MaD Science – Bottle Rockets

How can we make our bottle rockets go the furthest, fastest and highest?

#CreatingScienceBottleRockets

DANGERS!

This section cannot explain every possible danger in this activity. Adult care and surveillance is required at all times. Please exercise all appropriate caution at all times.

The rockets fly away with considerable force. If left unchecked, they will;

- Smash through glass windows
- Break small, fragile bones
- Injure eyes
- Take out birds and their nests
- Land in the neighbour's yard, bopping unsuspecting neighbours on head, an potentially dinting their car
- And anything else a moderately fast projectile can be expected to do.

Please exercise all responsible adult levels of caution and care at all times.

Suggested Outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Physical sciences 4: Forces can be exerted by one object on another through direct contact or from a distance (ACSSU076)
- Physical sciences 7: Change to an object's motion is caused by unbalanced forces, including Earth's gravitational attraction, acting on the object (ACSSU117)
- Also Physical sciences 8: Energy appears in different forms, including movement (kinetic energy), heat and potential energy, and energy transformations and transfers cause change within systems (ACSSU155)

Science inquiry skills

This is a scientific inquiry investigation, thus, we use skills at this level, for instance,

- Questioning and predicting 4: With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge (ACSIS064)

But also including: Planning and conducting, Processing and analysing data and information, Processing and analysing data and information, and Evaluating

Science as a human endeavour

- Nature and development of science 4: Science involves making predictions and describing patterns and relationships (ACSHE061)

Science vocabulary words

Tier 1 (Everyday words) Rocket, bottle, gravity.

Tier 2 (Dual meaning)

- Force. In general, force is synonymous with 'push', but in science it has a more specific definition given by Isaac Newton; in that it is an objects mass multiplied by its change in speed or direction. Each force comes in pairs, equal in size but pushing in opposite directions (usually onto two very different objects).

Tier 3 (Specialised vocabulary)

- Bung – the little stopper on the end of the pump that goes into the bottle. They were often made out of cork or rubber, and took those names. We will use 'bung' because it's fun, and a verisimilitude of its onomatopoeia when it is shot out the end of a bottle rocket and it slams into the far wall.
- Pressure. A special kind of push, one that operates in all directions at the same time.
- Mass. How much 'stuff' something is made out of. A planet has much mass, you, in comparison, do not. A black hole has infinite mass, a feather has little.

Preparation

We'll be outdoors today, so remember hats and sunscreen, and if it rains coats and towels!

Make sure you bring along your sextant from last week so we can measure height.

Learning Intent (student friendly)

'We are learning to' (WALT) explore the variables that effect bottle rocket height.

Success criteria

'What I'm looking for' (WILF) accurate measurements and averaged results, in order to scientifically justify why certain methods work to make the bottle go further.

Student learning goals

Help students make a self-monitored learning goal for this lesson.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations? See section on summative assessment.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students questions can and should guide student learning, more material is presented for you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is challenging for this age group, and they will need lots of help. Children at this age can have difficulty with focus. Avoid tangents into interesting side tracts if you're attempting to make a key point. They can operate the rocket safely with assistance.

Middle:

This activity is very well suited to this age group. Please manage appropriately.

Teen:

Watch for dangerous levels of experimentation in this age group. Students can be further challenged by building better launchers (available online), explaining the energy transformation during the flight, or using Isaac Newton's three laws of motion to interpret the rocket motion.

Engage

- ⇨ Note the Learning Intention of this lesson for students.
- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Set up the bottle rocket. Have students practice measuring the height of the bottle rocket.

Explore

- ⇨ Ask students – can you explain how the bottle rocket works?

What forces are in play that make the rocket move the way it does?

What would happen if there was no gravity, or no air pressure?

How would the rocket move if there was no inertia, and things only moved if a force is constantly pushing them? [After the water left the bottle, the bottle would stop right away and start to fall].

Explain

Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Here's the explanation we like to use:

1. What is in the bottle (water) and what else (air). Correct!
2. What is the air doing (bouncing around and pushing in all directions). So the air is pushing down on the water, but the bung is so tight in there that the water isn't going anywhere. Also, the air is pushing up on the top of the bottle, but the bottle is so strong the air doesn't rip straight through it. [The air is also pushing on the outside of the bottle, but since it's pushing in all directions we can ignore its effects for now].
3. Then we start to put more air into the bottle. It is pushing harder and harder. Can you see the bubbles of air going through the water? [use a drop of concentrated dish washing detergent so that you can see just how much extra air you put it. Does it come to about half, meaning it's about a full bottle of air in half a bottle?]
4. The air is pushing in all directions, but everything is resisting that pressure – until the bung pops out. Then what happens? The air pushes the water out, but the air is also pushing on the top of the bottle from the inside. Now that the air is pushing is pushing harder on the top of the bottle than on the water (since the water is flows out and getting out of the way) the bottle is pushed up from the inside.

⇨ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Elaborate

Better bottle rockets!

EXPERIMENT: Have students ask the question 'how can we make our bottle rocket go higher'?

Variables to consider include;

- How hard the bung is in.
- Amount of water – will less be better or not?
- Aerodynamics – will nose cones and fins help in any way?
- Launch pad – will specialised launch pads be safe and fun? Can the angle of launch make a difference if you want the rocket to go far, not high?
- Paint it red – will cool colours or decorations help flight?

HOWEVER – before we even begin experimenting, there are some things we need to consider: HOW will we go about making sure we create the best answers possible?

- Will one trial be enough, or should you average several trials?
- How will you make sure each trial is the same in every way, except the one way that you're trying to test? (control variables)
- How will you be accurate enough to be confident of your results?

Allow students to work on their own way and in their own time.

Real rockets

Real life rockets use a similar principal.

1. They make an enormous explosion underneath their rocket body.
2. This explosion pushes in all directions.
3. Then we make more explosions under the rocket – one long, continuous explosion.
4. Half the explosion is essentially wasted – it just goes down and away. But the other half slams into the bottom of the rocket and pushes it up.

So it's important to remember rockets don't go up by pushing against the air, they go up because there's an explosion right on their tail!

Equal and opposite

Another way to explain this is with Newton's third law – to every action there is an equal and opposite reaction. This helps to explain not only why bottle and real rockets fly, but also the balloon rockets from 'Creating Science: String Rockets'.

- ⇨ What does rule 3 mean? To put it simply; In order to go up, something else has to go down. In order to move right, something else has to move left. In order to get pulled down, something else is going to get pulled up.
- ⇨ [However, heavier things can move less and still exert the same 'pull'. This is from law number 2/ F=ma . This explains why when the earth pulls you down, you don't notice it coming back up at you – it's tooooooo heavvvvvvy!]

We like to say that rocket science is very hard, and let's face it, knowing that rockets ride at the edge of an enormous explosion, and that a rocket has to lift its own fuel in order to go up, IS one of the most complicated sciences of last century. However, at its heart, rocket science is pretty simple:

If you want something to go up,
Something else has to go down.

An in the case of most rockets, its burning, glowing, hot steaming water!

Why don't opposite forces cancel out?

Because they're acting on different objects.

As so eloquently explained (taken 1 march 2019) at https://www.centergrove.k12.in.us/cms/lib4/IN01000850/Centricity/domain/510/4th%20nine%20week%20files/third%20law.pdf

"The forces exerted by two objects on each other are often called an action-reaction force pair. Either force can be considered the action force or the reaction force. You might think that because action-reaction forces are equal and opposite that they cancel. However, action and reaction force pairs don't cancel because they act on different objects. Forces can cancel only if they act on the same object.

"For example, imagine you're driving a bumper car and are about to bump a friend in another car, as shown in Figure 14. When the two cars collide, your car pushes on the other car. By Newton's third law, that car pushes on your car with the same force, but in the opposite direction. This force causes you to slow down. One force of the action-reaction force pair is exerted on your friend's car, and the other force of the force pair is exerted on your car. …

"You constantly use action-reaction force pairs as you move about. When you jump, you push down on the ground. The ground then pushes up on you. It is this upward force that pushes you into the air."

Energy

What is the energy story happening in the bottle rocket? Can you spot where the entropy is happening?

1. Elastic potential energy is built up as the bottle is filled with particles of air.
2. This turns into kinetic energy as the air pushes the water out of the bottle, pushing the bottle upwards as well.
3. Moving upwards gives the bottle gravitational potential energy.
4. Gravitational potential energy turns into kinetic energy as the bottle moves towards the ground.
5. The bottle achieves a resting state, or equilibrium, as it rests on the ground.

Answers:

1. Elastic potential energy is built up as ...
2. This turns into kinetic energy as ...
3. Moving upwards gives the bottle ...
4. This turns into kinetic energy as the bottle ...
5. The bottle achieves a resting state, or equilibrium, as it rests on the ground.

Entropy

1. Noise, at any point is energy being lost
2. Having to push the air out of the way causes wind, which is the transfer of kinetic energy away from the rocket and into the air. (And that's why rockets can only reach their top speeds in outer space).
3. Compressing air actually causes it to heat up, and as that heat is conducted through the bottle and to your hand or the air, some energy is lost as heat. But that's also why the bottle will often form a cloud inside after launch.

Evaluate

- ⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

What can you learn from this activity?

- ⇨ What scientific practices work best in order to help YOU generate effective scientific knowledge?
    - o Multiple trials and averaging the results?
    - o Accurate measurements?
    - o Trial and error – just keep messing around with things until it works?
- ⇨ What will you do next time?
    - o Did you have enough materials, or did you need to find more?
    - o Were you instruments accurate enough for measuring, or were more needed?

Success criteria

- ⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- ⇨ Did you achieve your learning goal?
- ⇨ What did You learn?
- ⇨ What worked to help you achieve it?
- ⇨ What might you do better next time?
- ⇨ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Practice using sextants to judge an objects height.

From the activity in the appendix, have students try and guess the forces on a bottle rocket during flight.

Be sure to watch out for the following common alternative conceptions:

- Rockets go up by pushing against the air – a very common misconception once kids try to really think about how rockets fly. In order to push something away, it must also push against you, for example, throwing a heavy ball is much harder than a light one. This is how the air in the bottle feels – it 'throws' the water out and is shoved back against the top of the bottle with a lot of force!

Teacher torment: See if any of your students notice that a cloud will often form inside the bottle once it's launched (areas of extreme heat and low humidity can ignore this notice). DO NOT TELL THE STUDENTS – see if one of them can notice it first. If not. Point it out at the end and ask why. [Why does the cloud form? You'll have to read **#CreatingScienceClouds**!]

Formative:

As students are learning, help them self-monitor their own learning and achievements.

For some really great advice, try the activities and questions below taken 1 march 2019 from https://www.sciencelearn.org.nz/resources/406-water-bottle-rockets However, our rockets are designed to let themselves go once pressure is high enough. This specialised launcher can make the pressure go dangerously high! If your bottle begins to deform, it may explode with ear shattering force (in the rare and inexplicable situation where a vulnerable person has their head pressed against the bottle when it explodes.)

Discussion questions:

- What is pushing the rocket to make it go faster?
- What keeps the rocket moving once the water has all come out?
- How does aerodynamic drag affect the motion of the rocket?
- How does gravity affect the motion of the rocket?
- What effect do the nose cone and fins have?
- What effect does the angle of the launch have?
- What things might reduce the aerodynamic drag?
- What things might increase the thrust?

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Draw a poster of the forces acting on a bottle rocket during flight.
- Give a speech or Utube presentation on building and SAFE use of a bottle rocket.
- Prepare a research report on the variables you experiment on in your bottle rocket activity.

So what?

You don't need fancy tech to answer tough problems – just a simple tool and some maths!

You can solve fun tech problems, such as how to make a rocket go higher!

Creating science

Science understanding

As students explored bottle rockets and attempted to understand the forces involved, they had the chance to:

- Physical sciences 4: Forces can be exerted by one object on another through direct contact or from a distance (ACSSU076)
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Science inquiry skills

This is a scientific inquiry investigation, thus, we use skills at this level, for instance;

- Questioning and predicting 4: With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge (ACSIS064)

But we also had the chance to do some;

- Planning and conducting
- Processing and analysing data and information
- Processing and analysing data and information
- Evaluating

Science as a human endeavour

As we predicted the results of our investigations and experimented on them, we, too, saw that;

- Nature and development of science 4: Science involves making predictions and describing patterns and relationships (ACSHE061)

Appendix: A research report

Why not write a report of your own findings using the semi-official scientific format!

Aim: So people know what you're doing, i.e., To investigate which variables can make a bottle rocket fly the highest.

