Physics Major Practical

Aim:

- Identify Conceptual ideas in physics, and enhance these skills by building a Water Propelled rocket.
- Master Newton's law of conservation of momentum, and hence analyze this rocket using the principles given.
- Identify correct variables, which have a significant impact on the rockets performance.

We aim to construct this rocket from a discarded PET (Polthylene Teraphetlate) drink bottle.

Background Information:

The bottles are one of those rare miracles of serendipity: although designed for something else altogether, they are nearly perfect for making water rockets. They're designed to hold liquids at high pressures, they're very lightweight, and they have a conveniently located ring molded around the neck that's handy for holding the bottle down while pressurizing it. About the only thing that could make them better is to have the fins and nose cone molded in for you.
The rockets made from these bottles are surprisingly powerful. A standard 2-liter pop bottle 1/3 full of water, pumped to 80 psi and then released, will eject all its water in less than one-tenth of a second, and at that point ("burnout") will be only about 2 meters off the ground. Amazingly, its velocity at burnout is around 76 meters per second. That's over 170 miles per hour! This means the average acceleration during thrust is 111 g's! Yowza. **Safety rule number 1: Never get in the way of one of these rockets...**

3rd law of Newton affects the lift off the rocket as the law states that, "for every reaction there is an equal and <u>opposite</u> reaction." (Quote from sir Isaac Newton)
The bottle will be turned upwards when the pressure in the bottle is released, then the air will push out the water and hence
If the bottle is inverted when pressure is released, the air pushes the water out, and in line with Newton's 3rd law (For every action there is an equal and opposite re-action) the bottle is propelled upwards.

Hypothesis/ Prediction

Part A- General Prediction

There are many variables that may be acquired within this practical, but by far the most critical variable is the amount of water we use before we launch the rocket. We are making numerous assumptions throughout the practical:

(a) We assume that the pressure inside the bottle before each launch always remains constant. (The error factor in this is +- 4 kpA). We decide to keep pressure as a constant because we do not have the sufficient resources to record and vary the pressure, as pressure is proportional to the amount of water in the bottle. This would make the practical much too complex. (i.e. the higher the pressure the bottle is released in the farther it will go, but the amount of pressure depends on the water level. To find the escape amount of pressure we would need to find the rate at which the water was escaping the bottle from to analyze the pressure properly). We also take into fact that the bottle cap was screwed on the same amount each time, so that the pressure remains constant.

(b) We also take into account that air resistance is negligible; we are not resourceful enough to record the wind speed.

Part B – Proving Projectile range theoretically.

We wish to prove that at the angle 45 degree's we will get the furthest range with a projectile:
We take 2 identical initial velocities and identical time of flights and compare our results:

u = 20m/s

We test for 3 different angles and compare our results. We wish to test the angle 45, 60 and 30.

