EXPERIMENT MANUAL

Water Power

Rocket-Propelled Cars, Boats, and More

Discover the driving force of water

THAMES & KOSMOS

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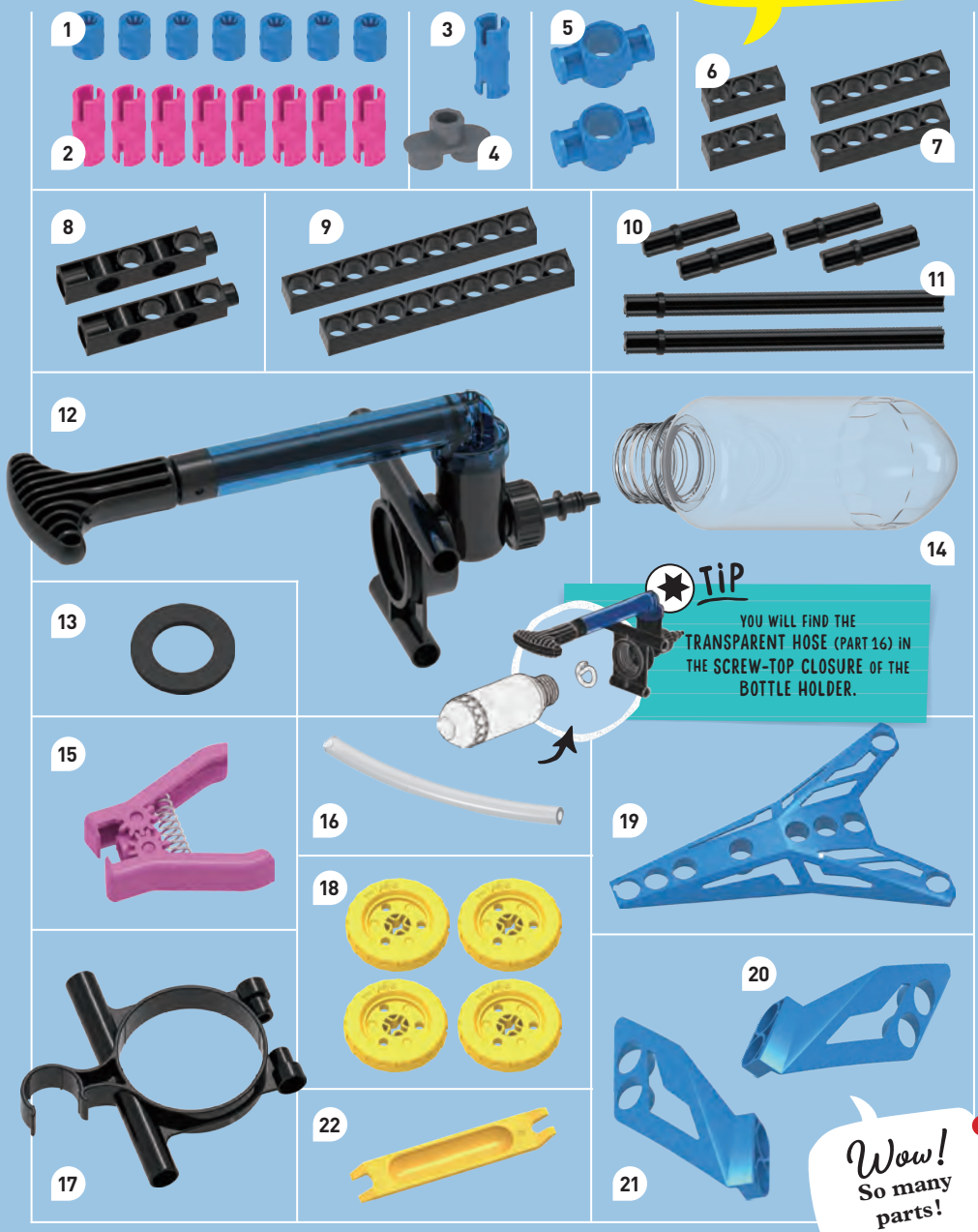
KIT CONTENTS

What's inside your experiment kit:



Good to know!

If you are missing any parts, please contact Thames & Kosmos technical support.

TIP

YOU WILL FIND THE TRANSPARENT HOSE (PART 16) IN THE SCREW-TOP CLOSURE OF THE BOTTLE HOLDER.

Wow! So many parts!

CONTENTS

TIP

ADDITIONAL INFORMATION CAN BE FOUND IN THE CHECK IT OUT SECTIONS ON PAGES 8, 14, AND 32.

YOU WILL ALSO NEED:
Plenty of water and spare clothes. You will be getting wet! You will also need a marshmallow, a piece of toasted bread, and a marble or die for one experiment.

Checklist:

✓	No.	Description	Quantity	Part No.
○	1	Short anchor pin	7	719435
○	2	Connector pin	8	722818
○	3	Joint pin	1	717768
○	4	Two-to-one converter	1	720774
○	5	1-hole connector	2	723837
○	6	3-hole rod	2	719234
○	7	5-hole rod	2	716876
○	8	5-hole cross rod	2	717889
○	9	9-hole rod	2	717806
○	10	30-mm axle	4	716860
○	11	100-mm axle	2	716901

✓	No.	Description	Quantity	Part No.
○	12	Pump with bottle holder	1	719208
○	13	Gasket	1	710135
○	14	Compressed air bottle	1	719207
○	15	Compressed air clamp	1	723840
○	16	Hose	1	723839
○	17	Bottle stabilizer	1	719219
○	18	Wheels / float	4	723838
○	19	Front module	1	720765
○	20	Spoiler / left wing	1	720763
○	21	Spoiler / right wing	1	720764
○	22	Anchor pin lever	1	702590

TIP

easy ⊙○○ medium ⊙⊙○ hard ⊙⊙⊙

ABOVE EACH MODEL, YOU WILL FIND A BAR THAT SHOWS HOW DIFFICULT THE MODEL'S ASSEMBLY WILL BE.

Scan this QR code for more resources for educators

Ready? Let's get building!

SAFETY INFORMATION

WARNING!
Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Keep the packaging and instructions as they contain important information.

WARNING!
Only to be used in water in which the child is within its depth and under adult supervision.

For the water gun: **WARNING!** Do not aim at eyes or face.

Dear Explorers,

Please read these notes carefully. This information will help you avoid possible risks and get the most out of this experiment kit.

Proper handling of parts and models

→ In order to prolong your enjoyment of this experiment kit, please note the following: even though some of the components may be very small, they can still be very important for assembling the various models. To keep track of the pieces that you don't need for the model you are currently working on, you might want to keep them safe in a resealable bag.

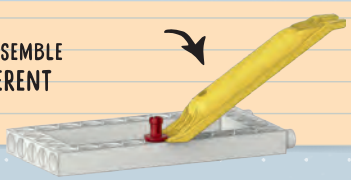
→ Each model sprays water when used, so only perform the experiments in a place that can get wet (like the outdoors or in the bathtub). Of course, you will have the most fun using the models outside. Let the model dry fully after each experiment.

Playing near the water

→ If you want to try using your boat models outside on a natural body of water, please note two things: **Never play without an adult at the water. An adult needs to be there to call for help in case you fall in, or something else happens.** So always take a grownup with you. Second, you should always tie the boats to a cord or string, so that they do not get lost even if they travel far away on the water.

TIP

YOU WILL USE THE ANCHOR PIN LEVER TO DISASSEMBLE EACH MODEL AFTER YOU USE IT. IT HAS TWO DIFFERENT ENDS FOR DIFFERENT-SIZED PARTS.



IMPORTANT INFORMATION

Dear parents and adults,

Children want to explore, understand, and create new things. They want to try new things and they want to do this on their own. They want to gain knowledge! They can do all of this with Thames & Kosmos experiment kits. With every single experiment, they grow smarter and more knowledgeable.

— Before building and experimenting, read the instructions together with your child and discuss the safety instructions. Support your child with advice and a helping hand, especially during tricky assembly steps or experiments. This kit contains very small parts. Help your child make sure to keep the parts together.

— To prevent damage to the work surface on which your child is building and experimenting, provide them with a mat or other surface protection.

— Water is an important component of this kit, and none of the models will work properly without it. In most of the experiments, the water will squirt out of a small nozzle. Make sure that your child only performs the experiments in locations that can get wet, such as in the bath or outdoors.

— If your child would like to test the models in natural bodies of water, make sure that he or she doesn't go alone, and is always accompanied by an adult.

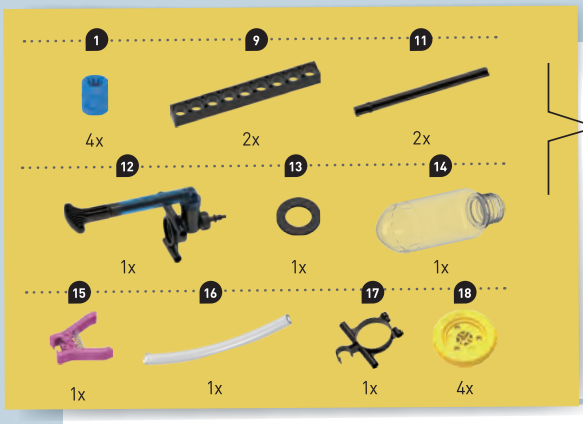
Have fun!