Hypothesis: What ARE you testing? That is, what is your prediction, and what is the underlying theory beneath your prediction. I.e., That a bottle with no air will go further ***because*** there's no water holding it down.

Materials: So other people can know what they'll need to try it too!

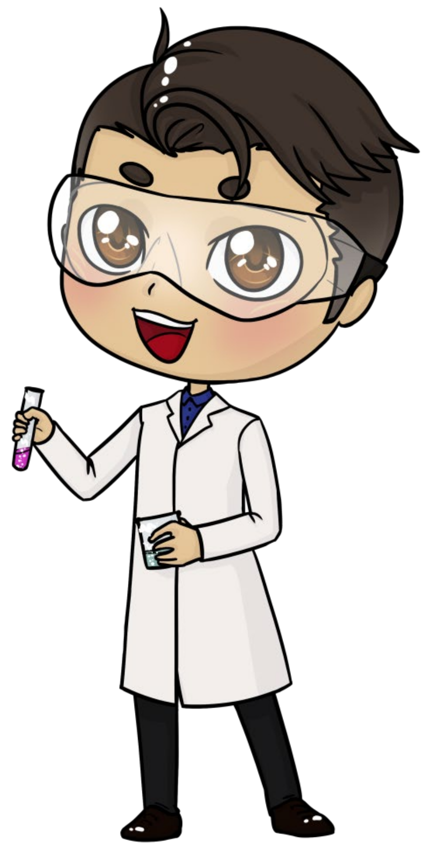
Method: As above. Be as detailed as you need so that other scientists can know how you got your results, and they can try it too if they want to.

Results: A careful recording of your results so people can check your conclusions. Just the results, don't think about what they mean just yet.

Discussion: What do **you think** your results mean? Also, be sure to include a paragraph on 'limitations' or 'what we think we could try next time.

Conclusion: Look back on your hypothesis. Was it answered? What does this say about your underlying theory, was it supported?

Now you give it a go!



Research report:

Scientists name: Date of research:

Aim:

Hypothesis:

Materials:

Method:

Results:

	Test 1	Test 2	Test 3	Average
Condition 1				
Condition 2				

Discussion:

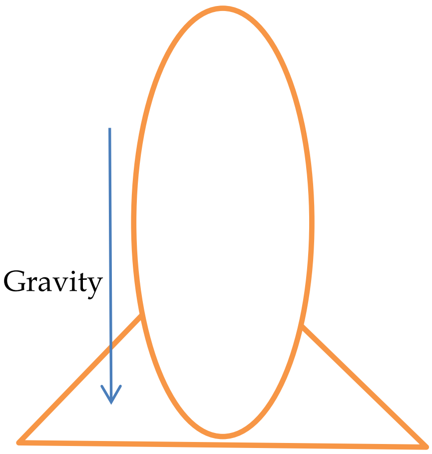
Conclusion:

Appendix: Summary of the forces acting on a rocket

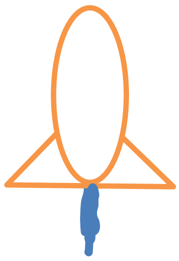
Note – a CHANGE in speed or direction happen ONLY when a force is acting on an object and there's no opposing force to stop it. Otherwise objects just keep doing what they were doing.

Can you ***DRAW the forces*** acting on the rocket at each stage? We're ignoring air pressure.

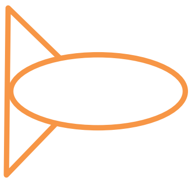
1. Rocket is on the launch pad. Gravity holds it down so that it doesn't float away.



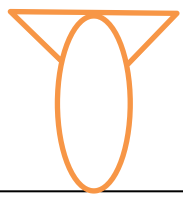
2. Rocket begins to fly



3. At the top of the rocket's flight, AKA the "Apogee"



4. Just as the rocket hits the ground.



Appendix: Summary of the forces – the answers

Note – a CHANGE in speed or direction happen ONLY when a force is acting on an object and there's no opposing force to stop it. Otherwise objects just keep doing what they were doing.

Can you ***DRAW the forces*** acting on the rocket at each stage? We're ignoring air pressure.