For 30 degrees

$u_y = 20\sin 30$

$= 10\ m/s$

$x_y = ut + \frac{1}{2}gt^2$

$t = 0 \quad or \quad t = 2.04$

$\therefore x = ut$

$x = (20\cos 30) \times 2.04$

$x = 35.34\ m$

For 45 degrees

$u_y = 20\sin 45$

$= 14.14\ m/s$

$x_y = ut + \frac{1}{2}gt^2$

$t = 0 \quad or \quad t = 2.88$

$\therefore x = ut$

$x = (20\cos 45) \times 2.88$

$x = 40.81\ m$

For 60 degrees

$u_y = 20\sin 60$

$= 17.32\ m/s$

$x_y = ut + \frac{1}{2}gt^2$

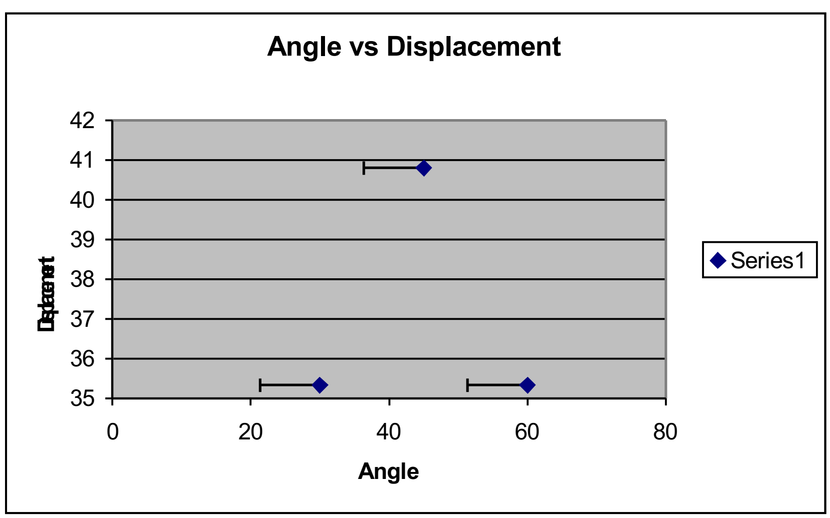
$t = 0 \quad or \quad t = 3.53$

$\therefore x = ut$

$x = (20\cos 60) \times 3.53$

$x = 35.34\ m$

As it can be see that we get maximum range only from the 45-degree angle. We have proven this by using the same initial velocity for all the angles. Here is a graph, which illustrates our results.



Selection of variable's

The Key variable's the key variables in this assignment are related to the rocket it's self and the environment the practical was performed in. We will be investigating the variable of the amount of water we filled the rocket with, and hence compete our results with different combinations of the amount of water used and the range obtained. Please note to investigate water as the key variable we must keep all other variable's constant such as (a) pressure (b) Weight of the water as 1g/mL (this can vary slightly sometimes) (c) Wind speed (d) Tightness of the cork (factor of pressure) (e) People employed to take readings and perform practical (i.e. use the same person to pump, use the same person to put the cork on) etc. Wind direction and speed has a major influence on the range of the rocket, but variables such as these are incontrollable. If these variables were kept constant we should be able to find the relationship between water and the range of the rocket.

Materials:

- PET bottle
- Valve stem –(found on bicycle tires)
- Pump with pressure gauge
- Straws
- Stop Watch
- Launcher (bricks in this case)

To make the water rocket follow the steps:

(a) Find a PET bottle, empty it of it's contents
(b) Next you must find a rubber cork (this is important because rubber corks are most effective to hold in the pressure) of diameter of about 3 cm's.
(c) Drill a hole in the Cork and fit the valve stem in such that the area where the air will be released is in the bottle.
(d) Now get two straws and attach straws on the rocket with duct tape.
(e) Tape the Styrofoam ball to the end of the rocket.

Your final product should look like this:

After you have made your rocket, the rocket should be set on your launcher as shown below:

Control of Variable's

1) In the above diagram we have illustrated what the setup should look like. The bricks should always be titled at a 45-degree angle; we kept a person to make sure there were no errors in this.
2) After each launch we made sure that the rocket was not damaged or this could affect the range of the rocket and hence damage our results.
3) We kept the same people to do each task so there isn't any variation or error's being introduced by different people handling the same task. None of the equipment was changed throughout the practical to keep a consistency.

Method of Collection for Data:

The method for collecting data includes several steps and these steps are described below:

1) After the equipment has been set properly. Fill the bottle with exactly 200 mL of water. Then set it on the launcher as shown in the diagram above.
2) Next you may start pumping. Please make sure the bottle is tilted at precisely a 45-degree angle. Now use 1 person in your group to record the pressure at which the bottle took off, and also have a person timing the time of flight of the bottle. Record the distance the rocket traveled – this is the horizontal range of the rocket.
3) The pressure you obtain from this first trial must be kept constant no matter what, so in some cases you may have to screw the lid slightly easily not tightly.

4) Perform the trial 3 times with 200mL and hence another 3 times each with water levels of 400mL and 600mL

The results I obtained are shown in the table below

200 ml:

Trial no:	Initial air pressure in the bottle(kPa)	Mass of the system (g)	Weight of the system (N)	Time (s)	Maximum Horizontal displacement (m)
1	44	200	2000	3.23	22.8
2	45	200	2000	3.33	26.7
3	46	200	2000	3.01	21.3
Average	**45.67**	**200**	**2000**	**3.16**	**23.6**

400ml:

Trial no:	Initial air pressure in the bottle(kPa)	Mass of the system (g)	Weight of the system (N)	Time (s)	Maximum Horizontal displacement (m)
1	46	400	4000	2.11	23
2	46	400	4000	2.14	20.4
3	44	400	4000	2.99	21.5
Average	**45.67**	**400**	**4000**	**2.87**	**21.6**

600ml:

Trial no:	Air pressure in the bottle(kPa)	Mass of the system (g)	Weight of the system (N)	Time (s)	Maximum Horizontal displacement (m)
1	45	600	6000	1.55	8.91
2	41	600	6000	1.7	13.7
3	43	600	6000	1.88	8.16
Average	**45.67**	**600**	**6000**	**1.81**	**10.9**

Launched at 90 degrees

average =2.5 seconds

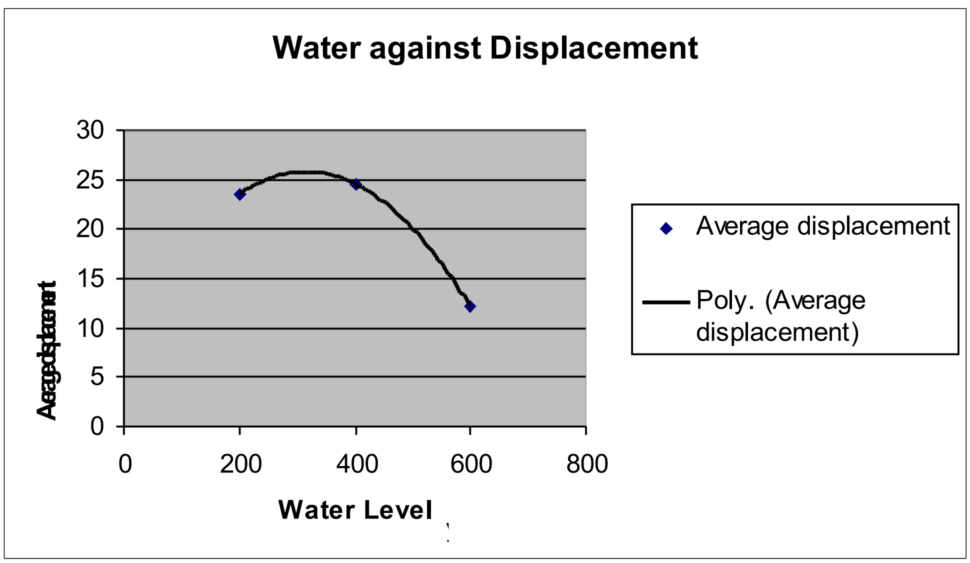
Vertical Displacement (m)	Time (s)
0m	3.2
0m	2.44
0m	1.86

Observations:

The practical went pretty well except for a few hiccups. The day we conducted this practical the weather forecast was terrible, there was strong easterly wind, which affected our displacement slightly. Table 1,2 and 3 show the results taken after it was tested on the different levels of water. Table 4 tells us the vertical displacement and the time taken for our rocket to get to the ground (i.e. tells the maximum height reached at a 90 degree angle) we need table 4 to work out the theoretical range of the rocket.

Presentation of Data

Well as water was our key variable. We can see from our results as the amount of water increases the displacement decreases. (This hints that the water level may actually be proportional to the pressure and the pressure is the component, which determines the displacement[1]) I have plotted an average displacement against water level graph with scattered points to illustrate the relationship. I have used Microsoft excel to create this graph.



The graph tells me that as the water level increases the displacement seem to have decreased. It seems to me that The Displacement (d) seems to be a function of the water (W). Or d = -0.0002W^2 + 0.1063W + 9.1User friendly: d =0.1W +9
(This is not related to physics but is the relation ship we got when we performed our experiment)

Data Analysis:

So we have agreed that the higher the water level the more of a decrease we shall get in the horizontal displacement (i.e. range).

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[1] IE the higher the pressure the farther the rocket will go

Now there is a difference between the theoretical values of the range we should have acquired compared to the experimental value we have. Many factors differentiate both these values slightly. So assuming everything is a constant variable and if we can take the bottle as a particle, we may attempt now to prove this relationship between the experimental range and theoretical range using projectile motion concepts.

Method 1

We shall just analyze our average result obtained from the 200mL data. If this turns out to be true we assume the rest to be true if they obey the projectile motion laws. To do this firstly we bring in table four where we got have experimental data of the rocket being projected at a 90 degree angle. We can find the theoretical value if and only if all other variables are kept at constant and we assume the rocket as a particle being projected.

Please note. u = initial velocity. x = displacement t = time V=final velocity

$u = ? \quad t = 2.5 \quad x = 0 \quad a = -9.8$

Vertical analysis

$$0 = u(2.7) - \frac{1}{2} \times 9.8 \times 2.7^2$$

$$u = 12.25\ m/s$$

[using the kinetic equation –ut+0.5gt^2=x]

$\text{When the rocket is projected at } 45^\circ$

$u = 12.25 \quad u_y = u \sin 45 \quad u_x = u \cos 45 \quad x = ?? \quad t = ??$

$\therefore 0 = (12.25 \sin 45)t - 0.5gt^2$

$t = 0 \quad or \quad t = 1.84$

$if \quad t = 1.84$

$u = 12.25 \cos 45$

$x = ut$

$x = 12.25(1.84)$

$x = 15.93\ m$

What we can see here is the difference between the theoretical range (22.5 m) and the range we got (23.6) is about 23.6-15.93 = 7.66 m← we were only 7 meters of the theoretical range.

We get a percentage error of about |23.6-15.93/15.93| multiplied by 100

=48 %

Method 2.
From method 1 we use the time and hence find the theoretical range. We assumed many things to be constant. There is also another way of doing it.

We apply the formula to find the initial velocity:

$$\frac{mass \times \pi \times volume^2}{Weight \times Volume \times time \ of \ flight} = initial \ velocity$$

I will not prove this formula to be true here but show it to be true by substituting given experimental values:

Using our farthest average values from 200 mL:

Volume: 200mL
Time of flight: 1.84seconds
Mass of system: 200 g
Weight of the system: 2000 N
Displacement: 23.6 m

$$\frac{200 \times \pi \times 200^2}{2000 \times 200 \times 3.09} = 20.33 \ m/s$$

$$20.33 \cos 45 = 14.37 \ m/s$$

$$using \ the \ time \ we \ obtained \ from \ method \ 1:$$

$$x = ut$$

$$\therefore x = (14.37)(1.84)$$

$$x = 25.92 \ m$$

So hence we do find a difference between the two methods. We cannot assume either one to better because they both have strengths and weaknesses in different areas. Overall the first method would be more preferable because it is more an applicable method. Less algebra is also required. The second method is more of a pure mathematical method where small factors can change the equation around. The second method does involve more calculus than physics concepts but then again is much more accurate.

Evaluation:

So hence after using water as our variable we establish that by increasing the water level the horizontal range decreases. We also found from our experimental data that with 200 mL of water we got our furthest range. Over all the experiment has been a success and we have compared our theoretical value of our range to the experimental value and found an acceptable error, which proves that our constant variables were controlled better than expected. (the error was small on the account of that there were variables which we could not control i.e. the wind speed- which was relatively strong that day)

The causes of the error's we did obtain were probably from the wind speed or even human error. (We couldn't exactly get the person screwing on the cork to do it exactly* the same each time). The design of the rocket also turned out to be a success; it proved to show that we could get a more aerodynamic rocket by adding extra features such as the nozzle and straw's.

If we were to do the experiment again the only thing we would try and improve were probably the weather conditions (i.e. do it on a calm day with virtually no wind). Other than that everything else went to plan, and we not only learnt and mastered a lot of physics concepts related to Newton's third law of motion we managed to actually have fun while doing an assignment.

We not only learnt that you get maximum range with a 45 degree angle (proven theoretically) but our assumptions made in the beginning could of made results fairly inaccurate, but as it can be seen when we were comparing our experimental data to the theoretical data our error percentage was actually quite low.