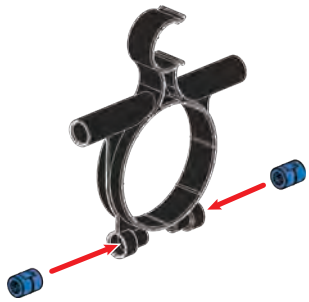
We hope you and your child have a lot of fun with this kit!

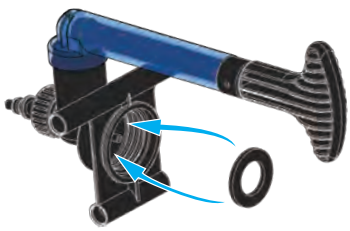
Water Car

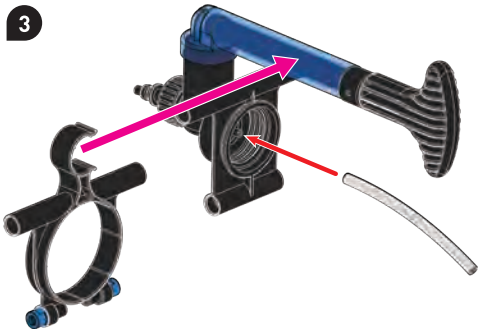
Are you ready? It's time to get started with your first water-powered model. Start by building a simple and cool car that will teach you the basics of how the pump and bottle work.

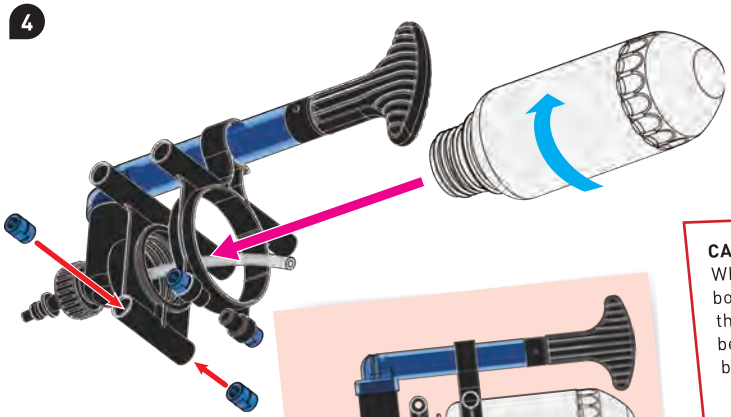
ASSEMBLY











CAREFUL!
When screwing on the bottle, make sure that the hose is inside and bending toward the bottom.

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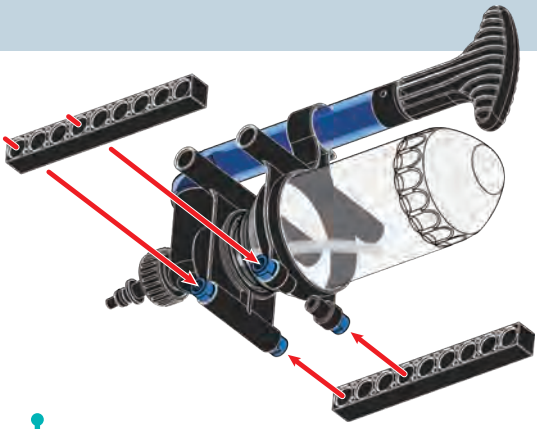

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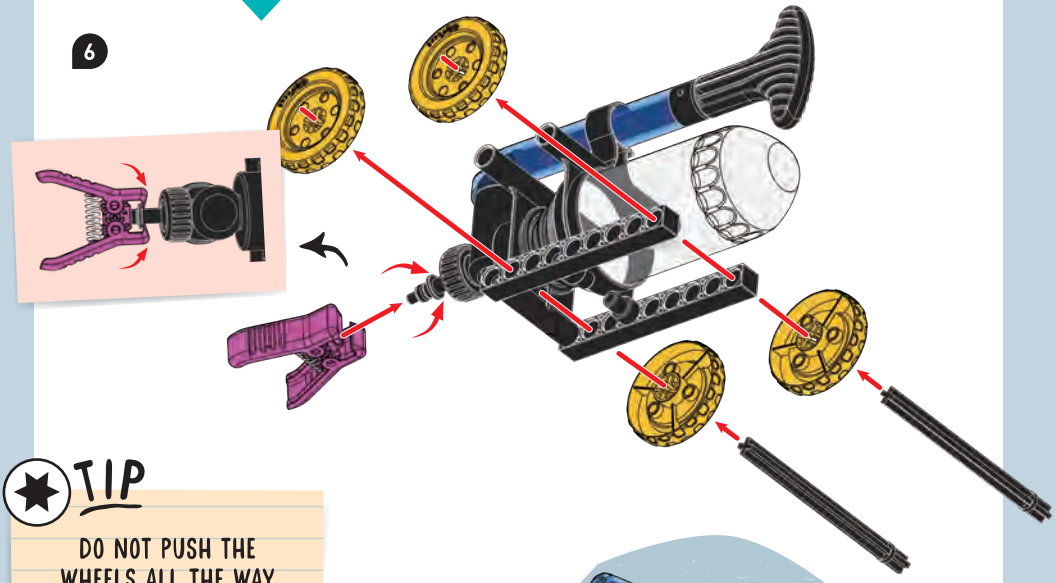
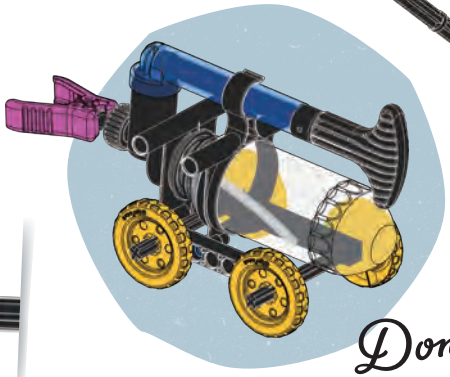


TIP

DO NOT PUSH THE WHEELS ALL THE WAY ONTO THE SHAFT. THERE SHOULD ALWAYS BE A GAP OF ABOUT ONE MILLIMETER BETWEEN THE FRAME AND THE WHEELS SO THEY CAN TURN FREELY.



Done!

EXPERIMENT 1

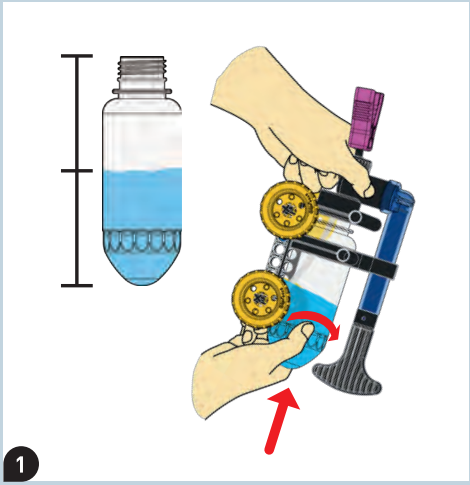
You will need

Your water car, some water, and a test track that can get wet

Here's how

1. Unscrew the compressed air bottle from your model, fill it halfway with water, then screw it back on. When you screw it on, make sure that the hose is bent downward so that it touches the lower inside wall of the bottle.
2. Pump about 50 or 60 times to build up pressure in the bottle.
3. Place the model on a solid surface that can get wet, then remove the clamp from the model. A mixture of air and water will flow out from the nozzle at the back, and the car will shoot forward.
4. Repeat the experiment without putting any water in the bottle.

What do you notice?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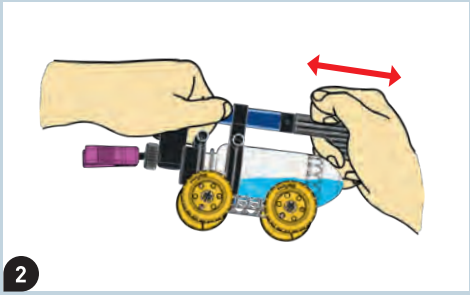
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WHAT'S HAPPENING?

When the clamp was removed, a mixture of air and water escaped from the nozzle at high speed, causing your car to shoot forward. On the next page, you will learn why that happened and why the car barely moved when there was only air in the bottle.

TIP

MAKE SURE THAT THE HOSE TOUCHES THE LOWER INSIDE WALL OF THE BOTTLE. YOU WANT HOSE TO SUCK UP WATER, NOT AIR, SO THAT IT SHOOTS WATER OUT OF THE NOZZLE.

WHILE YOU ARE PUMPING, IF AIR OR WATER ESCAPES FROM THE BOTTLE, CHECK TO MAKE SURE THAT THE GASKET IS PROPERLY MOUNTED, AND THE BOTTLE IS FIRMLY SCREWED ON.

