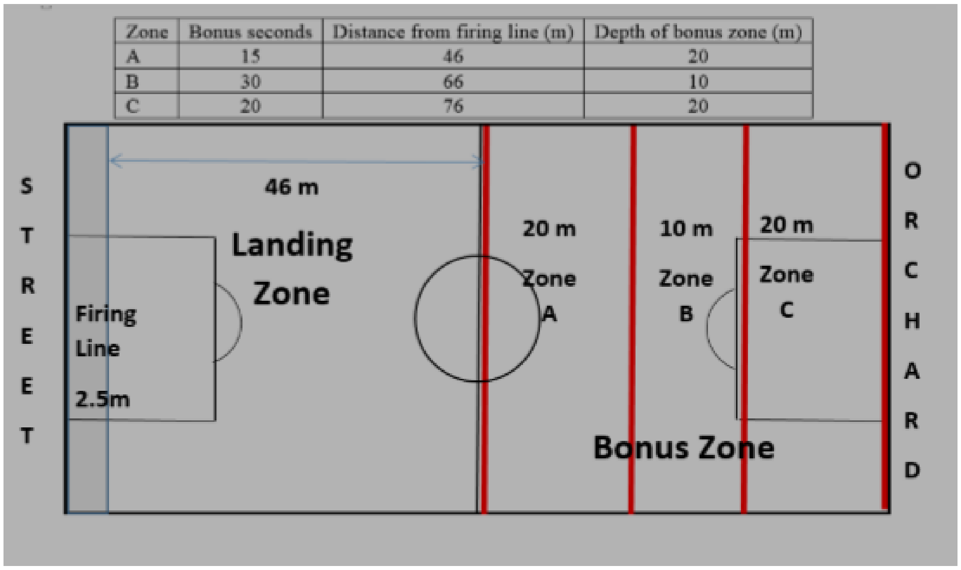
Whilst still at school and with a young inventive mind, Jean LeBot experimented with a champagne bottle filled partially with water and powered by compressed air from a bicycle pump fed through a cork with an inner tube valve at its center.

The rocket was launch from an inclined plank forming a ramp.

The glass champagne bottle rockets would invariably smashed on landing.

This is the first documented use of a water rocket and it´s based on a conversation with Jean LeBot and good friend a fellow pulse jet boat enthusiast in 1997.Jean LeBot was later to become Professor of Physics at Rennes University. This application of mechanics gave way to the creation of the Water Rocket Challenge and its being implemented in many colleges, considered a very famous event developed by the National Physical Laboratory.

The rocket has to fall at least at the 46m mark for us to get a good score, if we go further we get extra points on our assignment which is nice. Also the longer the rocket is in the air the better and we have 3 shots, those are the factors that decided the event winner.



Zone	Bonus seconds	Distance from firing line (m)	Depth of bonus zone (m)
A	15	46	20
B	30	66	10
C	20	76	20

The main purpose of participating in this event is to blend the theory with practice, to be able to see the results of our calculations.

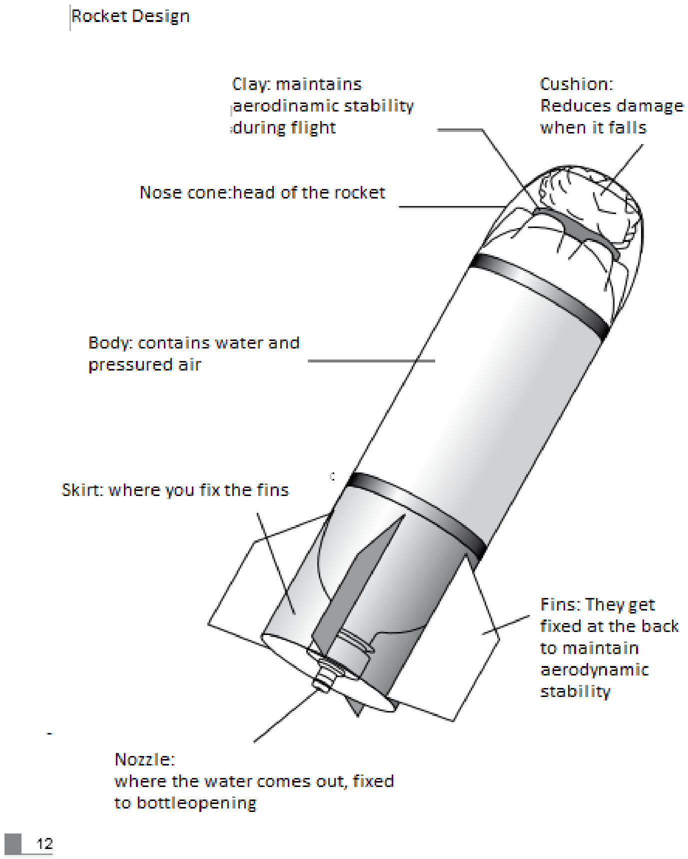
Methodology:

We used this basic concepts for our calculations:

- Estructural mechanics: in the fabrication of our rocket
- Propulsion and combustión: calculating pressure.
- Aerodinamics: evaluating rocket flight

Rocket Materials: 2 PET Bottles, Trash bag, Molding clay, Nozzle, PVC sheet, Plastic folder

Launcher Materials: Potractor, Wood boards, Water hose, Screw



ocket Work function:

$$W = \frac{PV}{1-r}\left[(1-f)^{r} - (1-f)\right] \qquad 0<f<1$$

$P = 405300$

$$W = \frac{PV}{1-r}\left[r(1-f)^{r-1} \cdot (-1) - (-1)\right] \qquad V_1 = 0.002603$$

$V_2 = 0.00267$

$$W = \frac{PV}{1-r}\left[-r(1-f)^{r-1} + 1\right]$$

$$f = 1 - r^{\frac{1}{1-r}}$$

$$W = \frac{PV}{1-r}\left[1 - r(1-f)^{r-1}\right] \qquad r = 1.4$$

$$W_1' = \frac{(405300)(0.002603)}{1-1.4}\left[1 - 1.4(1-f)^{1.4-1}\right] \qquad f_1 = 0.56879884$$

$$W_2' = \frac{(405300)(0.00267)}{1-1.4}\left[1 - 1.4(1-f)^{1.4-1}\right] \qquad f_2 = 0.568799$$

$$= \frac{405300\ 0.002603}{-0.4}\left[(1-0.568799)^{1.4} - (1-0.568799)\right] = 333.303$$

$$= \frac{405300\ 0.00267}{-0.4}\left[(1-0.56879884)^{1.4} - (1-0.56879884)\right] = 324.9396048$$

$$= \frac{\rho V}{1-r}\left[0-(r)(r-1)(1-f)^{r-2}\cdot -1\right]$$

$$'' = \frac{\rho V}{1-r}\left[r(r-1)(1-f)^{r-2}\right]$$ MÁX = 57% approx.

Work per unit of mass ρ = Water density → 1000^{K}

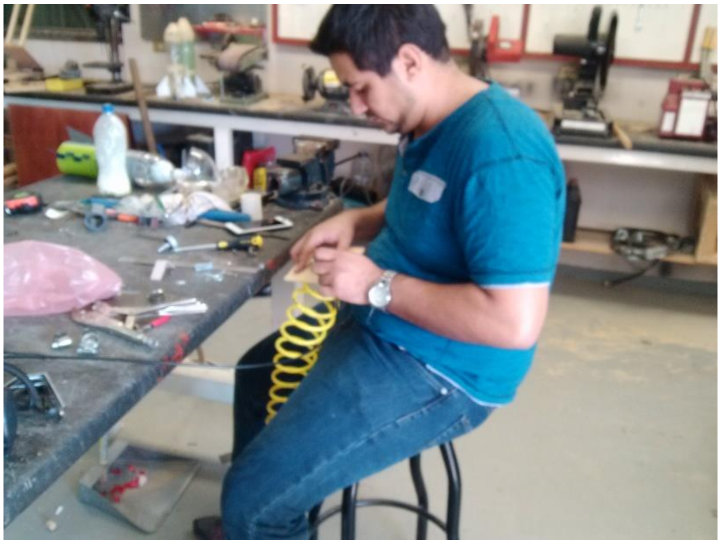
$$w(f) = \frac{\frac{\rho V}{1-r}\left[(1-f)^{r}-(1-f)\right]}{(m_0+\rho f V)}$$ m_0 = mass of the bottle

$$= \frac{\left[(m_0+\rho f v)\cdot\frac{\rho V}{1-r}\left[1-r(1-f)^{r-1}\right]\right]-\left[\left(\frac{\rho V}{1-r}\left[(1-f)^{r}-(1-f)\right]\right)\cdot\rho V\right]}{(m_0+\rho f v)^2}$$

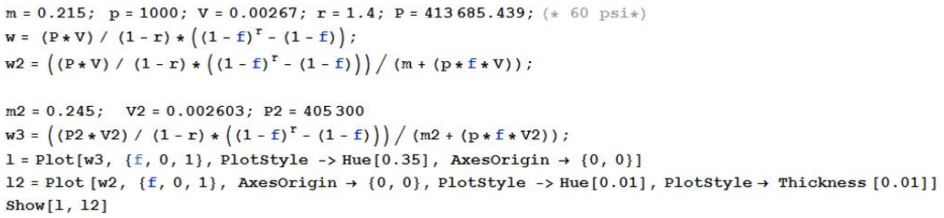
$$\frac{\rho V}{1-r}\left[\frac{(m_0+\rho f v)\left[1-r(1-f)^{r-1}\right]+\rho V\left[(1-f)-(1-f)^{r}\right]}{(m_0+\rho f v)^2}\right]$$

$mo+\rho f v=0$ $f=\frac{-m_0}{\rho V}$

Making of the rocket:



Results:



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m = 0.215;  p = 1000; V = 0.00267; r = 1.4; P = 413 685.439; (* 60 psi*)
w =  (P*V) / (1 - r) * ((1 - f)^r - (1 - f));
w2 = ((P*V) / (1 - r) * ((1 - f)^r - (1 - f))) / (m + (p*f*V));

m2 = 0.245;   V2 = 0.002603; P2 = 405 300
w3 = ((P2*V2) / (1 - r) * ((1 - f)^r - (1 - f))) / (m2 + (p*f*V2));
l = Plot[w3, {f, 0, 1}, PlotStyle -> Hue[0.35], AxesOrigin → {0, 0}]
l2 = Plot [w2, {f, 0, 1}, AxesOrigin → {0, 0}, PlotStyle -> Hue[0.01], PlotStyle → Thickness [0.01]]
Show[l, l2]
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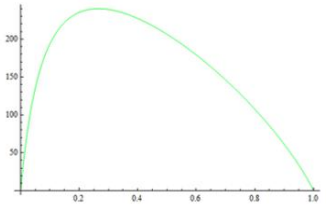

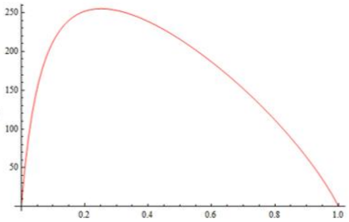

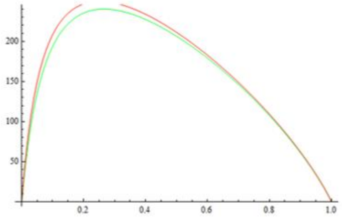

Software Used: Mathemática 8

In a similar manner we calculated to obtain these values:

Volume (L)	Volume (m^2)	Mass (kg)	Pressure(PSI)	Filling fraction	Work done
2.67	0.00267	0.215	50	0.251754	203.8194377
			60		255.0927667
2.603	0.002603	0.245	50	0.26593	204.3876347
			60		245.2657787

Conclusions (restate the thesis and summarize your main findings or evidences.):

In order to have a successful launch, a right amount of water and pressured air (depending on bottle mass and volume) is needed. Also a little bit of applied trigonometry will help you find the right angle for the shot, and some trial and error in testing since the rockets could break from the tip and ruin them.

References:

1. University of Montemorelos, Engineering and Technology Faculty. (2016). 2016-Rules FIT-UM WaterRocketChallenge [Digital document]. File:PDF

2. UM, FITEC. (2016). Flying table and scores [Digital document]. File:PDF.

3. UM, FITEC. (2016). Registration Form -Teams [Digital document]. File:PDF

4. UM, FITEC. (2016). Score Table for prizes [Digital document]. File:PDF

5. UM, FITEC. (2016). WaterRocket-Project-NPL [Digital document]. File:PDF

Appendix: