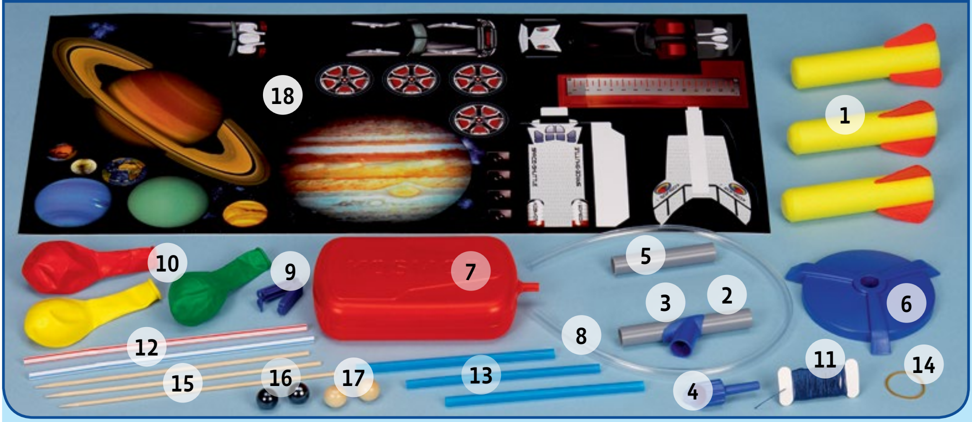
EXPERIMENT MANUAL

ROCKET SCIENCE

THAMES & KOSMOS

WARNING — Science Education Set. This set contains chemicals and/or parts that may be harmful if misused. Read cautions on individual containers and in manual carefully. Not to be used by children except under adult supervision.

What's in your experiment kit



Checklist: Find – Inspect – Check off

✔	No.	Description	Qty.	Item No.
		Rocket Set (parts 1 – 8)		712177
☐	1	Rocket	3	
☐	2	Launch tube	1	
☐	3	Launch tube holder	1	
☐	4	Connection piece for hose	1	
☐	5	Mounting rod	1	
☐	6	Mounting foot	1	
☐	7	Tank	1	
☐	8	Hose	1	
☐	9	Closure clip	1	706538
☐	10	Balloon	3	704939
☐	11	String	1	706762
☐	12	Bendable drinking straw	2	529118
☐	13	Straight drinking straw	3	707448
☐	14	Rubber band	1	161412
☐	15	Wooden stick	3	020042
☐	16	Marble (glass)	2	705088
☐	17	Marble (wood)	2	712780
☐	18	Die-cut cardboard sheet	1	712175

Please check all the parts against the list to make sure that nothing is missing. If you are missing any parts, please contact Thames & Kosmos customer service.

Additional things you will need:

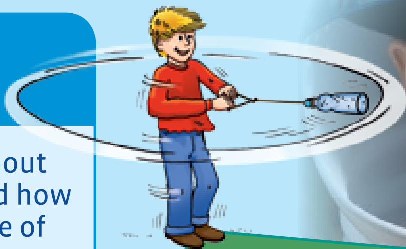
Plastic water bottle (16 ounces), tape, glue stick, scissors, water, book, two chairs, white glue, plate or shallow bowl, bicycle pump, bathtub, garden hose

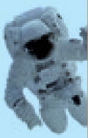
Rocket:
Warning! Do not aim at eyes or face.

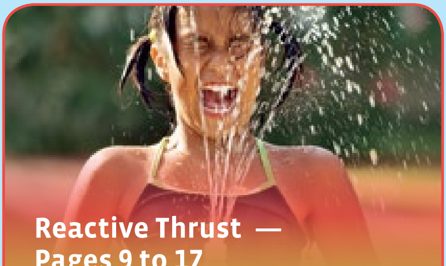
Any materials not contained in the kit are marked in *italic script* in the "You will need" boxes.

CONTENTS

Rockets have taken humans to the Moon, conveyed space probes to distant planets, and carried satellites into Earth's orbit. In the process, they have powerfully expanded our knowledge of space — and, thanks to satellites, of the Earth as well. But how do rockets actually work? You will find the answer to this question, along with a lot more information about space, the Earth, and laws of physics, inside this experiment kit.







CHECK IT OUT

You will find supplemental information on pages 8, 18, 26, 27, and 32.

WARNING!

CAUTION! Not suitable for children under 8 years of age. Use only under adult supervision. Read the instructions before use, follow them, and keep them on hand for reference.

Children under 8 years of age can choke on uninflated or popped balloons. Adult supervision is required. Keep uninflated balloons away from children. Remove popped balloons immediately. The balloons are made of natural latex. Use a pump for inflating them.

Individual parts of this kit have sharp points, corners, or edges in accordance with their function. Do not injure yourself!

Not suitable for children under 3 years of age. There is a risk of suffocation due to small parts that can be swallowed or inhaled. There is a risk of strangulation from pieces of string or hoses getting wrapped around the neck.

First check the parts list to be sure that all the right pieces are contained in the box.

Save the packaging and instructions, as they contain important information.

Rules for safe experimentation

→ Warning! Do not aim at eyes or face. Never aim the rocket at people or animals when you launch it. Even if it is just made of soft foam material and has a rounded nose, it could still cause injury. Do not lean over the rocket when launching it.

→ Before starting an experiment, get everything ready that you are going to need. Perform the experiment in a calm and thoughtful manner, precisely according to the instructions.

→ Keep young children (under 8 years) and animals away from the experiment area.

→ Store the experiment kit out of the reach of young children.

Dear Parents!

In this experiment kit, your child will learn about the propulsion of rockets by the reactive thrust principle, the forces inside air and water, and how these forces can be used as propulsion forces. Your child will also learn some simple and more complex laws and concepts of physics that are explained in the context of engaging and exciting experiments.

Please stand by your child’s side during the experiments and provide help and support when it is needed. The experiments will succeed with a little practice and patience — and the fun of shooting off a rocket is guaranteed no matter what.

Before the experiments that take place in the bathroom (in the bathtub), discuss with your child the importance of cleaning up any puddles (slipping hazard). For the experiments that take place outside, help your child find an appropriate location.

We wish you and your child a lot of fun and fascinating experimentation!

Air Is Not "Nothing"

The rocket in this experiment kit is propelled by air. That's reason enough to study the properties of this substance a little more closely. We need air to breathe and are constantly surrounded by it, but we usually don't think about it at all. Once in a while, of course, it makes its presence clearly felt — such as when a storm blows the roofs off of houses, uproots trees, or sinks ships. But what is actually happening when you compress air in order to propel a rocket?

The apparently empty hose

YOU WILL NEED

→ hose
→ *glass of water*
→ *plastic water bottle (16 ounces)*

HERE'S HOW

1. Hold your finger tightly over the upper end of the hose and lower its other end into a glass of water. The liquid will only push a few millimeters into the hose, as you can see through the glass.

2. You can perform the same experiment with an empty plastic bottle, with the same results.

3. But when you take your finger off the upper end of the hose, the water will rise up it to the same level as inside the glass. The same thing would happen if you poked a hole in the bottle.

→ WHAT'S HAPPENING?

The hose and the bottle are actually not empty at all — they are filled with air. True, you can't see the air, but it won't let itself just get pushed out of the way by the water. Only when it escapes can the water enter and rise up the hose. This fact comes in handy with diving bells, which are open at the bottom and nevertheless won't fill up with water.

EXPERIMENT 2

Compressed air

YOU WILL NEED

→ *plastic bottle (16 ounces)*
→ *water tap*

HERE'S HOW

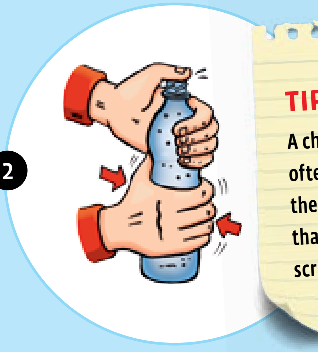
1. Completely fill the bottle with water by holding its opening under the tap and repeatedly squeezing the bottle to make the air escape as the water from the tap gets sucked in.

2. Then hold your thumb over the opening and try to compress the bottle by squeezing its plastic sides together. You will hardly be able to compress it at all.

3. Now let the water run out and hold your thumb over the opening again. This time, you will easily be able to push in the sides of the bottle a little.

1

2



TIP!

A child's hands are often too small to hold the bottle closed. In that case, just use the screw-top lid!

3

→ WHAT'S HAPPENING?

This experiment shows that air can easily be compressed, and that it expands again when the external pressure lets up. Air is elastic, a property that is put to use in air-filled soccer balls and car tires. Water (and other liquids), on the other hand, can hardly be compressed at all, and solid materials such as rocks are even less elastic.

EXPERIMENT 3

Spray bottle

YOU WILL NEED

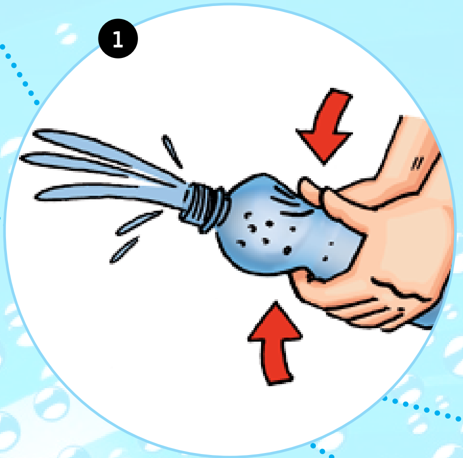
→ *plastic bottle (16 ounces)*
→ *water tap*

HERE'S HOW

You should try this experiment in the bathroom or outside!

1. Fill the bottle completely with water and squeeze its sides together. The water will shoot out.

2. Empty the bottle and repeat the experiment. If you hold its opening near your face as you quickly squeeze it, you will feel the air escaping.



1

2

→ WHAT'S HAPPENING?

The force of your fingers creates pressure inside the bottle when they squeeze its sides together. This pressure, in turn, pushes some of the water or air out of the opening. This is similar to the way a water pistol works. And it's the pressure created by the water plant that makes water run out of the tap into your sink.

EXPERIMENT 4

Pressure gauge

YOU WILL NEED

→ tank
→ hose
→ 2 wooden sticks
→ polystyrene tray from your kit box
→ cardboard cutout with scale (die-cut sheet)
→ *book*
→ *tape*

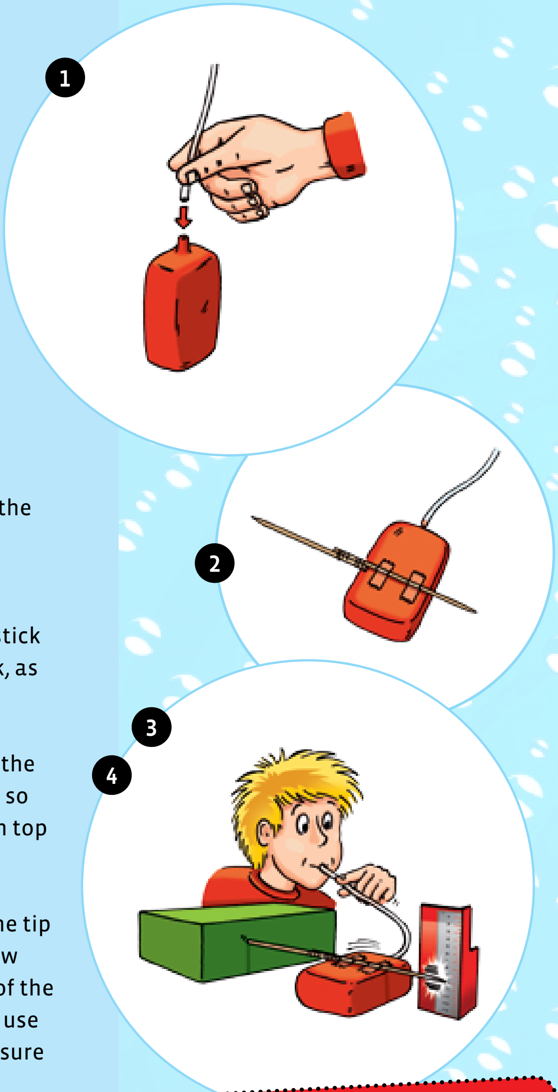
HERE'S HOW

1. Insert the hose into the opening of the tank.

2. Tie together the blunt ends of two wooden sticks with tape. Tape the stick assembly to the flat side of the tank, as shown in the drawing.

3. Insert the long end of the stick into the side surface of the polystyrene tray so that it cannot move. Place a book on top of the tray to serve as a weight.

4. Place the cutout with the scale at the tip of the wooden stick. Now, if you blow into the hose or suck on it, the end of the stick will move up or down. You can use the scale to read the change in pressure in the tank.



→ WHAT'S HAPPENING?

The pressure inside the tank moves its plastic wall, letting the device indicate changes in pressure. This is similar to the way a barometer or altimeter works.

CHECK IT OUT

Barometers...

... are used in many homes for forecasting the weather. They have an enclosed container connected to a pointer, with the container altering its shape depending on the atmospheric pressure and thus moving the pointer. When the weather changes, there's a change in air pressure (the pressure that the layers of air exert on us), which is what the barometer shows.

Air pressure changes with altitude as well: The higher you climb, the lower the air pressure. Mechanical **altimeters** make use of that fact. They work similarly to weather barometers, except their scale is divided into feet or meters.

altimeter

The Power of the Wind

A strong wind can exert a powerful force on buildings or trees. At a wind strength of 6, which is when large branches start to sway, the wind exerts a pressure of 7 kilograms per square meter. At a wind strength of 10, which would be a storm, the force is 36 kilograms. At hurricane strength, the force is over 50 kilograms. At this strength, the wind can make walls collapse, devastate entire forests, rip off roofs, and even blow cars off the street.

Reactive ››› ‹‹‹ Thrust

In the spray bottle experiment, the water shot out of the bottle with quite a bit of force. So force and pressure seem to be closely related. Now it's time to investigate that relationship a little more closely.

The power of flowing water

YOU WILL NEED

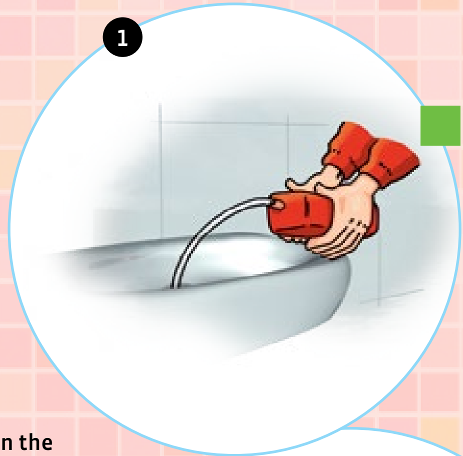
→ tank
→ hose
→ *water tap*
→ *sink*

HERE'S HOW

You should perform this experiment in the bathroom!

1. Fill the tank with water and insert the hose, letting the other end of the hose hang loose over the sink.

2. Now squeeze the tank forcefully. A stream of water will shoot out of the hose opening, and the end of the hose will move in the opposite direction from the stream.



→ WHAT'S HAPPENING?

The stream of water is exerting reactive thrust on the hose. In doing that, it is obeying a law discovered by the English physicist Isaac Newton (1642–1726) a long time ago: every action has an equal and opposite reaction. The water shoots out of the hose, but pushes the hose in the opposite direction at the same time. All rockets work according to this principle, as do jet planes.

EXPERIMENT 6

Rotating straws

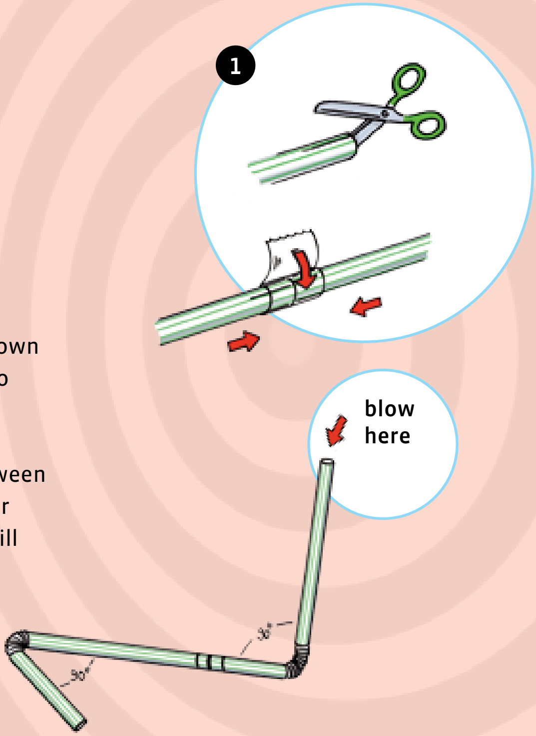
YOU WILL NEED

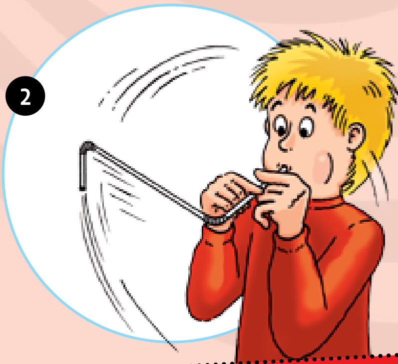
→ 2 bendable drinking straws
→ *tape*

HERE'S HOW

1. Tape the two straws together as shown in the illustration, and bend them to match the drawing.

2. Hold the bottom straw loosely between your fingers and blow into the lower opening. The entire arrangement will start to rotate.





TIP!

Moisten your lips well before blowing into the straw. It will rotate a lot more easily then, since there will be less friction against your lips.

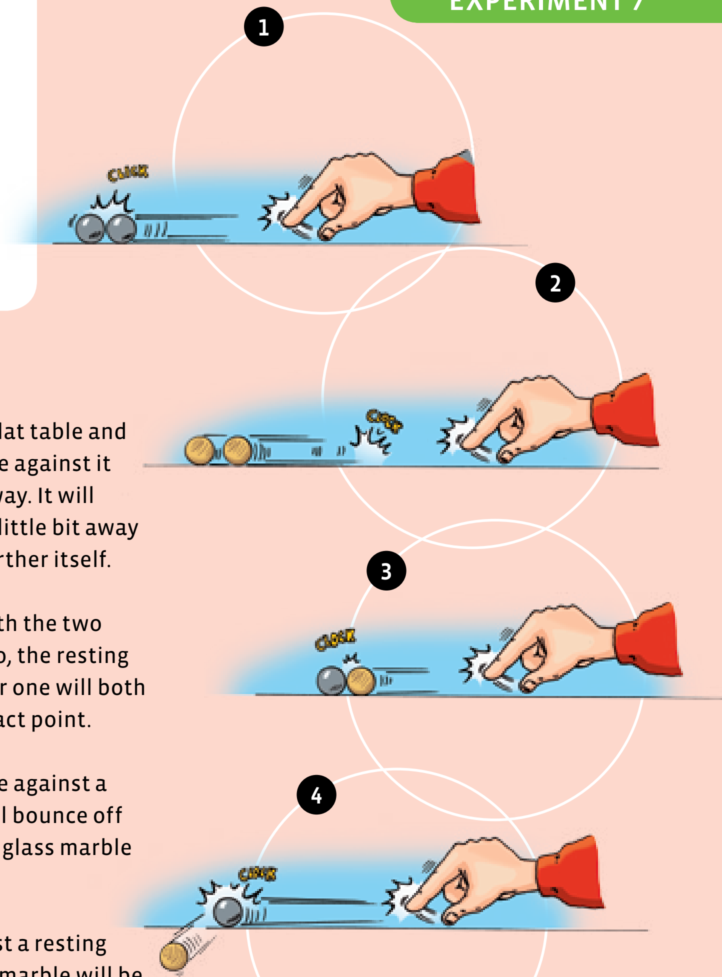
→ WHAT'S HAPPENING?

The air flowing out of the upper opening exerts reactive thrust on the straw and sets the straw into rotation, with the lower straw acting as the rotational axis.

Marbles on a collision course

YOU WILL NEED

→ 2 glass marbles
→ 2 wooden marbles



HERE'S HOW

1. Place a glass marble on a flat table and flick the other glass marble against it from a few centimeters away. It will push the resting marble a little bit away and will also roll a little farther itself.

2. Repeat the experiment with the two wooden marbles. Here, too, the resting marble as well as the other one will both shoot away from the contact point.

3. Now flick a wooden marble against a resting glass marble. It will bounce off without really moving the glass marble much at all.

4. Flick a glass marble against a resting wooden one. The wooden marble will be pushed away and hardly seems to slow down the glass marble.

→ WHAT'S HAPPENING?

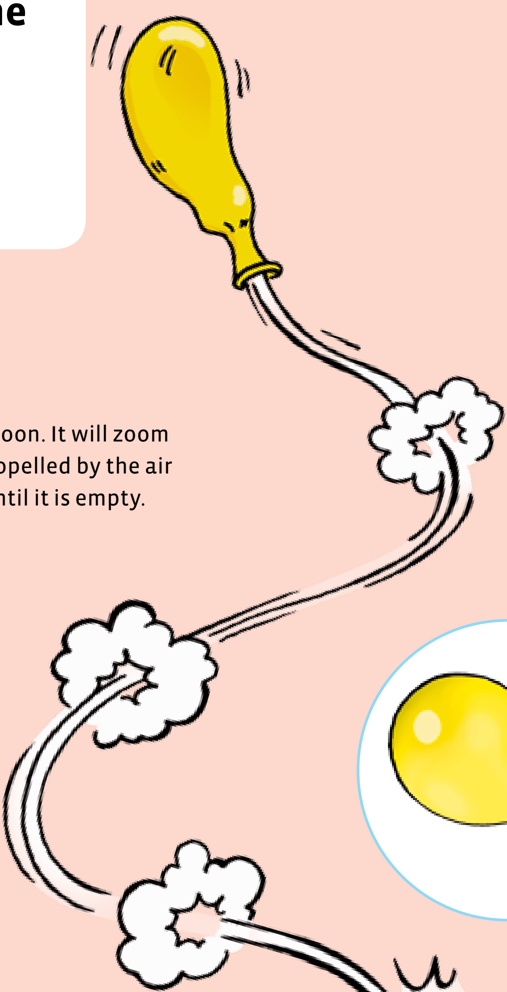
The rolling marbles are different in terms of a measure that physicists call "impulse." For rocket engineering, impulse is very important. The greater the impulse, the stronger the moving marble acts on the resting one. The glass marbles have a greater impulse than the wooden ones. But on the other hand, wooden marbles can be driven off by a much lighter push with much less impulse.

EXPERIMENT 8

Balloon on the loose

YOU WILL NEED

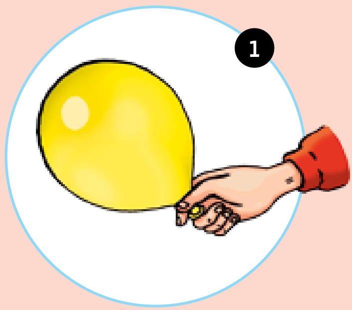
→ rubber balloon

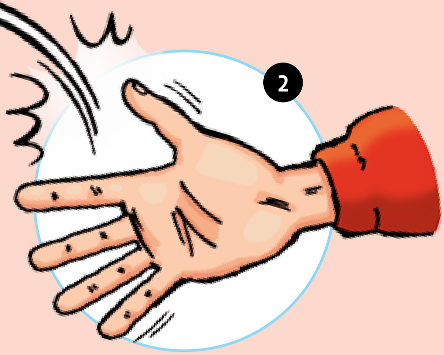


HERE'S HOW

1. Pump up the balloon.

2. Then let go of the balloon. It will zoom through the room, propelled by the air streaming out of it, until it is empty.





→ WHAT'S HAPPENING?

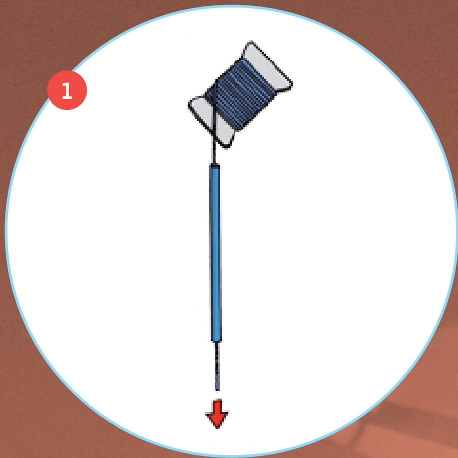
The air blowing backward out of the opening pushes the balloon forward: The balloon is moved forward by the reactive thrust of the air streaming out. Added to the normal pressure of the air in the balloon is the pressure of the rubber, which tries to contract back to its previous state. That is why air blows so forcefully out of a balloon.

EXPERIMENT 9

Using reactive thrust to go straight

YOU WILL NEED

→ balloon
→ closure clip
→ string
→ straight straw
→ cardboard rocket (die-cut sheet)
→ *tape*
→ *glue*
→ *2 chairs*



HERE'S HOW

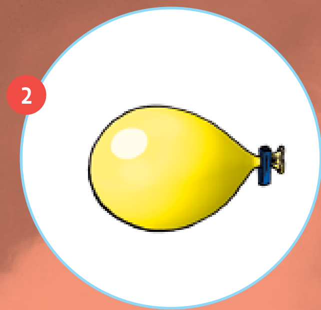
1. Thread the string through the small blue tube.

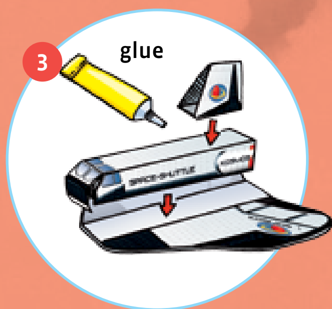
2. Pump up the balloon and close its opening with the clip.

3. Fold together the cardboard rocket and glue it to the balloon.

4. Stretch the string tightly between two chairs and tape the rocket to the blue tube.

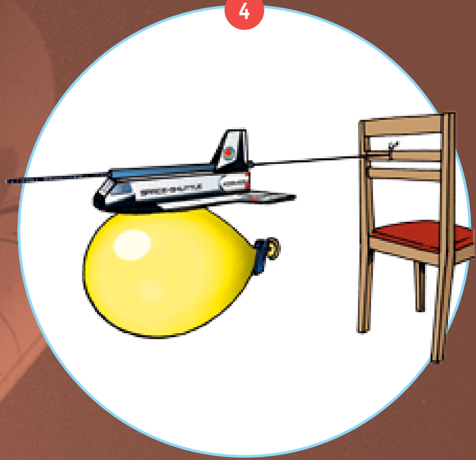
5. Release the clip — and the rocket zooms off along the string.



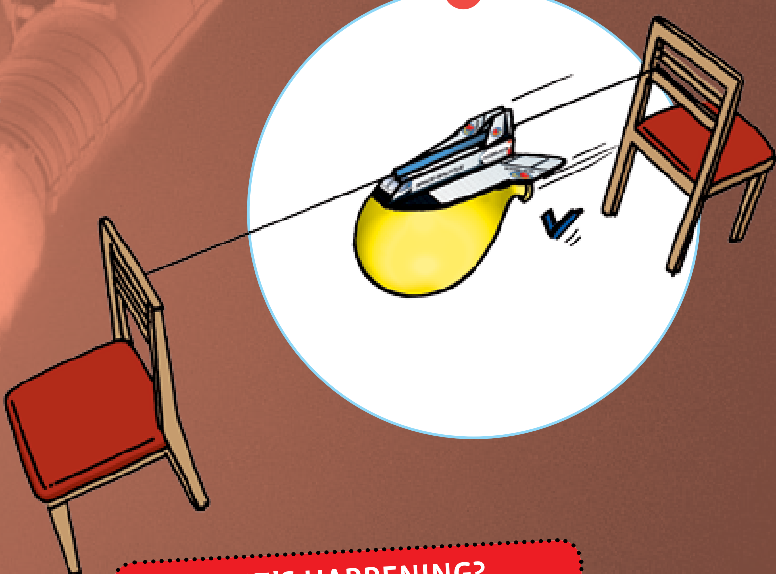


EXPERIMENT 9

4



5



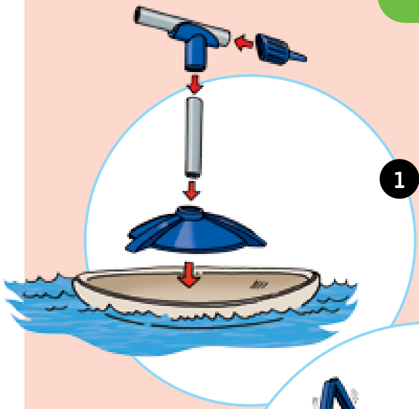
→ WHAT'S HAPPENING?

The air streaming out of the balloon exerts reactive thrust on the rocket, driving it forward. The string sets its direction.

Plate in motion

YOU WILL NEED

→ balloon
→ launch tube with holder
→ connection piece
→ mounting rod
→ mounting foot
→ rubber band (if needed)
→ closure clip
→ *plate or shallow bowl (plastic, if possible)*
→ *bicycle pump*



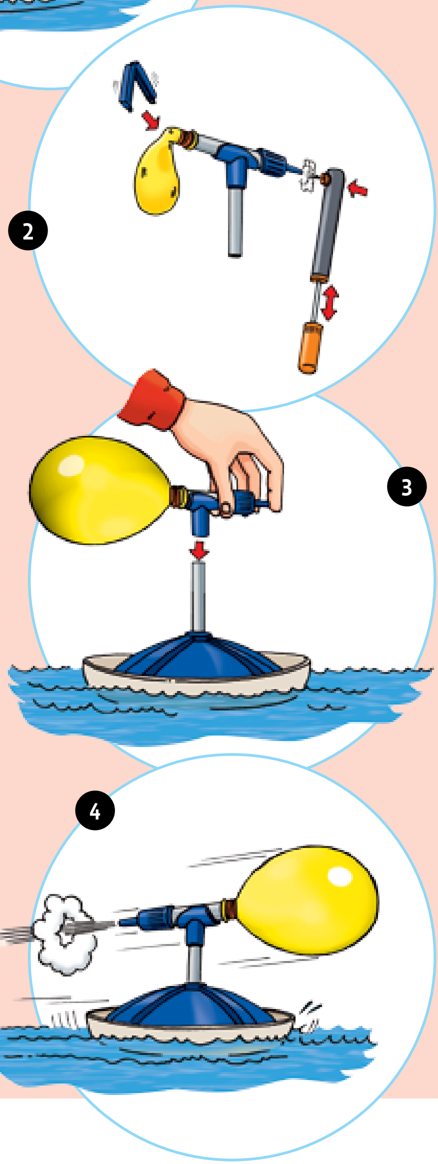
HERE'S HOW

1. Assemble the stand and place it in the exact center of the plate. Set the plate in the bathtub so it can float freely. Don't attach the launch tube yet.

2. Slide the balloon over the wide opening of the launch tube. If it doesn't sit tightly, secure it with a rubber band. Now use the bicycle pump to pump up the balloon through the blue connection piece, and close it with the clip.

3. Now set the launch tube on the stand, seal the blue tube opening with your finger, and remove the clip.

4. Release the opening. The air will stream out and the plate will slowly float off in the opposite direction.



→ WHAT'S HAPPENING?

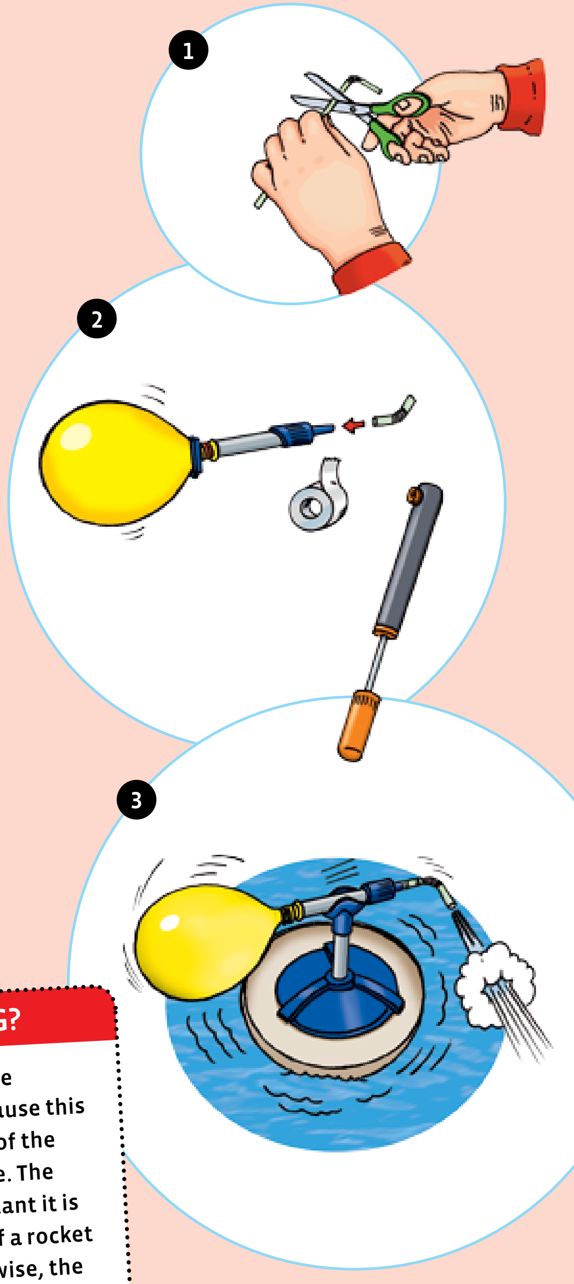
The force of the air streaming out is strong enough that it can even move the floating plate.

EXPERIMENT 11

Carousel in the bathtub

YOU WILL NEED

→ bendable straw
→ launch tube with balloon, stand and plate from Experiment 10
→ closure clip
→ *scissors*
→ *tape*
→ *bicycle pump*



HERE'S HOW

1. Cut both ends off of a drinking straw, leaving just the bending joint with about 2 centimeters of each arm.

2. Pump up the balloon as in Experiment 10, and seal it closed with the clip. Tape one end of the remaining straw to the blue part of the launch tube.

3. Now set the launch tube on the stand, seal the opening of the straw with your finger, and release the clip. Angle the straw at about 90 degrees and let go of the balloon. As the air streams out, the plate starts to turn.

→ WHAT'S HAPPENING?

The air streaming out to the side generates reactive thrust. Because this does not happen in the center of the plate, the plate starts to rotate. The experiment shows how important it is for the gases to exit the rear of a rocket exactly in the center — otherwise, the rocket would immediately go off course.

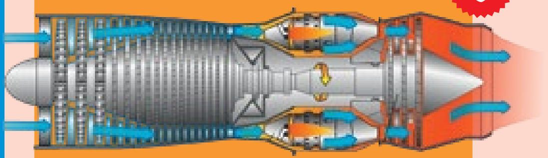
Impulse: critical for rocket engineering

Everybody know that a steel ball thrown at a pane of glass will have a much greater effect than a ball of polystyrene foam flying just as fast. Physicists identify this kind of difference in terms of a unit of measurement called impulse. Impulse is calculated from the mass of a body multiplied by its speed. A rocket could also be propelled (in principle) by pushing very heavy objects out of its engine nozzle relatively slowly.

In reality, however, gases (which are very light, after all) are expelled at high speeds. The combustion gases of modern rockets race out of the nozzles at speeds of several thousand meters per second. If the gases are accelerated by electrical forces, small quantities of fuel are often enough.

Something that is purely in the realm of science fiction, on the other hand, is the antimatter rocket drive. Still, it is intriguing to think about the gigantic distances that could be overcome with the extreme amounts of energy that might be released by antimatter.

CHECK IT OUT



Using Nozzles to move through the air

Large modern airplanes are powered by jet engines that are similar in function to rocket engines. They have a combustion chamber into which air and fuel are injected. The fuel burns with oxygen from the air, producing hot combustion gases in the process. As they escape through nozzles at the rear, they provide the airplane with some of its forward motion, pushing it along by reactive thrust.

Meanwhile, a turbine (a kind of propeller) is used (with the help of additional propellers) to take in surrounding air, some of which is compressed into the combustion chamber. Most of the air, though, is led past the turbine and surrounds the combustion gases escaping to the rear, which increases the thrust as well as reducing the noise.

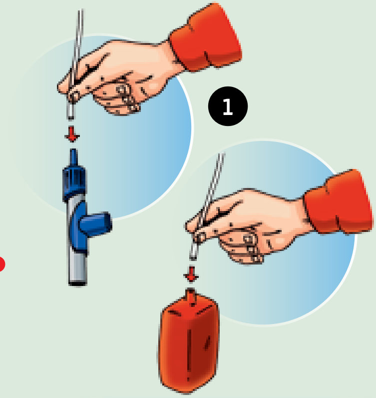
And this is the most important difference compared to most rockets: Rockets carry the oxygen needed for combustion along with them inside tanks, so they don't need to take in any air and can work in the vacuum of space.

Test Launch in the Living Room

In this chapter, you will finally have a chance to launch the rocket that is contained in your experiment kit along with a launch pad. You can use it to play a really neat game, and even to build a rocket car.

Launch pad on the table

CAUTION!
Never aim the rocket at people or animals! Make sure that there isn't anybody in the launch path.



YOU WILL NEED

→ rocket
→ launch tube with holder
→ connection piece
→ mounting rod
→ mounting foot
→ tank
→ hose

HERE'S HOW

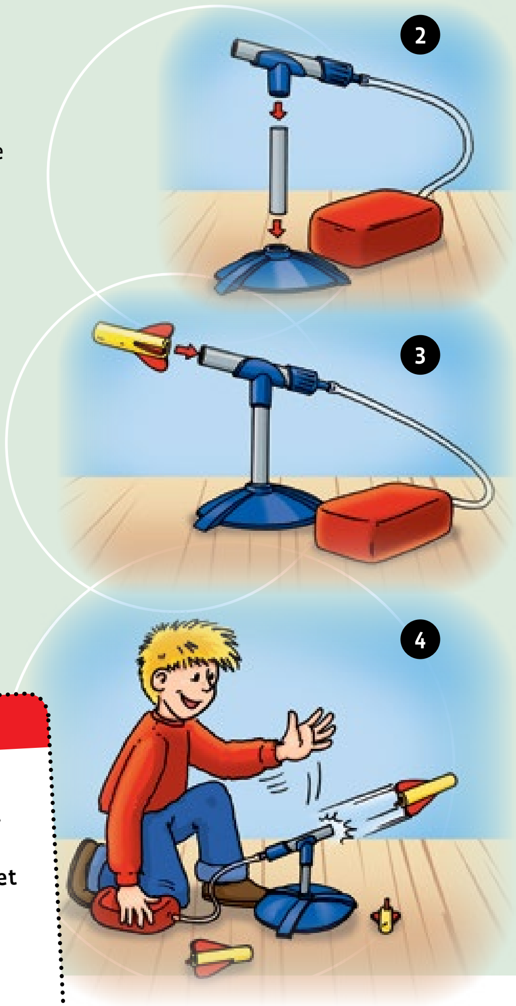
1. Push the ends of the hose onto the blue opening of the launch tube and the attachment nipple of the tank.

2. Mount the stand and place the launch tube in the holder.

3. Push the rocket onto the launch tube.

4. Push firmly on the tank. The rocket will zoom off and fly a distance of several meters.

5. Repeat the experiment. Try using your foot or fist for the launch. Compare flight distances.



→ WHAT'S HAPPENING?

By compressing the tank, you are increasing the pressure inside it. That makes the air escape in a burst. The sudden burst of air provides the rocket with reactive thrust and pushes it forward.

EXPERIMENT 13

Just the right angle

YOU WILL NEED

→ rocket and launch pad from Experiment 12
→ *water tap*
→ *bathtub*
→ *garden hose*

CAUTION!
Never aim the rocket at people or animals! Make sure that there isn't anybody in the launch path.

HERE'S HOW

1. This experiment is best performed outside, such as on an open lawn or in a field or meadow. Hold the tube in your hand as you launch the rocket, trying different launch angles (also known as the angle of incidence). Each time, take note how far the rocket flies. Is there an angle that works best for making it fly the farthest? What is the angle of your launch pad stand?

2. A second test launch in the bathroom: Fill the tank with water, attach the hose to it, and squeeze the tank. The water will shoot out the other end of the hose. Again, try holding the end of the hose at different angles. Which angle lets the stream of water go the farthest?

3. Of course, you can also try it in the garden using the garden hose. It's best to let a grown-up help you with this.

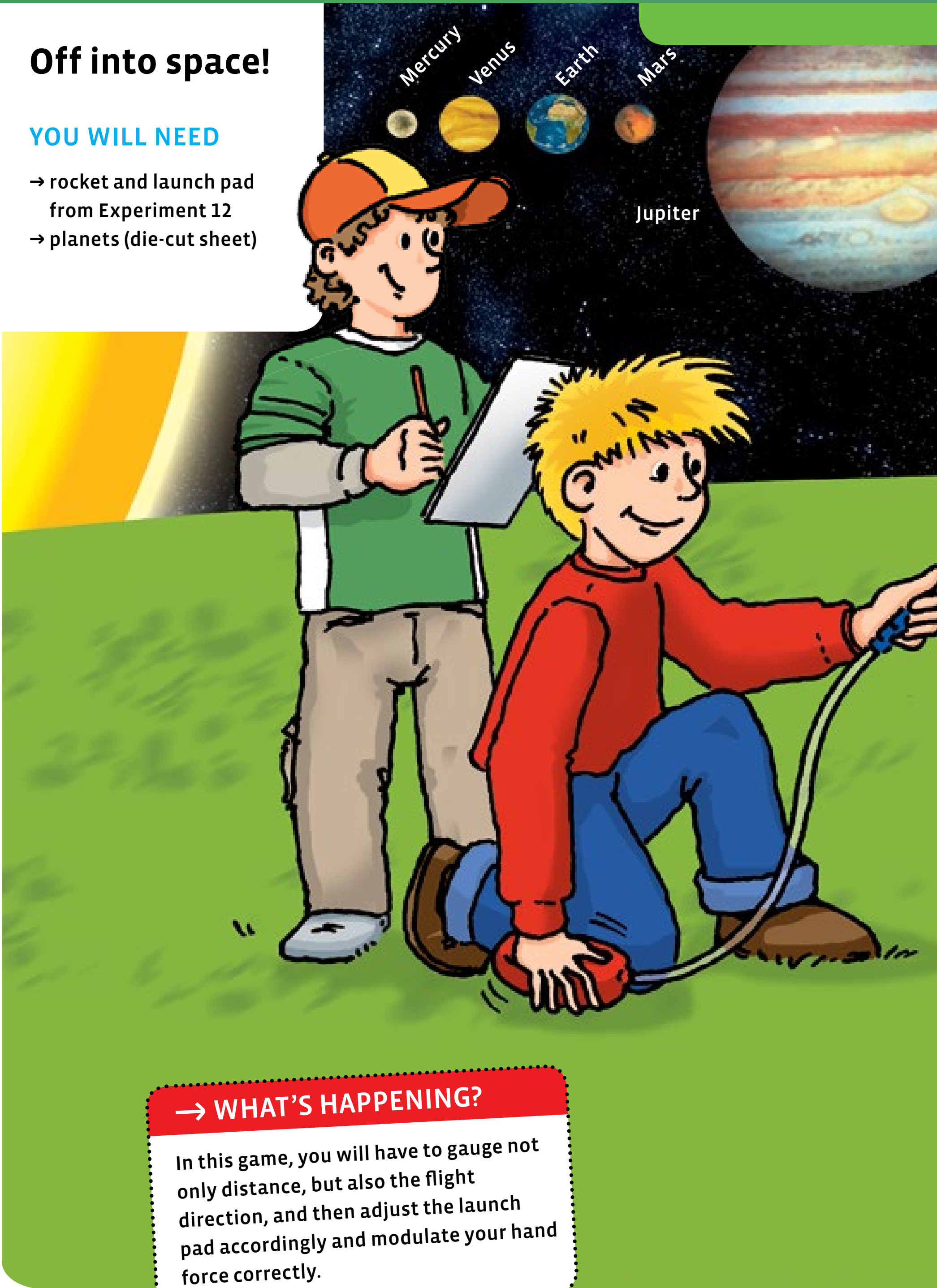
→ WHAT'S HAPPENING?

There is, in fact, an ideal launch angle: The rocket will fly the farthest when it is shot at an angle of about 45 degrees, or about halfway between vertical and horizontal (as in your launch pad). The stream of water will also go farthest if you hold the hose nozzle at that angle.

Off into space!

YOU WILL NEED

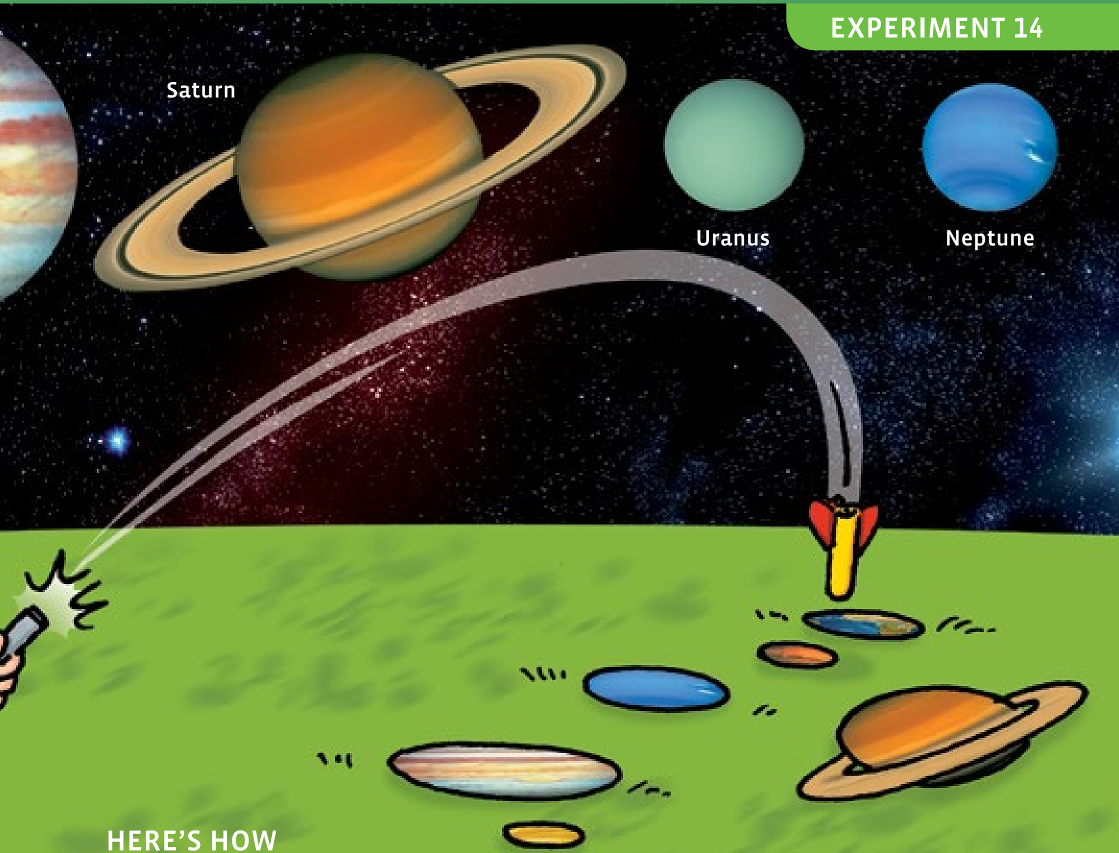
→ rocket and launch pad from Experiment 12
→ planets (die-cut sheet)



→ WHAT'S HAPPENING?

In this game, you will have to gauge not only distance, but also the flight direction, and then adjust the launch pad accordingly and modulate your hand force correctly.

EXPERIMENT 14



HERE'S HOW

1. This experiment is best performed outside, such as in a field or meadow. It's most fun to do it together with a friend and treat it as a competition or contest. Remove the planets from the die-cut sheet and distribute them over the area where you expect your rocket to land.

2. Decide how many rocket launches you want to make before determining who wins — for example, 20 launches. Place the planets near the Sun — Mercury, Venus, and Mars — close to the launch pad. They will be worth 10 points each. Place the others a little farther away. They will be worth 20 points each.

3. Set up the rocket and launch it. If you hit a target, give yourself the corresponding number of points, keeping a running tally of your score.

4. Keep track of the number of launches. Once you have reached the number you agreed on, the player with the most points wins.

5. You can vary the game if you like. For example, you could require each player to say in advance which planet he or she is trying to hit. A successful hit can result in another turn. You could also agree on different point allocations, such as more points for smaller planets.

Rocket car

YOU WILL NEED

→ rocket car (die-cut sheet)
→ balloon
→ closure clip
→ rubber band (if needed)
→ launch tube
→ 2 straight drinking straws
→ 2 wooden sticks
→ *glue stick*
→ *tape*
→ *bicycle pump*

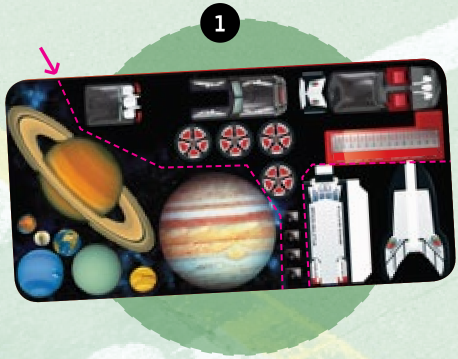
HERE'S HOW

1. Remove the rocket car pieces from the die-cut sheet.

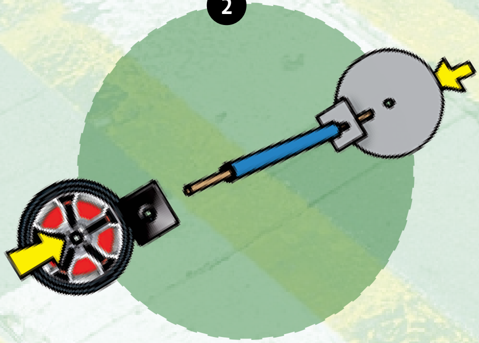
2. Assemble the axles with the wheels. If you like, you can shorten the straws and wooden sticks a little so that they don't stick out so far beyond the car's body. Start with one wheel and glue it to the axle reinforcement plate. Insert the stick with the straw into that wheel, and then add the second wheel with its axle reinforcement.

3. Fold and glue the car's body together as shown in the illustration. Secure the axles to the bottom with tape.

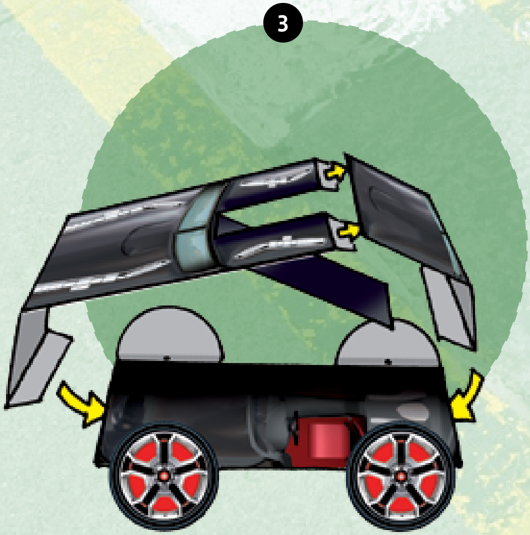
1



2



3



TIP!

If you have a friend who also has a rocket kit, you can race your cars against each other.

EXPERIMENT 15

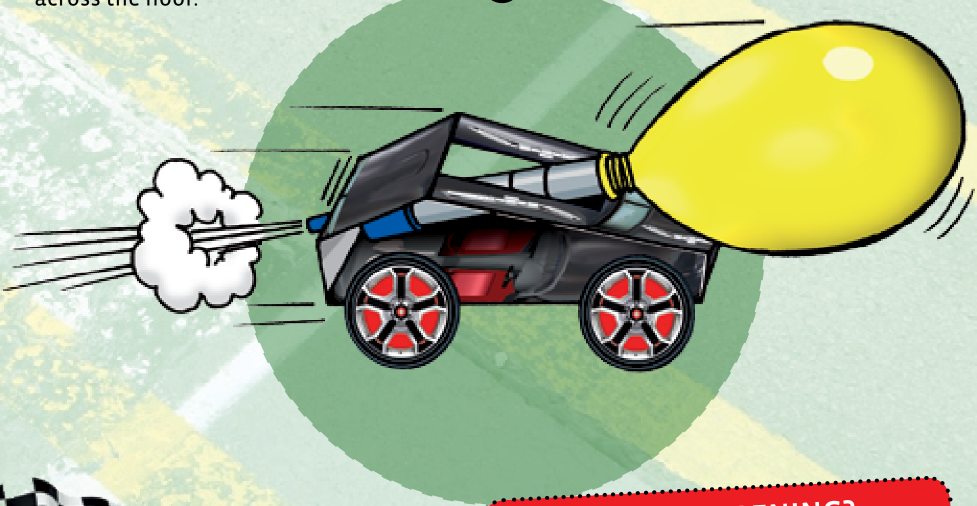
4. Fit the balloon over the end of the launch tube, holding it tight with the rubber band if necessary. Wedge the launch tube in the car's body, and secure it with tape (see arrow).

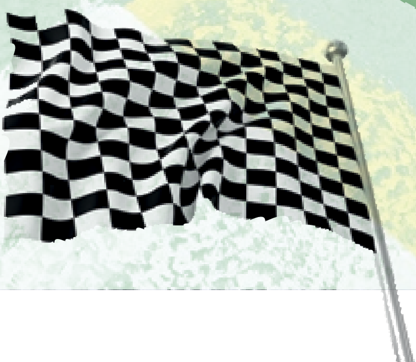
5. Pump up the balloon through the launch tube opening and close it with the clip. Look for a long, straight stretch of floor to serve as your racetrack.

6. Release the clip. The car will zoom off across the floor.

4 5

6



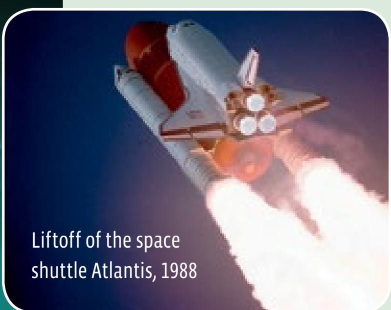


→ WHAT'S HAPPENING?

Because the wooden axles turn so easily inside the straw sections, the air shooting out of the balloon is strong enough to push the car several meters in no time at all — farther than the rocket flies, even.


Sputnik 3


Ariane 4


Liftoff of the space shuttle Atlantis, 1988

Rockets

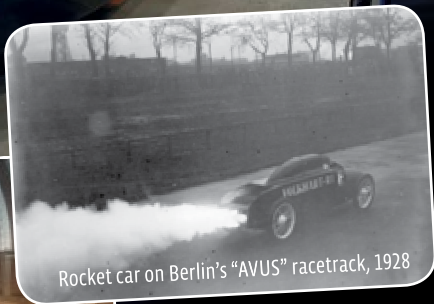
The first rockets, which were similar to those used for fireworks, were invented in China. They were launched in battles in order to frighten the enemy's horses. In Europe, the first small rocket was launched in 1555. In the following decades, rockets were primarily developed for use as weapons. In 1957, though, a rocket carried the first satellite, known as "Sputnik," into Earth's orbit. Since then, large rockets have primarily been deployed to send probes and satellites into space.

No airplane can penetrate into space, because its wings need air in order to fly. Space, however, has no air at all. So space ships have to work differently, like a kind of fireworks rocket. They produce large quantities of hot gases, which they expel at the highest possible speeds. This stream of gas creates a reactive thrust that propels the rocket forward. The faster the gas streams out, and the greater its mass, the greater the thrust.

Admittedly, if a rocket is too heavy it won't be able to reach the speed required to get away from the Earth. That is why engineers design rockets to be as light as possible.

Large rockets always have multiple stages. In other words, they consist of several rockets built on top of one another. At launch, they ignite their main engine, which is the first stage. Once the main engine's fuel has been used up, that stage is discarded. That is followed by the ignition of the second engine in the second, smaller, stage, which takes the rocket into its intended orbit. Some rockets, such as the Ariane 5, even have three stages.

CHECK IT OUT


Rocket car on Berlin's "AVUS" racetrack, 1928


ThrustSSC (Thrust SuperSonic Car)

Rocket Cars

To set speed records with cars, people have equipped them with rocket engines having a high level of thrust. In 1928, a powder-powered rocket car reached the then-astonishing speed of 228 kilometers per hour on Berlin's AVUS speedway. In 1997, the rocket car "ThrustSSC" reached 1227 kilometers per hour — about the speed of sound – on a dry seabed in the Nevada desert. During the following nears, rocket cars such as the Bloodhound supersonic car were to reach speeds of over 1600 kilometers per hour.

Even if you were to set the launch pad out in the open and shoot the rocket straight up, it wouldn't go very high. Why not? The answer lies in gravity, which is the topic of this chapter. In the final experiment, though, you will find out how you can achieve a weightless state, even if only briefly.

The Force of Attraction

EXPERIMENT 16

Inert mass

YOU WILL NEED

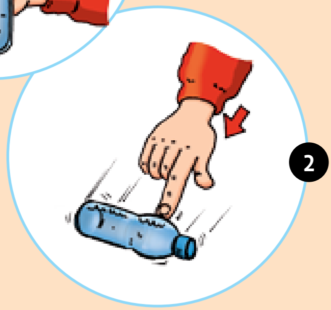
→ *plastic bottle (16 ounces)*
→ *water tap*

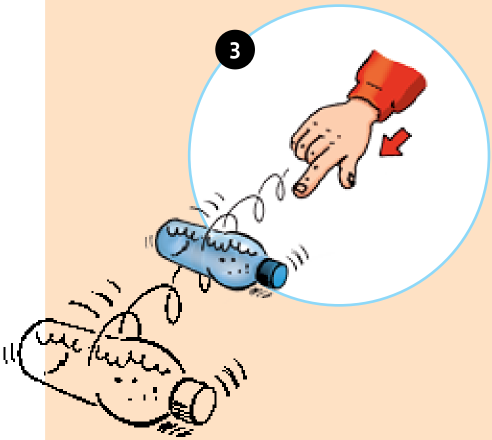
HERE'S HOW

1. Fill a plastic bottle with water and screw the lid on. Lay the bottle on its side on a flat, smooth surface. It won't roll.

2. Push your finger gently against the bottle. It will move a little. Once you stop pushing, the bottle will remain motionless again.

3. Give the bottle a good shove. Even if you don't keep pushing it, it will keep rolling a little ways.





→ WHAT'S HAPPENING?

The experiment shows that an object will strive to maintain its current state of motion. You have to exert force to change it. At first, the bottle was at rest and only moved because you pushed against it. But once it moved, it kept rolling a little without you having to keep pushing, at least until friction made it stop. This kind of phenomenon is known as "inertia."

A rocket in empty space, where there is no friction, would always keep flying straight due to its inertia — unless it used its own power to accelerate, brake, or change direction, or unless it were pulled by the gravitational force of another heavenly body.

EXPERIMENT 17

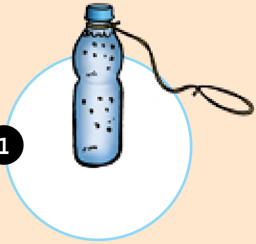
Inertia

YOU WILL NEED

→ *plastic bottle (16 ounces)*
→ *water tap*
→ *string*

CAUTION!
Perform this experiment outside, for example on a lawn. Be sure that you have enough space around you and that there isn't anybody right next to you.

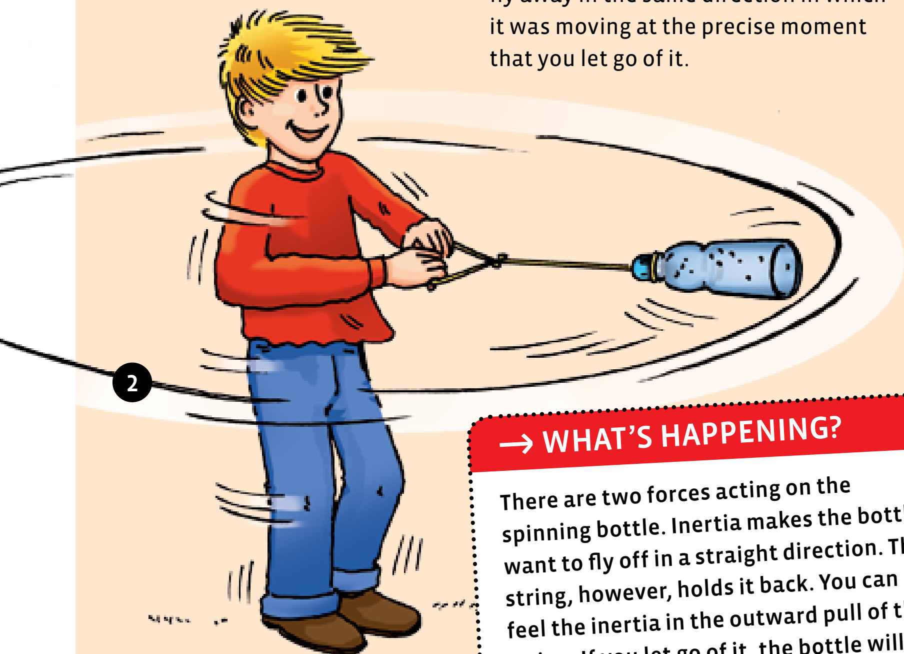
HERE'S HOW



1

1. Fill your bottle with water and fasten a piece of strong around its neck. Tie a tight knot so it can't slip off. Tie a loop at the other end of the string to serve as a handle.

2. Hold the string tightly in front of you at about breast height and spin around in a circle. You will feel a pull on the string. Then let go of the string. The bottle will fly away in the same direction in which it was moving at the precise moment that you let go of it.



2

→ WHAT'S HAPPENING?

There are two forces acting on the spinning bottle. Inertia makes the bottle want to fly off in a straight direction. The string, however, holds it back. You can feel the inertia in the outward pull of the string. If you let go of it, the bottle will fly off in the direction it is moving at precisely that split second.

EXPERIMENT 18

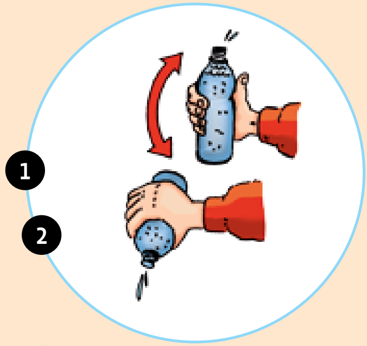
Weightless in your own garden

YOU WILL NEED

→ *plastic bottle (16 ounces)*
→ *water tap*

HERE'S HOW

Perform this experiment outside, for example on a wide path without any passers-by.



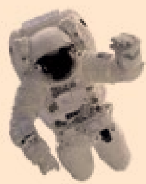
1. Fill a plastic bottle with water. Do not close the bottle.

2. Briefly turn the bottle upside down. Water will run out.

3. Now throw the bottle a few meters away from you, with the open end down. How does the trail of water look on the ground?

→ WHAT'S HAPPENING?

You would think the bottle would have to leave a visible trail of water on the ground, since its cap is not on. But you can easily see that it doesn't do this as it flies through the air — only before you throw it and after it lands does water flow out. The reason: As the bottle falls in an arc to the ground, it is (like any free-falling object) weightless. During its fall, the water feels no gravity at all, any more than astronauts in a space station feel gravity.



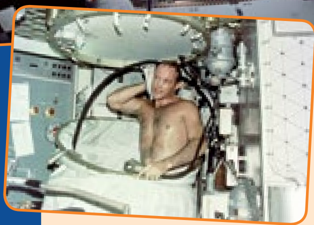
Forces at Play

Gravity also acts on a satellite orbiting the Earth, pulling it towards the Earth's center. But it can evidently resist this force, since it continues in its orbit at high speed. Thanks to inertia and the absence of friction in airless space, it can maintain its speed for a long time. You can picture the flight of the satellite as a constant falling — thanks to its high speed, it keeps falling around the Earth, so to speak. And in a free-falling object, you feel no gravity.

Why does the satellite "fall around the Earth"?

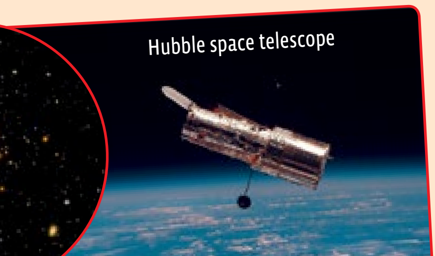
Try performing a thought experiment: Imagine that you shoot a round ball horizontally out of a cannon. At a low muzzle velocity, it might fall back to the ground a few kilometers away, while it might fly a few hundred kilometers if the speed is high enough. But if it were even faster (about 8 kilometers per second), it wouldn't land at all. It would enter an orbit around the Earth. This is called the "first cosmic velocity," or "escape velocity." At even higher speeds, it would orbit higher and higher around the Earth, and starting at 11 kilometers per second (the second comic velocity, around 40,000 kilometers per hour), it would leave orbit and shoot off into space.

CHECK IT OUT



Manned space travel...

... is a lot more expensive than unmanned voyages. After all, the astronauts have to take along air to breathe and food to eat. And for longer voyages, they need a lot of room for moving around, sleeping, going to the bathroom, and a lot of other things that computers don't need to do. On top of that, humans (unlike computers) want to return home. That means that they have to carry along enough air, food, and fuel for the return trip as well. So a space ship for humans is much heavier and larger and needs a lot more fuel than a rocket that just carries a probe into space.



Hubble space telescope

Kosmos Quality and Safety

More than one hundred years of expertise in publishing science experiment kits stand behind every product that bears the Kosmos name. Kosmos experiment kits are designed by an experienced team of specialists and tested with the utmost care during development and production. With regard to product safety, these experiment kits follow European and US safety standards, as well as our own refined proprietary safety guidelines. By working closely with our manufacturing partners and safety testing labs, we are able to control all stages of production. While the majority of our products are made in Germany, all of our products, regardless of origin, follow the same rigid quality standards.

1st Edition 2012

Conception: Ruth Schildhauer
Editing: Christiane Theis, lektorat&textlabor, Gärtringen
Project direction: Dr. Mark Bachofer, Ita Meister
Product development: Elena Ryvkin
Design and layout: Atelier Bea Klenk, Klenk/Riedinger

Project direction: Dr. Mark Bachofer,
Text: Ruth Schildhauer, Dr. Rainer Köthe
Product development: Elena Ryvkin
Design and layout: Atelier Bea Klenk, Klenk/Riedinger
Illustrations: Wolfgang Peschke, Peschke Grafik-Design, Ostfildern
Photos: ag visuell , p. 6, 7; Alterfalter, p. 6; Andres Rodriguez, p. 1 ml, 2; Artur Synenko, p. 8; Carol Hyman, U1; Eric Isselée, p. 2; GAP artwork, p. 24, 25; Gerda Bermes, U1; Gina Sanders, p. 8; Lasse Kristensen, p. 1 bm, 30, 31; Lucky Dragon , p. 1 bl, 9, 10, 11; Mat Hayward, p. 1 tr, 16 l; mik ivan , p. 8; Moreno Novello, p. 8 tm; Paul W. Brian, p. 4, 5; picsfive, p. 11 ff.; remar , p. 12; Robert Hoetink, p. 8; seasonal art, p. 10; Taras Kovalchuk, p. 12; tiero, p. 25 bl; Tjefferson, U1/U4; virtua73, p. 16 (all ©fotolia.com); Bundesarchiv, p. 27 mr; Cmglee, p. 27 m; Enin Arsenij, p. 26 tl; Jeff Dahl, p. 15 tr (all wikipedia, CC-BY-SA-3.0); Tony Hisgett, p. 26, 27 (wikipedia CC-BY-2.0); NN, p. 10 (wikipedia public domain); NASA, p. 1 tl, 13, 14, 15 bl, 26 ml, 26 bl, 28, 32 tr, 32 b, 32 b; Oliver Klasen, Stuttgart, U1; Michael Flaig, pro-studios, Stuttgart, U1, U2

Packaging design and layout: Atelier Bea Klenk, Klenk/Riedinger
Packaging photos: Gerda Bermes, Carol Hyman, Tjefferson (all ©fotolia.com); Pikarl (wikipedia public domain); Oliver Klasen , Stuttgart; Michael Flaig, pro-studios, Stuttgart and illustration by Oliver Marraffa, Atelier Bea Klenk, Berlin
Quiz flap photos: humbak, Delphimages, Tino Hemmann, Li-Bro, picsfive (all ©fotolia.com); NASA and Cmglee (wikipedia CC-BY-SA-3.0)

Text and Concept: Ted McGuire; Additional Graphics and Layout: Dan Freitas
Distributed in North America by Thames & Kosmos, LLC. Providence, RI 02903
Phone: 800-587-2872; Email: support@thamesandkosmos.com

Printed in Germany / Imprimé en Allemagne