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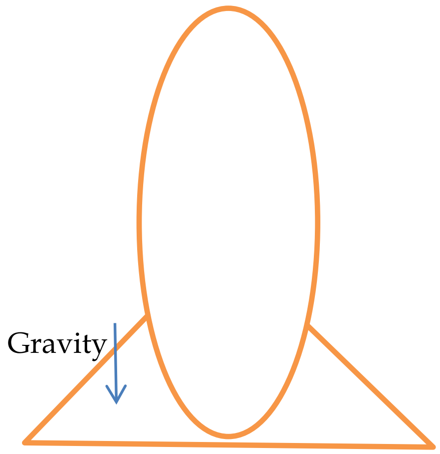
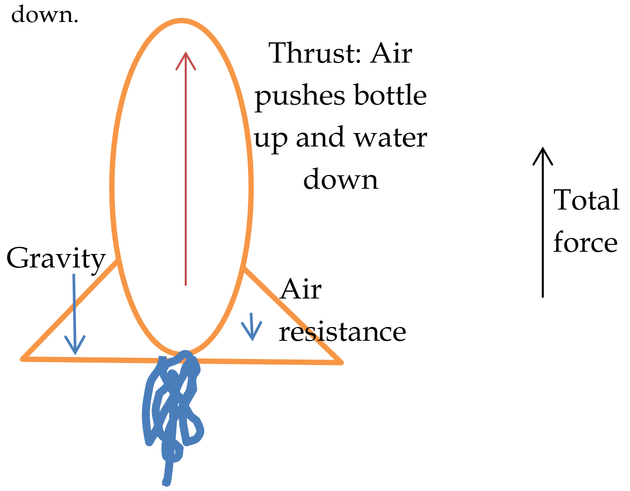
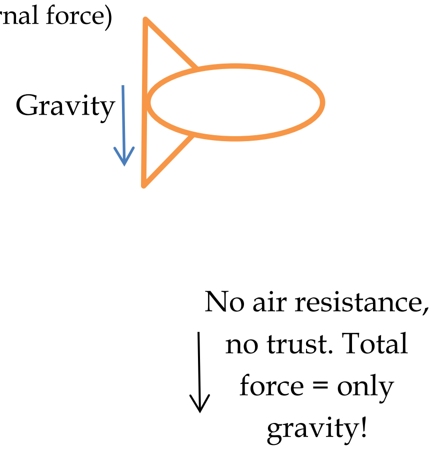


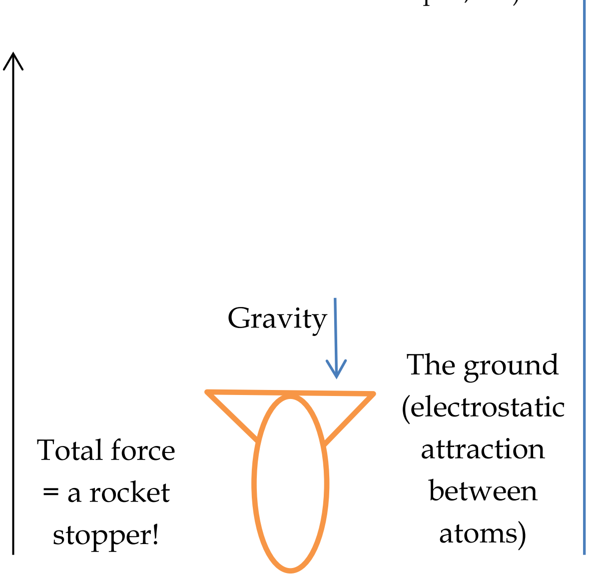
2. Rocket begins to fly. Air pushes bottle up and water down. Gravity is still pulling the rocket, slowing it down, otherwise the rocket would go much faster and just keep going up! The faster the rocket goes, the more air slows it down.



3. At the top of the rocket's flight, AKA the "Apogee", gravity has *slowed* the rocket down, but it's still pulling! Otherwise the rocket would stay floating up there (since an object at rest will remain at rest unless acted upon by an external force)



4. Just as the rocket hits the ground, gravity is still pulling it down, but the ground pushes back much harder than gravity and makes the rocket stop (the ground has the electrostatic forces between the atoms to hold it together, otherwise the rocket would plough straight on through the ground like a brick in water – since an object in motion remains in motion unless acted upon, etc!)



Tips from the Masters to make it work: