AIRBUS FOUNDATION

DISCOVERY SPACE

Teaching resources

For sessions with young learners using the experiment videos

How the videos work

Each video starts with a simple question related to aeronautics or aerospace, which sparks the team's desire to understand through experimentation i.e. to research the subject and then conduct experiments to check the information obtained.

What's important here is not so much the outcome of each experiment—which may or may not work!—but the reasoning used. How can I test and implement my ideas simply in order to prove or disprove a theory?

The theories presented in these videos can therefore:

- be tested directly by reproducing the experiments suggested
- be adapted by testing different objects or by modifying the experiments suggested
- be developed by further pursuing the line of questioning and testing new theories
- inspire other science questions of interest to the participants.

Reproducing the experiments at home

The experiments suggested in the videos are easy to reproduce at home, using the objects shown.

If this is your course of action, then we recommend letting your young learners do as much as possible by themselves, while providing a safe setting if any risk is involved (fire, hammer, oxygenated water, etc.).

Let the participants explain for themselves the aim and purpose of each experiment, what they learned and what the experiment taught them.

Note that there are lots of alternatives to the objects suggested for each experiment.

So one task could be to find a series of alternatives for each of the objects used. This would in turn help to clarify the experiment's purpose and procedure.

How to apply scientific reasoning with young learners, starting from a specific question

The adult's key role here is to support the young learners in their progress and reasoning so that all avenues may be explored.

1) Help your young learners to formulate their question clearly
The clearer and more precise the question, the clearer and simpler it will be to formulate theories and conduct research. So first get your young learners to explain what they already know about the question asked, before moving on to the experiment stage in order to test that knowledge.

2) Use any resources available on the internet or around you, in order to widen your research.
Where information is unclear, assist your young learners in their reading and research methods (changing website, cross referencing sources, etc.).
They can also call on other adults or, if a group of youngsters is working together, it would be good for them to pool their existing knowledge in order to reach a common starting point.

3) Formulate theories to answer the question
What are the possible causes? How can I check them myself? Help your young learners formulate their theories clearly.

4) Invent an experiment using everyday objects
It is vital at this stage to let your participants' imagination run free. All experiments and procedures are worth doing, provided they're not dangerous. Be sure to get them to agree on the purpose of the experiment:

- Why are you doing it?
- What result do you expect?
- If it doesn't work, what does that mean?

Even if a particular experiment seems unfeasible or too complicated, let them try it out and come to their own conclusion.
For your part, be sure to specify which objects may be used.

5) Let them try things out and experiment for themselves
It is important to let youngsters conduct their own experiments and reach their own conclusions, while helping them to clarify their thoughts.
If their reasoning seems wrong, you can tell them, but more importantly encourage them to check it themselves through research. If several youngsters are working together, you can also get them to compare their theories by asking if they all agree and if not, why.

6) Develop their reasoning and encourage them to ask new questions
An experiment is never an end in itself but rather part of, and a step towards, the development of more complex reasoning.
Encouraging youngsters to develop their reasoning and ask new questions enables them to open up to the world and to seek an ever better understanding of the phenomena around them.

Managing frustration

These kinds of experiments can cause frustration in young learners, because they don't give the desired result every time.

When this happens, you can encourage them to:

- try again: experiments don't always work and maybe you need to be more careful or take your time over it more;
- understand that a failed experiment is a result too and teaches you things, just like a successful experiment does. What have I learned from this experiment? What does it tell me?

NB: The majority of scientific research experiments either fail or don't produce the expected results, but researchers still keep on trying!

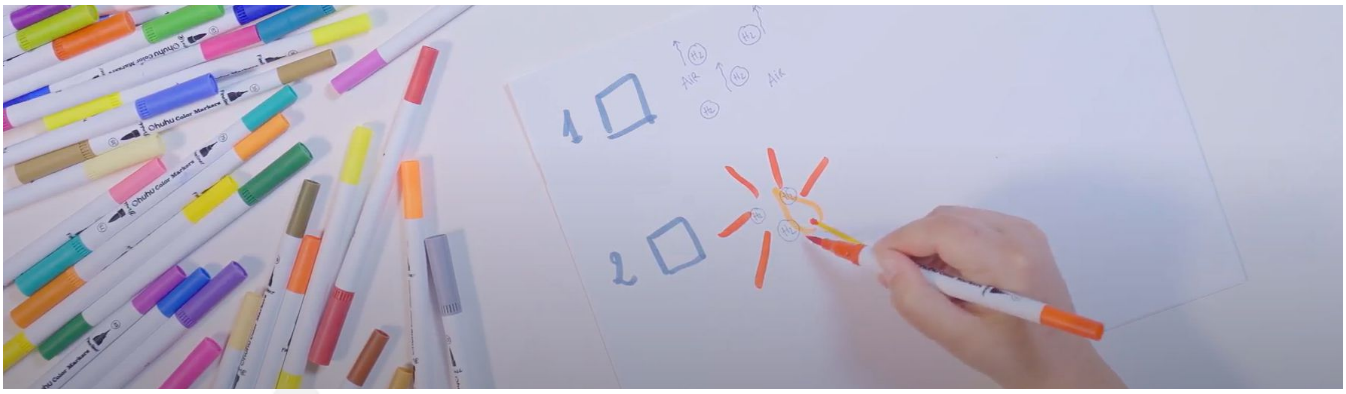
To end the session on a high note, help the participants find an experiment that will definitely work and that will get them over their frustration.

Have fun!

**These experiments and videos are mainly designed to help young people have fun while learning.
So above all, don't forget to have a laugh while experimenting!**

Contents

1. How do you produce hydrogen?



The science question in this video

In this video, Paul realises that hydrogen gas can be used to power vehicles and discovers how to produce this gas and what its characteristics are.

By putting a battery in water, Paul unwittingly creates a chemical reaction known as water electrolysis. The water (H20) molecules are split by the electric current as it passes through the water, resulting in the formation of two distinct gases at each end of the battery: dihydrogen (H2 or hydrogen gas, commonly known as hydrogen) at one end, and dioxygen (O2) at the other. Twice as much dihydrogen is produced as dioxygen, which explains why the hydrogen bubbles are so much easier to see and collect. This same principle is used on a massive scale in special power stations, to produce large quantities of dihydrogen.

The reverse process is used in hydrogen-powered vehicles. The reaction created by combining dihydrogen with dioxygen powers the engine and drives the vehicle, emitting only water vapour.

Paul then conducts a simple experiment to check the two main characteristics of dihydrogen:
- Because it is less dense than air, it rises, allowing it to be collected inside a small container.
- It is highly inflammable, so capable of generating an explosion.

Related experiment: Another way to produce oxygen

Careful! This experiment uses hydrogen peroxide, a liquid that can burn the eyes and skin. Always have an adult present for this experiment and, if possible, wear safety goggles and gloves when handling things!

You will need:

- a bowl;
- an empty bottle;
- a packet of instant yeast;
- concentrated hydrogen peroxide, ideally 6% (dangerous product, please use with care!);
- washing-up liquid;
- a funnel;
- water;
- a mixing ustensil;
- a basin to conduct the experiment in.

1) Pour three tablespoons of lukewarm water and half a packet of instant yeast into a bowl and mix well until combined.
2) Pour about 15 cL of hydrogen peroxide into the empty bottle along with a small amount of washing-up liquid and mix gently without creating too many bubbles.
3) Place the bottle containing the hydrogen peroxide and washing-up liquid in the basin.
4) Using a funnel, pour the water and yeast mixture into the bottle.
5) Watch what happens. A large quantity of bubbly foam should form very rapidly. Be careful not to touch the foam because it is very hot!

Always get an adult to clean the equipment, and wash your hands thoroughly afterwards.

What do you think happened?

This experiment produces another chemical reaction that results in the production of large quantities of dioxygen (the gas inside the foam).
An enzyme (large molecule) in the yeast called catalase causes the hydrogen peroxide (H_2O_2) to split into two separate molecules:

- water (H_2O), which remains in the liquid mixture;
- gaseous dioxygen (O_2), which tries to escape but stays trapped inside the soap bubbles.

The catalase in this reaction plays a similar role to that of the electric current in water electrolysis. Both make it possible to split one molecule into two. This is known as disproportionation.

Challenge !

Can you make a vehicle that moves a short distance by itself without fuel or electricity?

If you need help, search the internet for:

- rubber band car;
- gas propulsion.

You can also watch the Propulsion video for more ideas!

2. How is fire used for rocket propulsion?

The science question in this video

In this video, Paul, Maxime and Clementine try to understand how fire is used for rocket propulsion. They experiment with a single flame before attempting to create a more directed flame that they think might be more effective.

The experiment in this video demonstrates that producing a flame is not enough to propel an object. The conditions to be met are actually far more complex. A rocket is first and foremost propelled into space by ejecting large amounts of gas downwards, which push it in the opposite direction. This is thanks to the law of action-reaction and is known as reaction propulsion.

The gas is produced by an explosion in the rocket engine and ejected at high velocity to produce very high thrust… and an impressive takeoff!

Related experiment: The match rocket

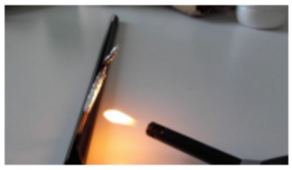
Careful, this experiment uses fire! It must be done with an adult present and outdoors, after checking that the match is not facing anything inflammable. Most importantly, make sure that no one walks in front of the match!

To better understand this experiment, search for ‘match rocket’ on the internet.

You will need:
- a match;
- a square of tin foil;
- a glass bottle;
- a lighter.

1) Wrap the top two-thirds of the match in tin foil, wrapping it around at least four times. The foil should sit tightly around the match with as little air inside as possible. It should also extend beyond the match head at the top.
2) Twist the foil that extends beyond the match head in order to seal it at the top. The foil should cover all of the match head.
3) Place the match on a fireproof surface (e.g. in the neck of a glass bottle), with the foil-wrapped head pointing upwards and towards an open space.

At this stage, make sure there's nothing inflammable in front of you and that nobody's about to walk past!



1) Bring the flame of a lighter under the tip of the match (where you would have liked to light the match).
2) Wait a few seconds, and watch the rocket go!

What do you think happened?

When the flame is brought near, the match head heats up and releases a large quantity of combustion gas which tries to escape. Since the only exit is out the bottom, when the gas suddenly manages to escape downwards, it propels the match upwards.

Challenge!

Can you make a rocket or propulsion system without using fire?

If you need help, search the internet for:
- Fireless propulsion
- Homemade rocket
- Fireless rocket

You can also watch the Propulsion video for more ideas!

3. How are satellites launched?

The science question in this video

This video looks at how satellites launched from the Earth are then placed into orbit around the Earth.
First, it's worth pointing out that the word 'satellite' doesn't refer solely to artificial satellites. Our moon, for example, is a satellite of the Earth!

Satellites in orbit
When a satellite approaches the Earth, it is affected by its gravity. The further away from Earth it is, the weaker the gravitational pull.
If a satellite moves too far away, it will be unable to remain in orbit.
But it's not just about gravity! If so, the satellite would fall back to Earth (provided it wasn't too far away), just like us when we jump off a diving board, for example.
So something else is required… Speed!
Imagine a salad spinner. When you turn it, the water is projected to the sides.
A similar thing happens with satellites. They must be launched at high speed to avoid falling back down and in order to orbit the Earth. But launch them too quickly and they go too far and drift off into space.
So for a satellite to orbit the Earth, you need to find the right balance between height and speed.

Possible orbits
It's this balance between a satellite's speed and its altitude that determines its movement around the Earth.
If a satellite exceeds the speed limit of 11.2 km/7 miles per second then, regardless of its altitude, the Earth's gravitational pull will no longer be enough to hold it and it will escape into space.
For any given altitude, there is a very specific speed or velocity that enables a satellite to orbit the Earth in a circle. It is at this velocity that the satellite must be launched to obtain a circular orbit.
For example, a satellite placed in circular orbit at an altitude of 300 kms/186 miles needs to have a velocity of nearly 8 km (5 miles) per second! Any faster or slower and its orbit will no longer be circular but elliptical!

Orbiting satellites
So how are satellites orbited?
It's the launcher/rocket that:

- takes off;
- climbs to the exact altitude where the satellite is to be orbited;
- starts orbiting the Earth at the velocity required by the satellite;
- finally, releases the satellite at precisely the right altitude and velocity!

Related experiment: The winner's pool table

Fancy making a pool table that lets you win every time?

You will need:

- a piece of cardboard;
- two thumbtacks;
- a piece of string;
- a pencil;
- two marbles;
- a shoelace.

1) On the sheet of cardboard, mark two points about 20 cms/8 in apart.
2) Cut a piece of string 28 cms/11 in long.
3) Tack each end of the string to the points drawn. The resulting attached string should hang loose unless you make it taut by stretching it out to the side.

We will now use this device to draw something called an ellipse.

4) Use the tip of your pencil to pull the string out to one side until taut.
5) You can now start drawing. Keeping the string taut with the tip of your pencil, draw an ellipse by moving the pencil and going around the thumbtacks (at one point you will need to lift and reposition your pencil).
6) Once you've drawn your ellipse, you can remove the string and thumbtacks.

And there you have it! A pencil-drawn ellipse. Now for the sides of the pool table.

7) Glue a shoelace onto the cardboard, following the outline of the ellipse.

Your pool table is ready!

Next:

8) Place a marble on each thumbtack hole.
9) Launch one of the marbles in a straight line in any direction.
10) Watch what happens!

You will undoubtedly notice that, whichever direction you launch the marble in, it always bounces off the shoelace and hits the other marble.

What do you think happened?

Satellites have an elliptical trajectory (with a circle actually being a specific kind of 'unflattened' ellipse).
When an object is launched in any direction from one of an ellipse's construction points, it automatically passes through the other construction point!

Challenge!

Of all the objects sent into space by humans, which are your 'top three' in terms of weirdness?

If you need help, search the internet for:

- objects sent into space;
- what we've sent into space.

4. What happens to the human body in a vacuum?

The science question in this video

In this video, Clementine, Maxime and Paul are inspired by Maxime's question of what would happen if a human found themselves in space without a spacesuit.
This gets them thinking about the concept of a 'vacuum' and how to create one.

In physics, a 'vacuum' refers to the absence of all matter. But it's not possible to create a space that contains ZERO atoms and ZERO molecules.
When we talk about the 'interstellar vacuum' or 'space vacuum', we actually mean an environment containing far fewer molecules than there are around us here on Earth.

Imagine, for example, a small cube of air measuring 1 cm on each side (1 cm3), floating above the palm of our hand:
- on Earth, that cube of air would contain approximately 20 quintillion (20 billion billion) molecules (20 000 000 000 000 000 000);
- if we were in one of the 'emptiest' parts of the universe, though, that same cube may contain a single molecule! In such cases, we describe the air as 'rarefied'.

There are devices that enable us to obtain a near vacuum by rarefying the molecules. Vacuum pumps, for example, suck as much air as possible out of a container. But they're not powerful enough to extract it all!

Another way to rarefy molecules is suggested in the video. Trap a volume of air in a jar, then expand the container (but without letting any air in or out!) The result is nowhere near a vacuum but it can still produce an effect.

We see this in the video when the air bubbles expand slightly. The molecules in the air of the jar are 'rarer' than those in the bubbles. So the latter tends to push against the surface of the bubbles from the inside, making them expand slightly.

The final experiment in this video shows how to use a syringe to further reduce the number of molecules in each cm3 of air inside. The water inside the syringe becomes surrounded by very ‘rare’ air and boils much more easily than in the conditions we’re used to, thereby filling this ‘rare’ air with water vapour. If you rarefy the air enough, the water will boil at room temperature!

N.B. The video never mentions pressure, but the experiments and resulting observations (‘aspirated’ balloon, expanding bubbles, boiling water) can provide a starting point for this concept!

Related experiment: The cold balloon

You will need:
- a balloon;
- a sharp object (to pierce the balloon).

1) Inflate the balloon.
2) Place the balloon on the ground and sit on it carefully (it shouldn’t burst :-))
3) While still sitting on the balloon, pierce it with the sharp object.
4) What’s the sensation around your bottom? Touch the balloon – how does it feel?

You should feel a cool sensation just after the balloon bursts.

What do you think happened?

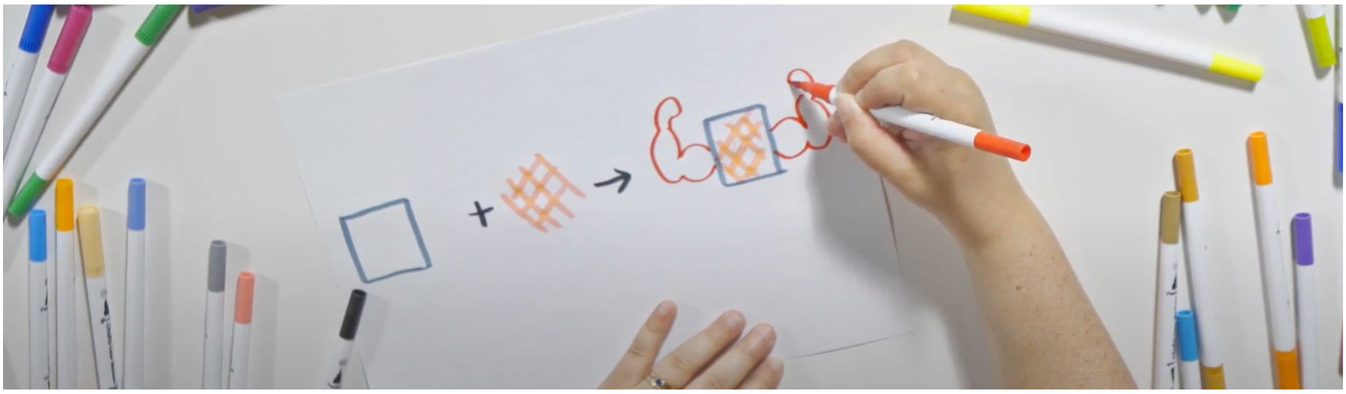
When you burst the balloon, the air inside which was very ‘constricted’ or under pressure is suddenly released and starts to fill up far more space than just before. It’s a bit like the experiment in the video where they pull on the jar top, except that here it’s much quicker.
When air very suddenly fills up much more space, it gets colder!
It’s this coldness that you can feel around your bottom or when you touch the burst balloon that has been cooled by the air.

Challenge!

Can you find three living things (plants or animals) able to survive in space without protection?

If you need help, search the internet for:
- an animal that survives in space;
- a plant that survives in a vacuum.

5. What are composites?



The science question in this video

This video deals with composite materials. Starting with questions about the materials used to make aeroplanes, we find out about composites and try to make some.

Composite materials are used in car chassis, aeroplanes, wind turbine blades… In fact, they're pretty much everywhere!
There are many different types of composites, some of which are adapted to industrial scale manufacture while others are reserved for cutting-edge technology and so on.
One major area of application is aeronautics because, by combining two different materials, you can produce a strong and lightweight composite.

The principle is always the same. Combine two different materials in such a way as to create a new material with properties that none of the originals had on their own.

A composite consists of (at least) two materials:

- The **reinforcement**: the 'skeleton' of the composite material e.g. rods or fibres arranged in a specific manner.
- The **matrix**: the material around the skeleton e.g. resin, concrete or metal.

Some examples!

Reinforced concrete: Concrete (the matrix) is poured around metal rods (the reinforcement).

Cob: Used to make walls and fences. The matrix is subsoil clay mixed with water, while the reinforcement consists of natural fibres such as straw, hay and horsehair.

Related experiments: Paper is stranger than you think!

First experiment

You will need:

- Several sheets of paper.

Most sheets of paper are rectangular, so have a long edge and a short edge.

1) Tear a sheet from the middle of a short edge and watch how it tears.
2) Now tear another sheet from the middle of a long edge and watch again.

You may have noticed that in one direction (usually when tearing from the short edge) the tear runs straight, while from the other edge it curves as though unable to go straight.

Second experiment

You will need:
- several sheets of paper;
- a pair of scissors.

Take a sheet of paper and cut out two rectangular strips, each measuring 10 cms long by 2 cms wide (approx. 4 in x 1 in).
1) Cut the first strip parallel to the long edge.
2) Cut the second strip parallel to the short edge.
3) Place the two strips precisely on top of one another and hold them together, horizontally, by pinching the short edges between your thumb and index finger. Watch what happens.
4) Turn your wrist 180 degrees so that the top strip becomes the bottom strip and vice versa. Watch what happens.

You will probably notice something changes!

One way, the bottom strip separates completely from the top one by bending downwards.
The other way, the bottom strip doesn't separate from the top one and the two strips bend downwards together.

What do you think happened?

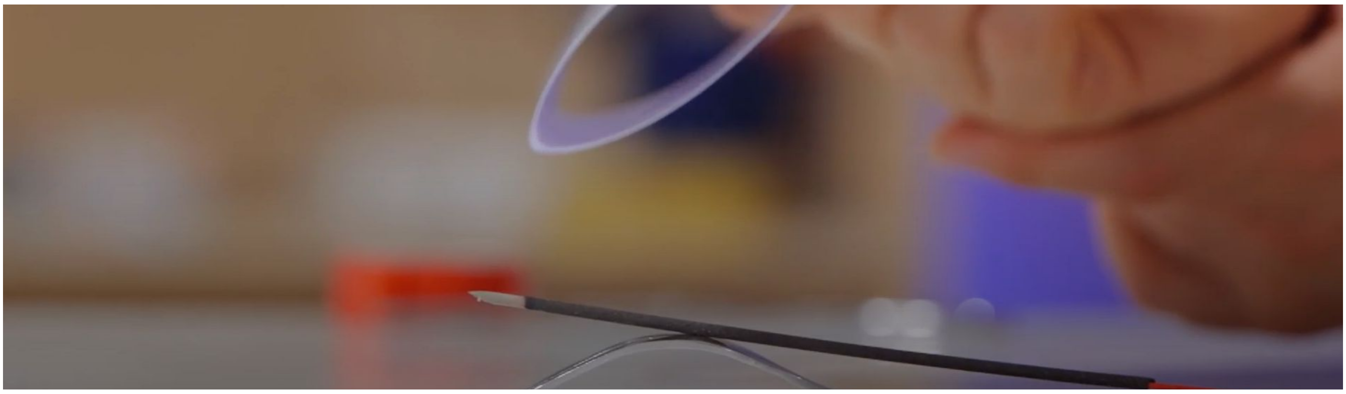
Paper consists of fibres, which generally run in one specific direction. So each sheet of paper will tend to tear along the fibres (first experiment) and will bend more easily in one direction than the other (second experiment).

Challenge!

Can you name five living things that have provided the source of inspiration for new materials?

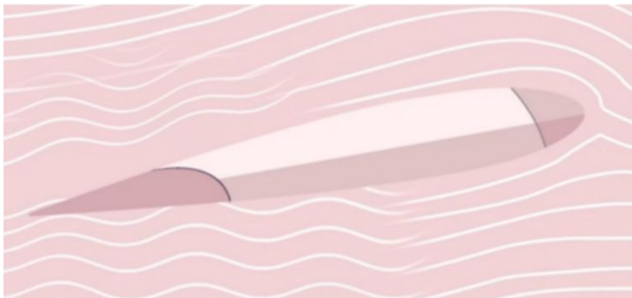
If you need help, search the internet for:
- biomimicry;
- biomimetic materials.

6. How does air flow around a wing?



The science question in this video

This video studies the following diagram:



It's the standard diagram used to show how air flows around an aeroplane wing. The aim of the video is to test the diagram experimentally.

It may seem strange at first that the air flowing in from the right and passing over the wing is deflected to follow the shape of the wing, as though 'stuck' to it.

But if you check, using an incense stick and a wing shape made out of paper, you'll see that's exactly right.

If you look closely above the wing, the diagram shows two zones:

- one zone above the first half of the wing, where the airflow follows the wing shape;
- an ensuing zone where the air appears to become 'unstuck' and starts to get a bit more turbulent.

These are two crucial types of flow to be considered in wing airflow.
The first is called **laminar flow**. Aeroplanes are designed to create as much as possible of this type of airflow, since it ensures maximum lift and safety. Laminar flow is where the air follows the wing contours.
The second is called **turbulent flow**. While turbulent flow cannot be eradicated, we generally try to reduce it as much as possible. This kind of flow causes the air to become turbulent and may create vortices that greatly limit an aircraft's ability to fly.

An aeroplane's ability to fly is closely related to these flow types. Firstly, through the concept of **lift** (the upwards force exerted on the wing that 'carries' the aeroplane) and secondly through the concept of **drag** (the force that opposes an aeroplane's motion through the air).

If an aeroplane gradually increases its pitch (points its nose upwards), at a given point the airflow will become purely turbulent and the aeroplane will stall and stop flying.

Whether the airflow over a wing or other obstacle is laminar or turbulent depends mainly on the shape of the obstacle. This explains why a lot of studies, calculations and experiments are done to determine the best possible wing shape.

Related experiment: The flying ping pong ball

You will need:
- a ping pong ball.

You're going to have to blow vertically, straight up!
So:
- Put your head back so that you're looking straight up.
- Hold the ping pong ball between your thumb and index finger and position it a centimetre (half an inch) away from your mouth.
- Start blowing. Imagine that you want to produce a very fine, powerful, vertical and constant stream of air.
- Once you've started blowing, let go of the ball.

With a bit of practice, you should be able to keep the ball in the air for several seconds (until you run out of breath!)

If you have trouble, you can try using a hairdryer instead.

What do you think happened?

If you watch the ball's movements closely, you will notice that it seems to be stuck in the airstream coming from your mouth. It looks like it's trying to escape to one side before being brought back to the centre, and then to the other side where it is brought back to the centre again, and so on. It wobbles from one side to the other but stays in the airstream, provided the flow is constant.

What is interesting about this experiment is the fact that the ball is continually brought back to the centre of the airstream. When it moves to one side, the air is much faster on the airstream side than on the other side of the ball. This difference in speed is the reason why the ball returns to the centre of the airstream.

Challenge!

Is it possible to make objects fly or levitate using different methods from those used by aeroplanes?

If you need help, search the internet for:
- levitation;
- acoustic levitation;
- magnetic levitation;
- electrostatic levitation.

7. How do you propel an object upwards?

The science question in this video

In this video, Maxime and Clementine try to understand different types of propulsion using things they already know about: helicopters and space rockets.

Their experiments show them there are several ways to propel an object to make it take off.

The first method they look at is **reaction propulsion**, which is used in both propeller systems and rocket launch systems. Reaction propulsion is based on **the law of action-reaction** or Newton's third law, which states that: "Any object A that exerts a force on object B is subjected to a force of equal magnitude in the opposite direction by object B."
→ As a propeller turns, it pushes the air downwards (action), which then propels it back upwards (reaction).
→ The gas ejected from a rocket pushes downwards (action), which then propels the rocket upwards (reaction).

This fundamental law also applies to other systems such as jet aeroplanes and propeller-driven boats, for example, enabling them to move forwards.

The second experiment explores another principle… If you increase the pressure applied to an object, that object will suddenly start moving due to thrust. So when the gas in a bottle is put under pressure, it pushes on the cork and ejects it upwards.

Related experiment: The water rocket

An adult must be present!

For more details on this experiment, see the following tutorial:
https://www.instructables.com/Pump-Rocket/
(Author: mikeasaurus sur le site Instructables ; License CC BY-NC-SA 4.0)

You will need:

- a rigid plastic bottle (ideally a soda bottle);
- a cardboard;
- scissors;
- a cork;
- a bicycle pump adapted for inflating footballs/basketballs.

1) Cut out three or four fairly large, identical rocket fins from the cardboard.
2) With the bottle pointing downwards, sticky tape your fins to the base, making sure they're placed perfectly symmetrically. The fins should extend beyond the bottle neck so that you can use them as a stand for your rocket (which will rest on them).
3) Stick the bicycle pump needle into a cork that is the same size as the bottle cap.
4) Pour some water into the bottle.
5) Push the cork with the needle into the neck of the bottle.
6) Taking the pump with you, move as far away from the bottle as possible (and certainly don't stand over it!)

SAFETY CHECK:
We're now going to start pumping up the bottle, which will take off without warning! It is therefore vital that:

- **an adult is present;**
- **the rocket is vertical;**
- **everyone present stays at least 1 m/3 ft away from the bottle and watches it all the way from take off to landing.**

7) Pump air into the bottle to build up pressure until it takes off all by itself! (Careful, you may get sprayed as it leaves!)

Now you can start again, varying how much water you pour into the bottle until you find the right amount to take your rocket as high as possible!

What do you think happened?

This experiment uses the principle of reaction propulsion. The air in the bottle is put under pressure using the bicycle pump. When the pressure reaches a certain level, the friction of the cork against the bottle neck is no longer enough to hold it. All of the air and water inside the bottle are suddenly ejected downwards, which propels the water rocket upwards.

Challenge!

Try to find a way of propelling a ping pong ball as high as possible, without using muscular force!

Got any ideas? Then go ahead and test them!