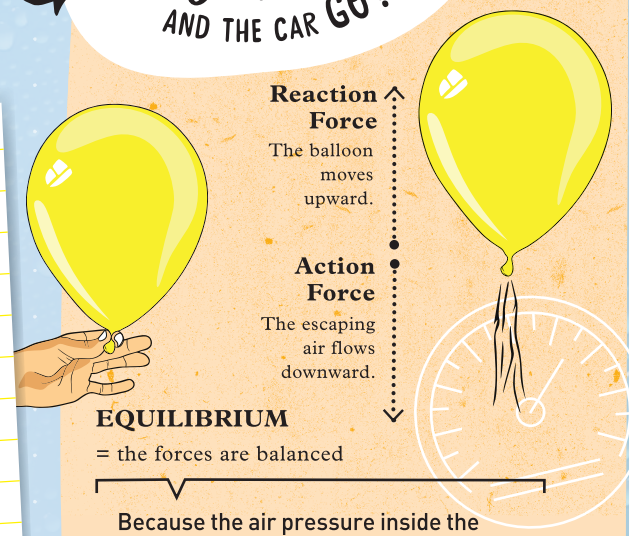
CHECK IT OUT

What's going on here?

In your everyday life, you have probably experienced the phenomenon that causes your water car to move forward. If you inflate a **balloon** and then let it go without tying it, the balloon will fly through the air. That is because the air pressure inside of the inflated balloon is greater than the air pressure outside of the balloon. The air inside tries to balance out this difference by escaping.

As long as you keep the opening of the balloon pinched closed, the air inside pushes against the elastic inner walls. As soon as you let go, though, the air flows out of the balloon **at high speed.** The same thing is happening with your car.

BUT WHAT MAKES the balloon fly AND THE CAR GO?



EQUILIBRIUM
= the forces are balanced

Because the air pressure inside the balloon is higher than outside, the air inside wants to get out. As it escapes downward, the air flowing out creates an equally large force in the opposite direction, causing the balloon to accelerate upwards. This principal is often called **recoil**, which is described by Newton's Third Law of Motion, attributed to the physicist Isaac Newton.

WHY IS THE *water* NECESSARY?

If you try to power the car with compressed air and no water, you will see that it hardly moves. That's because the action and reaction forces at work in your experiment depend on the mass of whatever is escaping out of the nozzle. A larger escaping mass will create more action force, and therefore more reaction force, which causes a larger acceleration. Since the mass of water is far greater than that of air, the force driving your car forward is greater when water is shooting out.

TIP

YOU CAN LEARN MORE ABOUT THE RECOIL PRINCIPAL IN NATURE AND TECHNOLOGY ON PAGES 14 AND 15.

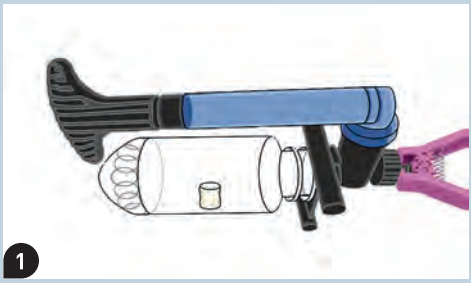
EXPERIMENT 2

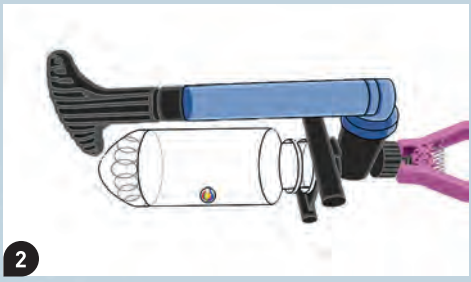
You will need

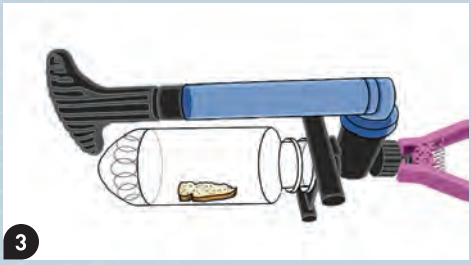
Your compressed air bottle with pump and clamp, a marshmallow, a piece of toasted bread, and a hard object like a marble

Here's how

1. Have an adult help you cut off a small piece of marshmallow and place it in your compressed air bottle. Screw the bottle onto the pump and place the clamp on the nozzle. Now pump about 80 times. Keep your eye on the marshmallow. Has it changed? Then remove the clamp and watch what happens.
2. Repeat the experiment, but this time put a die, a marble, or some other kind of hard object in the bottle.
3. Repeat the experiment again, but this time with a piece of toasted bread in the bottle.
4. Wash the bottle well afterwards.







WHAT'S HAPPENING?

The more air you pump into the bottle, the smaller the marshmallow becomes. And when you release the clamp, the marshmallow expands to its original size again. In that way, it behaves similarly to the air that you pump into the bottle. The more you pump, the more **compressed** the air becomes. The marble or die, on the other hand, behaves more like water, which is essentially **incompressible.** No matter how much you pump, it will not change its shape or size. The toast, too, retains its shape even though it is soft. That is because the toast is **permeable** to air — it lets air flow through it — so the pressure inside and outside of the toast remains balanced.

Wow ...

That's fast!

Rocket Car

Are you ready for another model car? This race car works just like the previous model, except in this case you won't need the hose. Let's go!

ASSEMBLY


1
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1x
2x
2x
2x
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2x
2x
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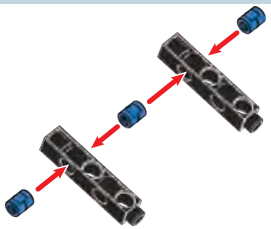
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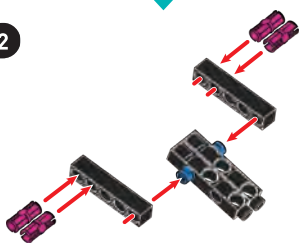
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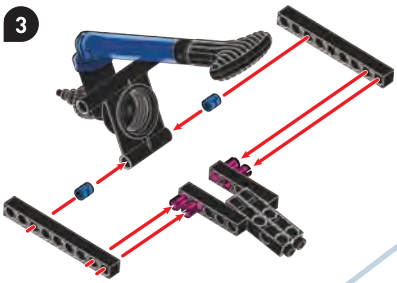
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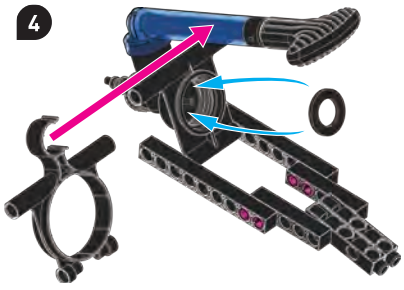
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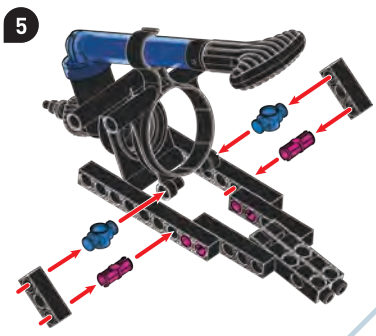
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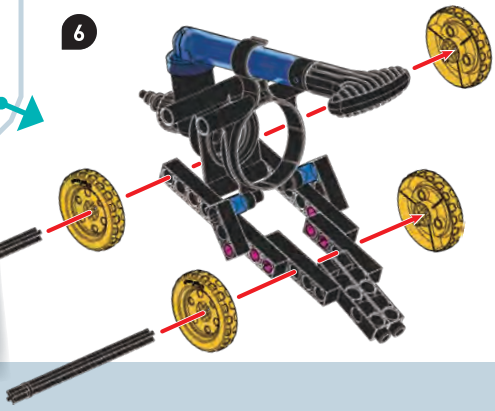
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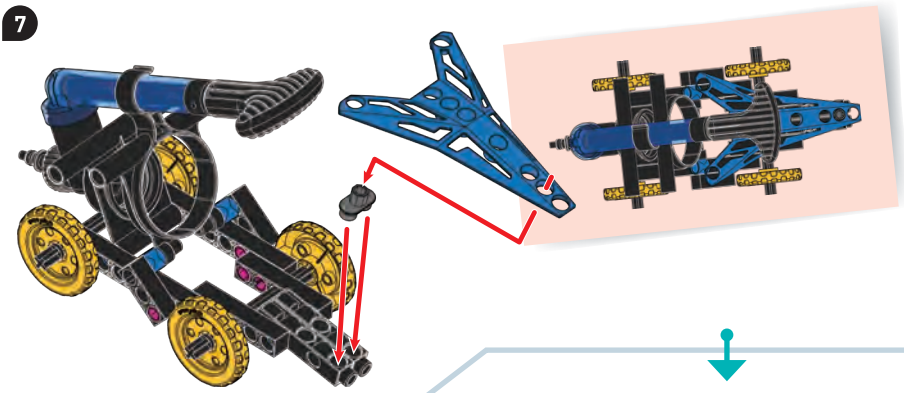

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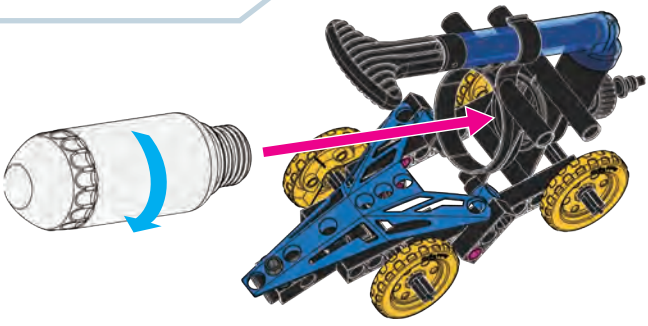

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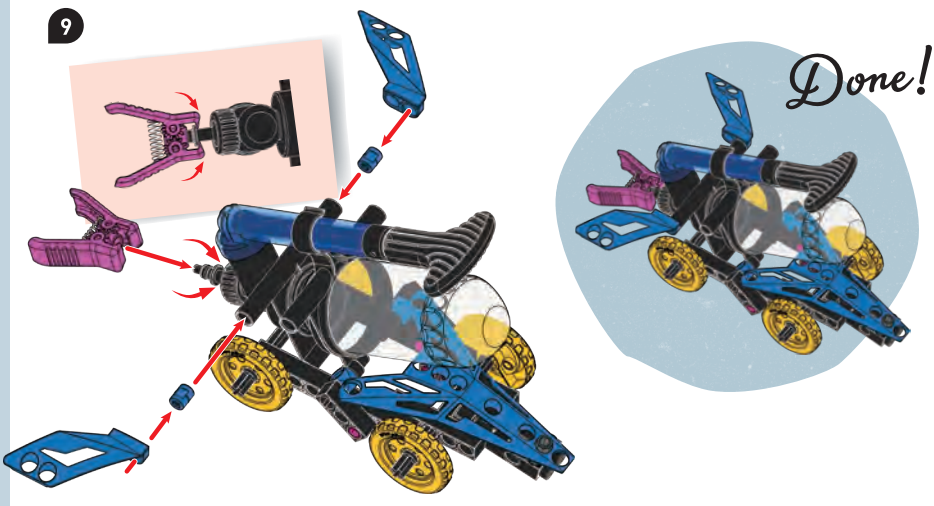


EXPERIMENT 3

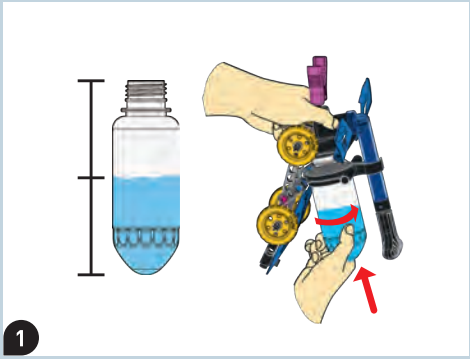
You will need

Your rocket car, some water, and a test track that can get wet

Here's how

1. Repeat steps 1 – 3 from experiment 1 (page 7).
2. Now try experimenting with different quantities of water in your bottle. What effect does that have on the range and speed of your rocket car? Make a prediction, then try it out. Enter your results into the data table below.

Volume of water in bottle at the start	Range in feet (how far did your car travel?)	Estimated speed (slow/ medium/fast)
No water in bottle		
Bottle 1/5 full (about 30 ml)		
Bottle 2/5 full (about 60 ml)		
Bottle 3/5 full (about 90 ml)		
Bottle 4/5 full (about 120 ml)		
Full bottle		



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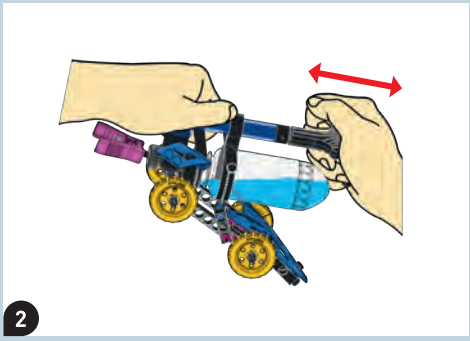

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WHAT'S HAPPENING?

You will see that your car drives fastest and farthest when the bottle starts 2/5 to 3/5 full (60–90 ml water). If your bottle is too empty, the water is quickly used up along with its thrusting force, and soon only air is coming out the nozzle, which doesn't propel the car as well (see page 8). If, on the other hand, you fill the bottle with too much water, you cannot pump very much air at all into the bottle. Because water cannot be compressed, the pressure in the bottle is quickly equalized. If there is not much pressure built up inside in the bottle, there will not be much propulsion either.

CHECK IT OUT

RECOIL in Nature and Technology

You have become familiar with the **recoil principal** in experiments 1 – 3 and in reading page 8 of this manual. Recoil frequently comes into play in nature and technology. These two pages explain where and how.

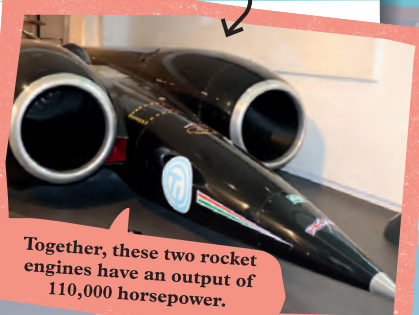
IN SPACE TRAVEL

NASA's Atlas V rocket takes off from Cape Canaveral.

Today's rockets are almost all powered by the recoil principle. That's because other means of propulsion, such as jet engines, cannot work in space. Jet engines suck in air, compress it, and then expel it at high speeds. That wouldn't work in space, because space is a vacuum — in other words, there is no air to suck in. **Rocket engines**, by contrast, contain everything they need for propulsion. Inside the rocket, a material is **combusted** and pushed out of a nozzle at high pressure. Rockets are a little more complicated than your water-powered models, of course, but work by the same principle.

On the ground

Long before humans went into space, we were using rocket engines in cars with the goal of setting ever-faster speed records, with the first rocket car driven in 1928 in Europe. Since then, the rocket engines installed in cars have become more and more powerful. In 1997, the ThrustSSC rocket car attained a speed of 763 miles per hour in the Black Rock Desert in Nevada, and became the first car to travel faster than the speed of sound. The rocket car, which admittedly looks more like a rocket than a car, is over 50 feet long and 12 feet wide, and weighs over 10 tons.



Together, these two rocket engines have an output of 110,000 horsepower.

IN THE Animal Kingdom

Usually, an **octopus** moves around by walking across the sea floor on its legs. But if an octopus has to move fast, to escape from an enemy for example, it relies on **recoil.**

To do that, an octopus will first suck water into the hollow interior of its mantle. Then, it pushes the water at high pressure through a nozzle of sorts. Just as with one of your models, the recoil created by that maneuver pushes the octopus forward in the opposite direction from where the water is shooting out. By adjusting the position of its "nozzle," this animal can choose the direction in which it moves. So you might even say that your models are powered by an octopus engine.

An octopus uses the recoil principle when swimming.

In the Plant Kingdom

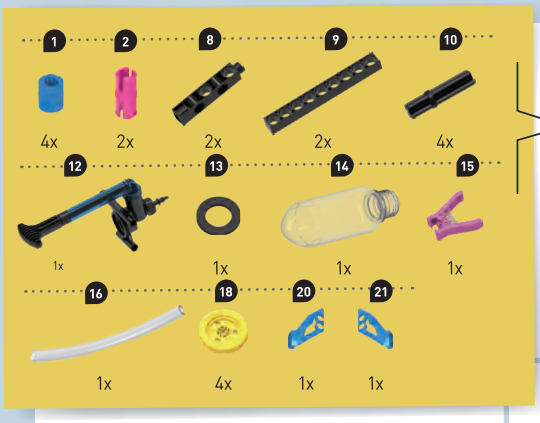
This plant has some tricks up its sleeve.

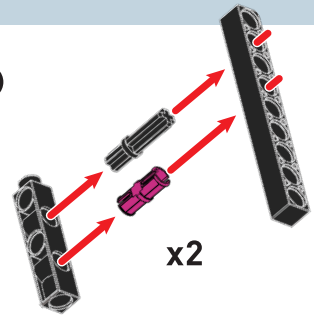
There are some plants that make use of the **recoil principal** as well. Plants don't to move themselves around, of course, but they do want to spread their seeds as far as possible. For example, there's the otherwise unassuming **sphagnum moss.** When its seeds are ripe, excess pressure builds up in the seed capsules. When the pressure becomes too great, the seed capsules explode. The plant is able to expel its seeds at speeds up to 80 miles per hour, and launch them high enough for the wind to carry them even farther along.

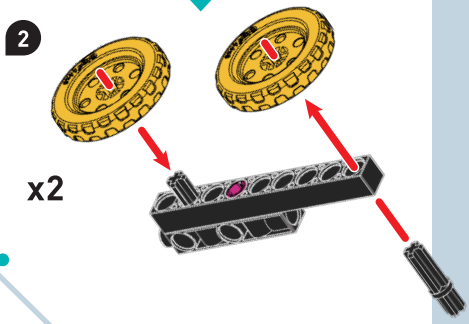
Cargo Barge

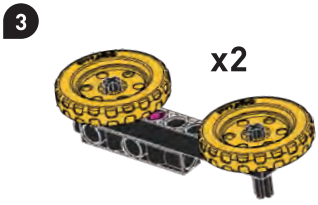
Now that you have tested your car models on the street or racetrack, it's time for some boat models. Ideally, try them out in a wading pool or your bathtub. Make sure an adult is present at all times if you are near water.

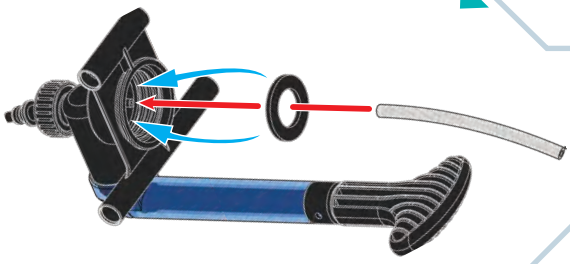
ASSEMBLY



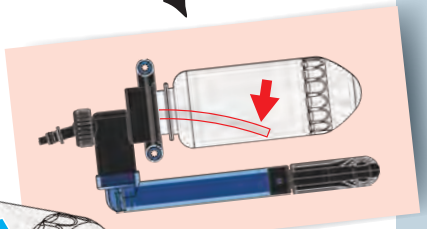


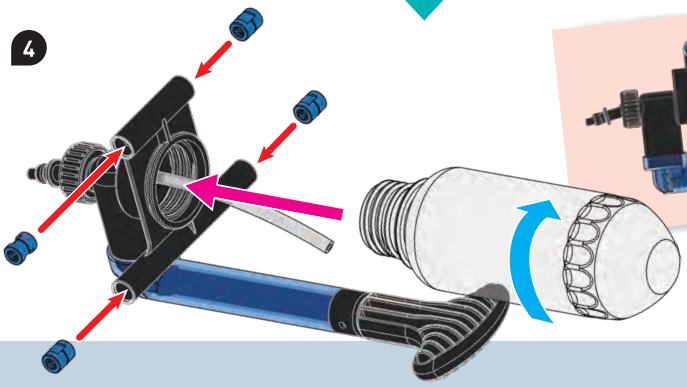






CAREFUL!
When screwing on the bottle, be sure that the hose is bending toward the bottom.





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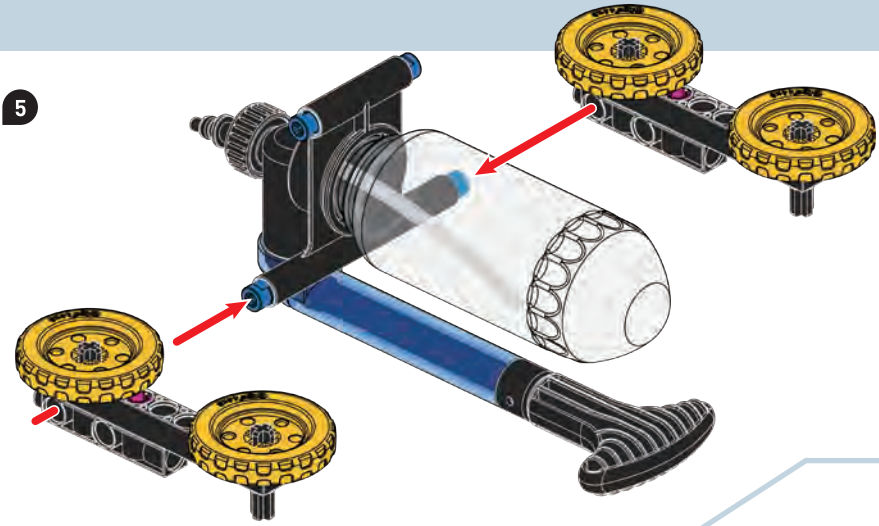

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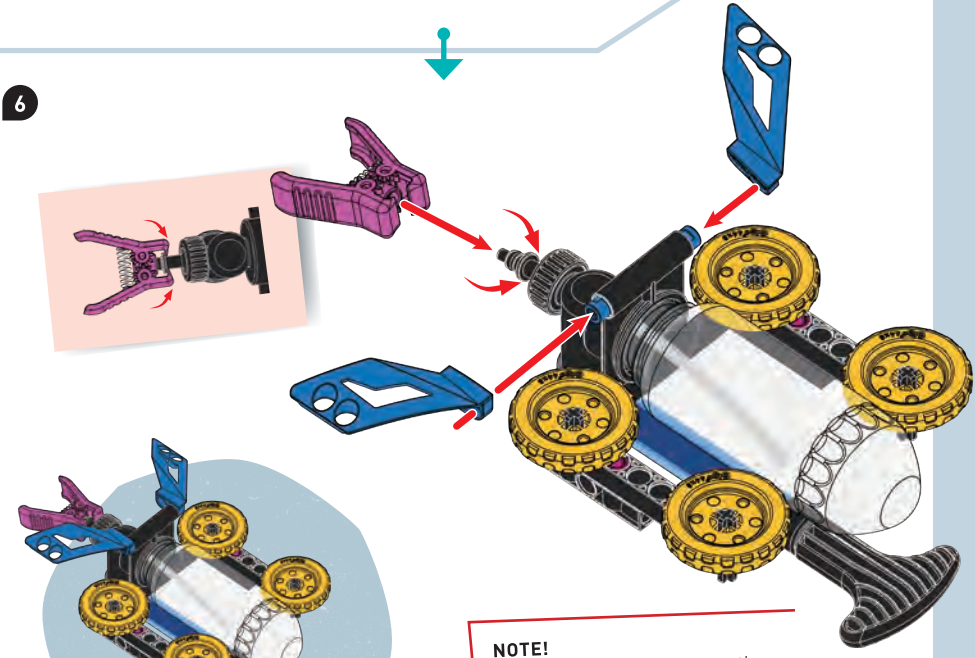


Done!

NOTE!
To keep your model from getting lost on the water, tie it to a piece of string that you hold onto when the boat takes off. That way, once the stored energy is used up, you can easily retrieve the boat.

EXPERIMENT 4

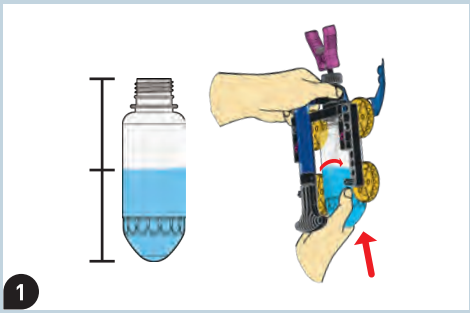
You will need

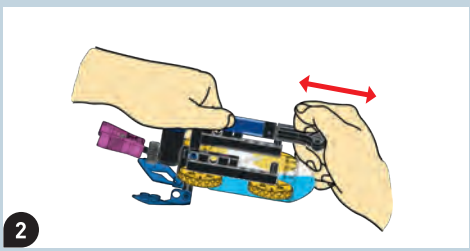
Your cargo barge, some water, and a body of water on which you can safely float your boat

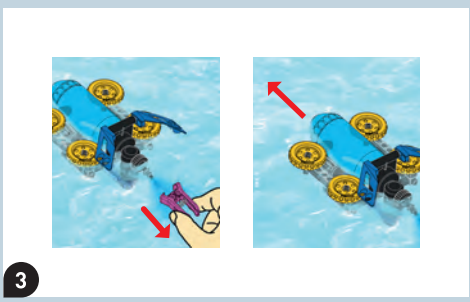
Here's how

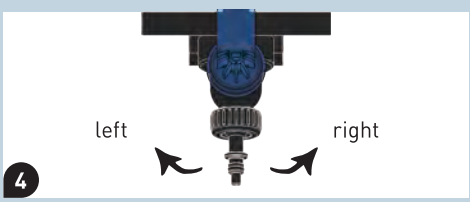
1. Unscrew the compressed air bottle from your model, fill it halfway with water, and screw it back on. When you screw it on, make sure that the hose is bent downward so that it touches the lower inside wall of the bottle.
2. Pump about 50 or 60 times to build up pressure in the bottle.
3. Place the boat on the surface of the water and remove the clamp.
4. Change the position of the nozzle and then repeat the experiment.

What do you notice?









WHAT'S HAPPENING?

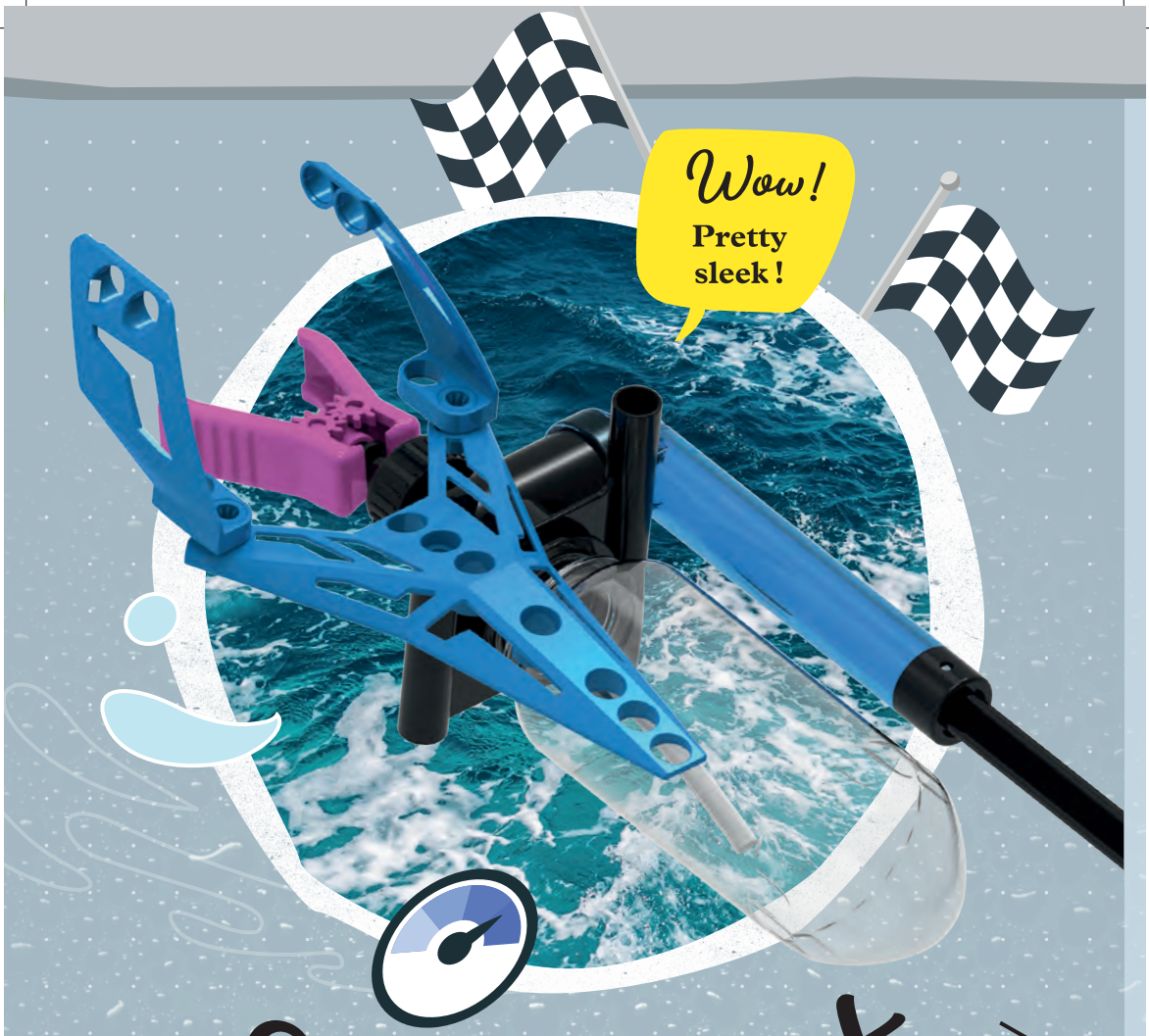
When the clamp was removed, a mixture of air and water escaped from the nozzle at high speed, causing your model to shoot forward. The barge moves in the direction opposite the direction that the mixture shoots out because of the recoil principal (see pages 8, 14, and 15).

TIP

MAKE SURE THAT THE HOSE TOUCHES THE LOWER INSIDE WALL OF THE BOTTLE, SINCE OTHERWISE THERE MIGHT ONLY BE AIR ESCAPING FROM THE NOZZLE.

WHILE YOU ARE PUMPING, IF AIR OR WATER ESCAPES FROM THE BOTTLE, CHECK TO MAKE SURE THAT THE GASKET IS PROPERLY MOUNTED, AND THE BOTTLE IS FIRMLY SCREWED ON.

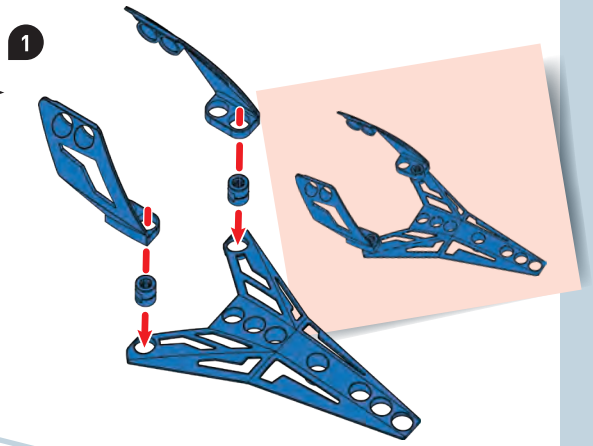
WARNING! If you want to try out your model on a pond, stream, pool, or lake, always take a grownup with you for help in case of emergency.

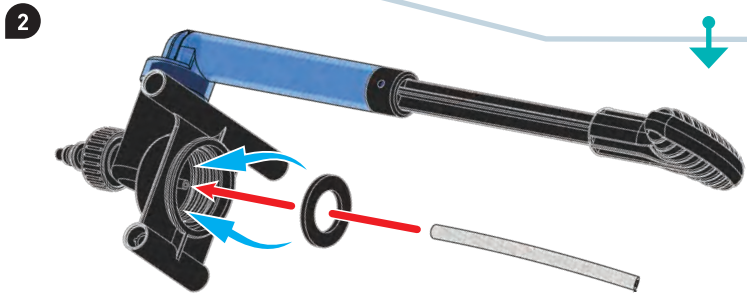


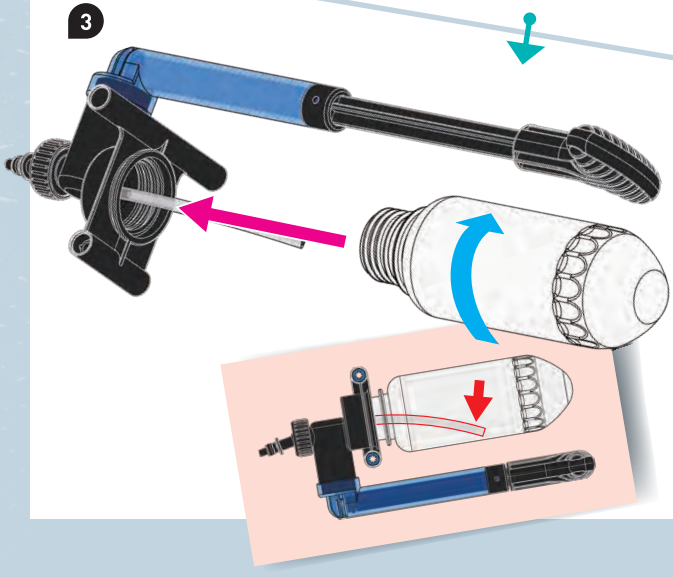
Speedboat

It's time for your second boat model. This one is sleeker than the first boat that you built, so it should move through the water a little faster than the cargo barge. Let's go!

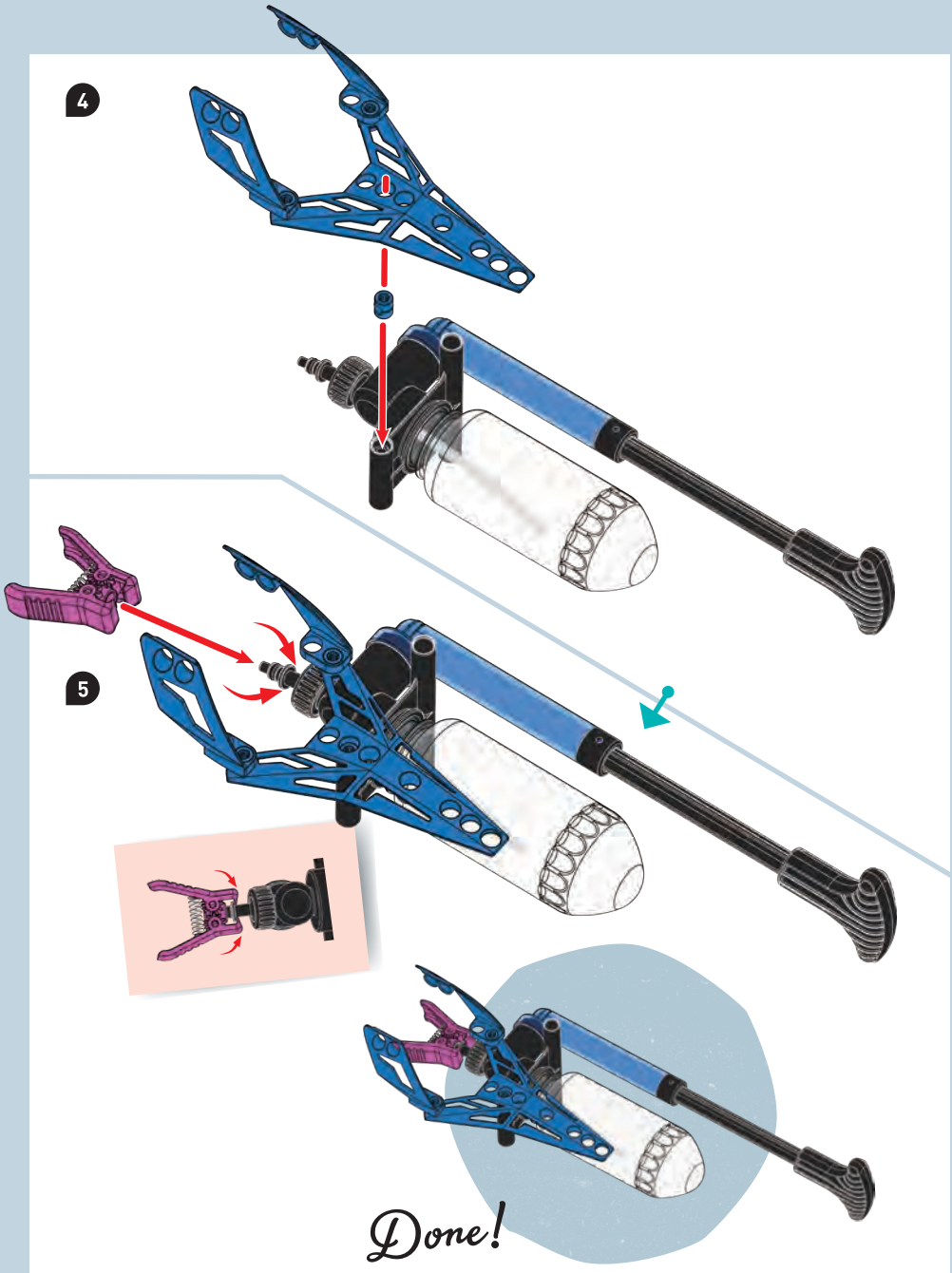
ASSEMBLY







CAREFUL!
When screwing on the bottle, be sure that the hose is bending toward the bottom.


4
5
Done!

EXPERIMENT 5

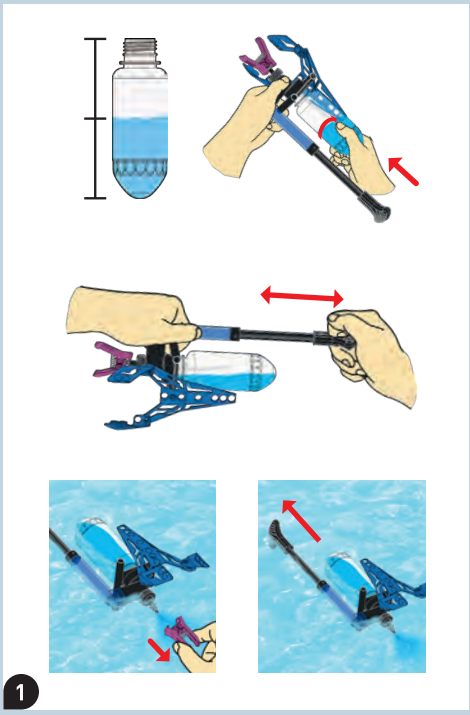
You will need

Your speedboat, some water, and a body of water on which you can safely float your boat

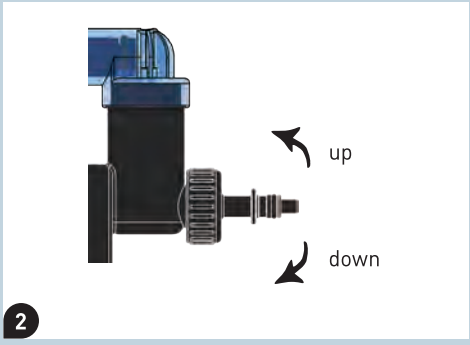
Here's how

1. Repeat steps 1 – 3 from experiment 4 on page 19.
2. Repeat the experiment, but this time don't fill the bottle with water. Also, try pushing the nozzle as far down as possible.

What do you notice?



1



2

WHAT'S HAPPENING?

When the clamp was removed, a mixture of air and water escaped from the nozzle at high speed and made your model shoot forward. If the nozzle is under water, this also works when there is just air in the bottle. The reason for this is that the escaping stream of air encounters strong resistance from the water, which generates more forward propulsion.

TIP

IF YOU ARE EXPERIMENTING WITH YOUR MODEL ON A BODY OF WATER, FOLLOW THE INSTRUCTIONS ON PAGE 2.

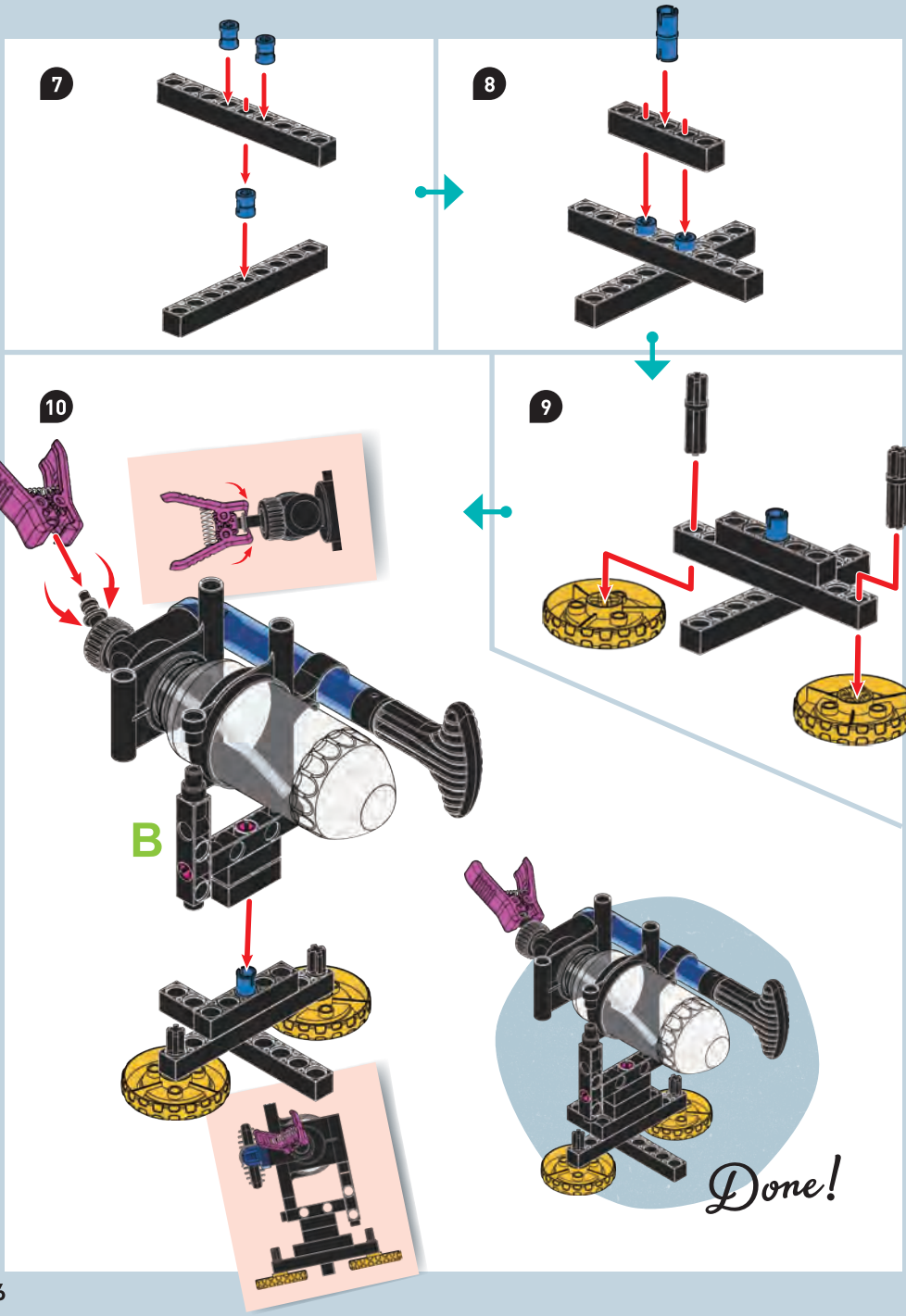
Lawn Sprinkler

Now that you have assembled and tested various means of transportation, it might be interesting to see if the bottle can power more than just vehicles. How about something nice and refreshing for a hot summer's day?

ASSEMBLY


1
2
3
6
7
8
6x
5x
1x
2x
2x
2x
9
10
12
13
2x
2x
1x
1x
14
15
16
17
18
1x
1x
1x
1x
2x

1
2
A
3
4
5
A
6
B


7
8
9
10
B
Done!

EXPERIMENT 5

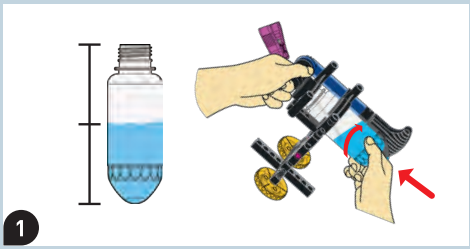
You will need

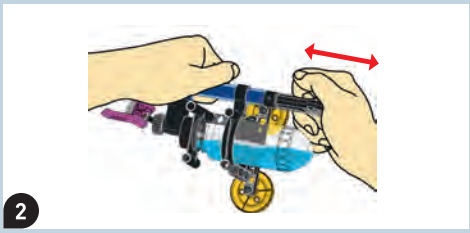
Your lawn sprinkler, some water, and an outdoor area that can get wet. You may also need something heavy enough to anchor the model to the ground

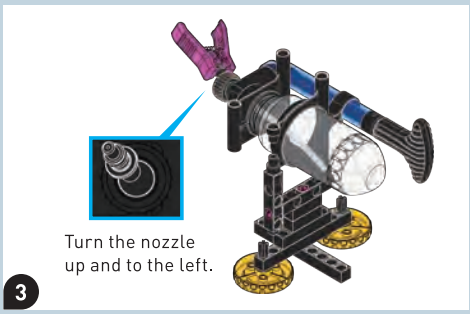
Here's how

1. Unscrew the compressed air bottle from your model, fill it halfway with water, then screw it back on. When you screw it on, make sure that the hose is bent downward so that it touches the lower inside wall of the bottle.
2. Pump about 50 or 60 times to build up pressure in the bottle.
3. Place the lawn sprinkler on a level surface and, if necessary, anchor the legs with rocks or other heavy objects, so that the sprinkler doesn't tip over when the water shoots out. Turn the nozzle so that it points upward and to the left.
4. Remove the clamp.

NOTE! This experiment must be performed outside, because things are going to get wet.







WHAT'S HAPPENING?

When the clamp is removed, the now-familiar mixture of air and water escapes from the nozzle. Because you turned the nozzle so that it pointed upward and to the left, the force of the recoil is exerted at an angle rather than straight at the model. That means that the lawn sprinkler starts turning in a counterclockwise direction.

TIP

WITH THE LAWN SPRINKLER AND A FEW FRIENDS, YOU CAN EVEN PLAY A VERSION OF TAG. START BY SITTING IN A CIRCLE AROUND THE MODEL. AFTER CARRYING OUT STEPS 3 AND 4, THE BOTTLE WILL START TO SPIN AND EVERYONE WILL GET WET. WHEN THE BOTTLE COMES TO A STOP, THE PLAYER AT WHOM THE NOZZLE IS POINTING IS IT. MAKE UP YOUR OWN YOUR OWN TAG RULES FROM THERE!

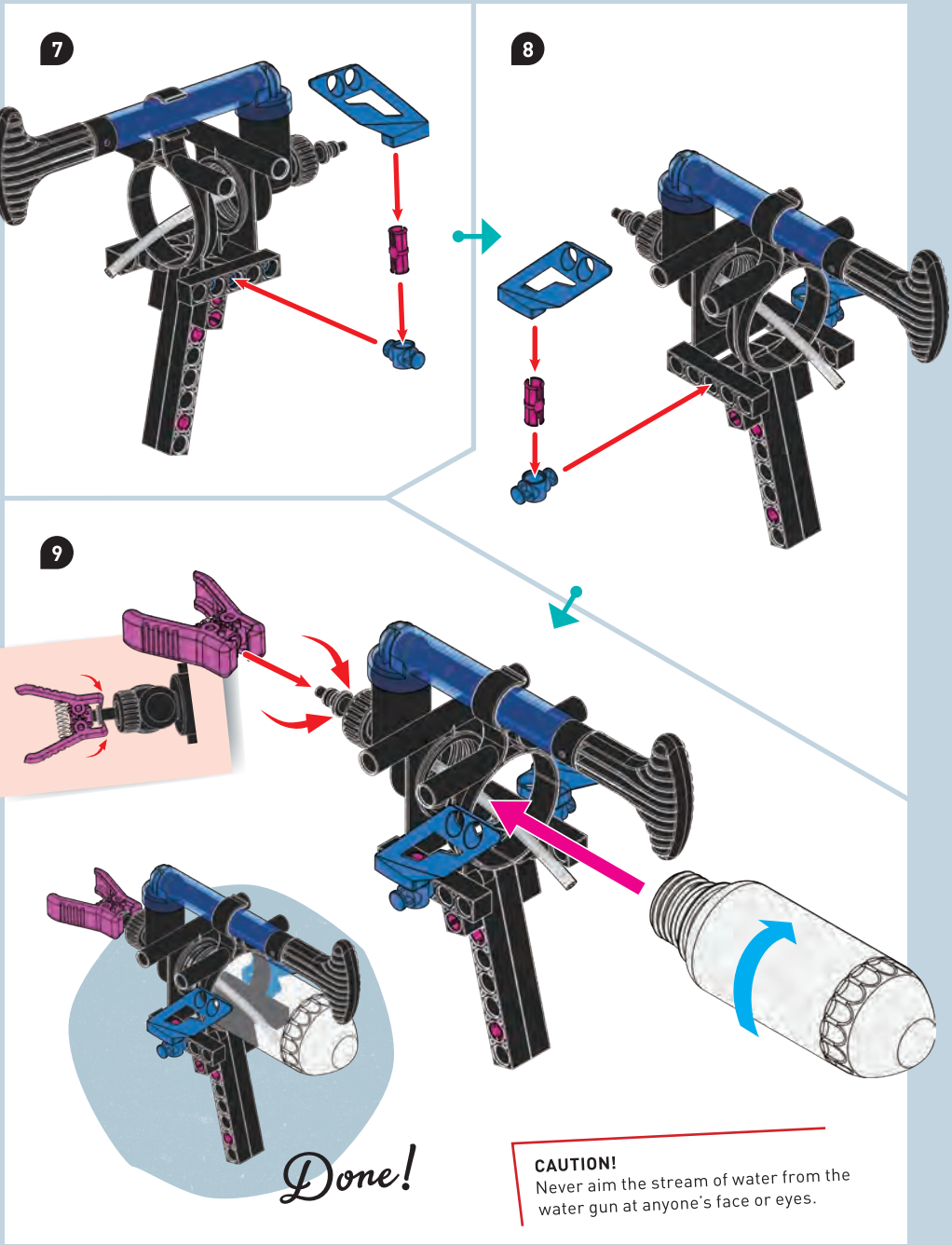
Water Gun

Now that you've gotten soaked experimenting with the last model, it's time for everyone else to get nice and wet too. The next few pages have instructions for building a water gun. Let's go!

ASSEMBLY


1
2
5
6
7
9
6x
8x
2x
2x
2x
2x
12
13
14
15
1x
1x
1x
1x
16
17
20
21
1x
1x
1x
1x

1
A
2
3
4
5
A
6



CAUTION!
Never aim the stream of water from the water gun at anyone's face or eyes.

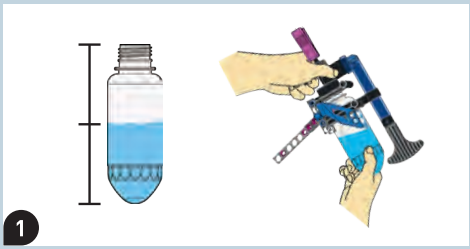
EXPERIMENT 6

You will need

Your water gun, some water, and an outdoor area that can get wet

Here's how

1. Repeat the usual steps for pumping the water gun with compressed air (for example, see page 19).
2. Experiment with the number of pump strokes to see what effect that has on how long and how far the water gun sprays. Enter your results in the table below.

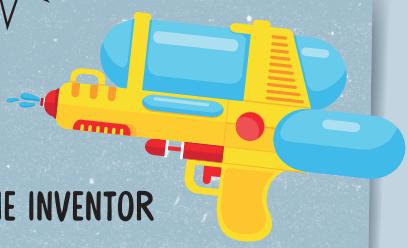


WHAT'S HAPPENING?

You will see that the less you pump at the start, the quicker the water gun stops spraying. If you can't remember why, take a look at page 8 again.

Number of pump strokes	Spraying distance in feet	Spraying time in seconds
10		
20		
30		
40		
50		
60		

SPOTLIGHT

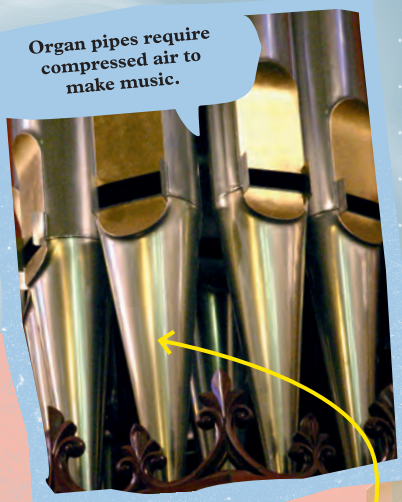


THE INVENTOR

This kind of water gun was invented by Lonnie Johnson and marketed in the 1990s under the name Super Soaker. Johnson is actually an aerospace engineer who was performing research in the 1980s on a new design of heat pump. As he was trying one out in his bathroom, he realized that his invention would lend itself to an exceptional water gun. The rest is history ...

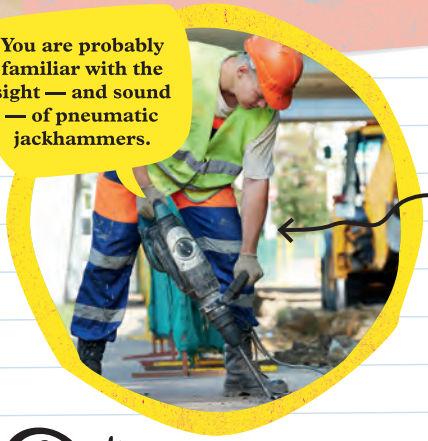
CHECK IT OUT

Compressed air has a lot of uses in technical equipment. The technical term is **pneumatic,** which comes from the Greek word for breath and wind.



Organ pipes require compressed air to make music.

In **pneumatic systems,** air is pressurized by a compressor. Electrically-controlled valves guide the compressed air in cylinders containing pistons, which perform desired movements. Compressed air cannot exert as great a force as compressed liquid. However, as you have learned, air has the property of being more compressible, so pneumatics have the advantage of being able to operate at high speeds. Also, systems like this are safer and easier to control than hydraulic systems, which use liquid.



You are probably familiar with the sight — and sound — of pneumatic jackhammers.

WHERE ARE Pneumatics USED?

There are many applications of pneumatic devices. Some of these may sound awful, such as **jackhammers**. Some, on the other hand, may sound very beautiful, such as **pipe organs**, which produce sound when compressed air is pushed through the pipes. Sometimes, compressed air helps to ensure a comfortable ride, such as in **car suspensions**. Pneumatic tube systems are still used in **hospitals** to deliver samples from patients' rooms to testing labs.

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