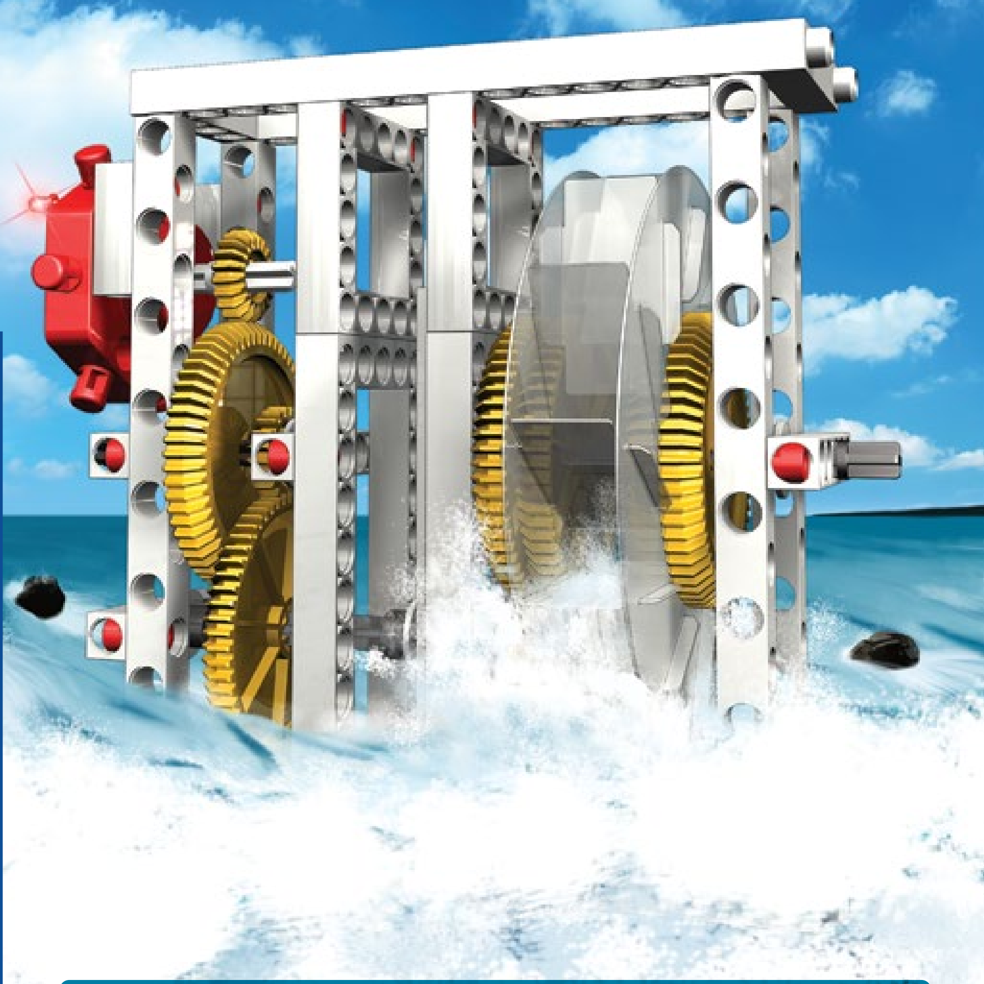
EXPERIMENT MANUAL

Hydropower



THAMES & KOSMOS

Franckh-Kosmos Verlags-GmbH & Co. KG, Pfizerstr. 5-7, 70184 Stuttgart, Germany | +49 (0) 711 2191-0 | www.kosmos.de
Thames & Kosmos, 301 Friendship St., Providence, RI, 02903, USA | 1-800-587-2872 | www.thamesandkosmos.com
Thames & Kosmos UK LP, 20 Stone Street, Cranbrook, Kent, TN17 3HE, UK | 01580 713000 | www.thamesandkosmos.co.uk

Dear Parents and Supervising Adults

This experiment kit will familiarize your child with the topic of environmentally-friendly energy production. The instruction manual and the materials in the kit will show you how to use hydropower to do work and produce electricity.

But first, it is natural to be concerned about safety. Specifically tell your child to read all instructions and safety warnings, and to keep them on hand for reference.

We wish you lots of fun and success with your experiments!

Safety Information

WARNING! Only for use by children aged 8 years and older. For use under adult supervision only. Read the instructions for use, follow them, and keep them for reference. Instructions for parents or other supervising adults are included and have to be observed. Keep the packaging and instructions as they contain important information.

WARNING!
- Not suitable for children under 3 years. Choking hazard — small parts. Strangulation hazard — long tube.
- This kit contains functional sharp edges or points. Do not injure yourself!
- The generator contains electrical parts and should not be submerged in water.
- It is recommended that the experiments be conducted in the sink, on a balcony, outside in a yard, or in the bathtub, to prevent "water damage" from splashes and spills.
- If the models are tested outside in streams or creeks, it is essential that an adult supervisor be present! The following rules must be followed:
  - Be careful of deep and fast-moving water.
  - People who cannot swim should wear flotation aids.
  - Never jump or dive into unknown waters.
  - Never push others into the water.

Notes on Disposal of Electrical and Electronic Components:
The electronic components of this product are recyclable. For the sake of the environment, do not throw them into the household trash at the end of their lifespan. They must be delivered to a collection location for electronic waste, as indicated by the following symbol:

Please contact your local authorities for the appropriate disposal location.

2nd Edition, Franckh-Kosmos Verlags-GmbH & Co. KG, Stuttgart, Germany / 2008

Text, experiments, and models: Dr. Uwe Wandrey
Graphic design and 3-D illustrations: Amadeus Rayhle, Stuttgart
Photos: Voith AG Heidenheim, Mafell AG Oberndorf/N., M. Berrer
Project management: Manfred Berrer

Translation: David Gamon; Additional Graphics and Layout: Dan Freitas; Editing: Stephanie Gerson, Ted McGuire

Distributed in North America by Thames & Kosmos, LLC.
Providence, RI 02903
Phone: 800-587-2872; Web: www.thamesandkosmos.com

Distributed in United Kingdom by Thames & Kosmos UK LP.
Cranbrook, Kent TN17 3HE
Phone: 01580 713000; Web: www.thamesandkosmos.co.uk

We reserve the right to make technical changes.

Printed in Taiwan

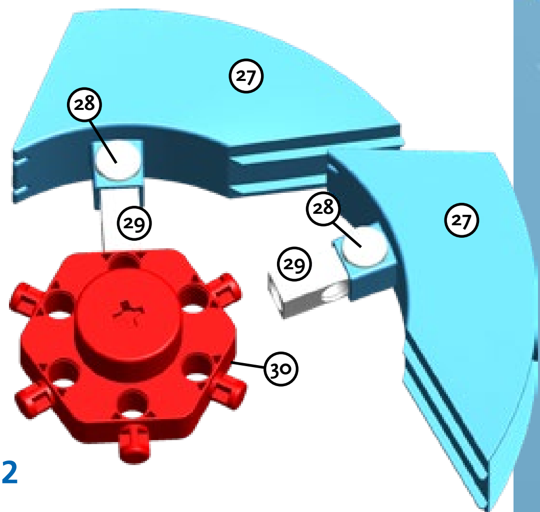
Hydropower

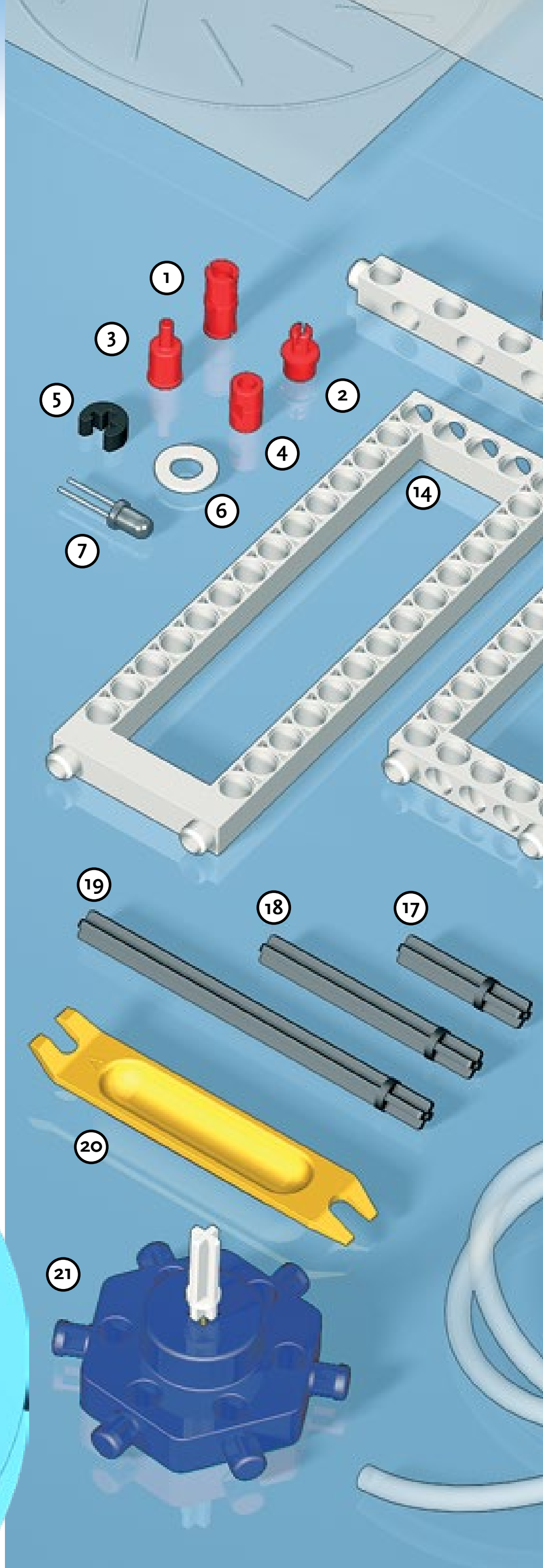
Experiment Manual

Thames & Kosmos, LLC,, Providence, Rhode Island, USA
Franckh-Kosmos Verlags-GmbH & Co. KG, Stuttgart, Germany

Kit Contents

No.	Name	Qty.	Part No.
1	Joint pin	1	702524
2	Shaft plugs	2	702525
3	Shaft pin	1	702526
4	Anchor pins	26	702527
5	Axle locks	4	702813
6	Washers	8	703242
7	LED, red	1	704072
8	3-hole rods	2	705015
9	5-hole rods	5	704063
10	Short rod	1	703233
11	Long rods	6	703235
12	5-hole frames	3	705016
13	Small frames	2	703232
14	Large frames	2	703239
15	Small gear wheels (20 teeth)	3	702504
16	Large gear wheels (60 teeth)	5	702506
17	Short axle	1	703236
18	Medium axle	1	703238
19	Long axles	2	703234
20	Anchor pin lever	1	702590
21	Universal adapter (blue) with motor and axle	1	708240
22	Tubing, 2.5 mm ID by 120 cm	1	707144
23	Red straw, 2 mm OD	1	703513
24	Tubing, 2 mm ID by 5 cm to 8 cm	1	707142
25	Plastic sheet	1	707141
26	Experiment book	1	707131
27	Blue turbine bucket	6	710421
28	Button pin	6	704062
29	3-hole dual rod	6	711987
30	Universal adapter, red (Pre-assembled from top, bottom, and 2 screws)	1	717059





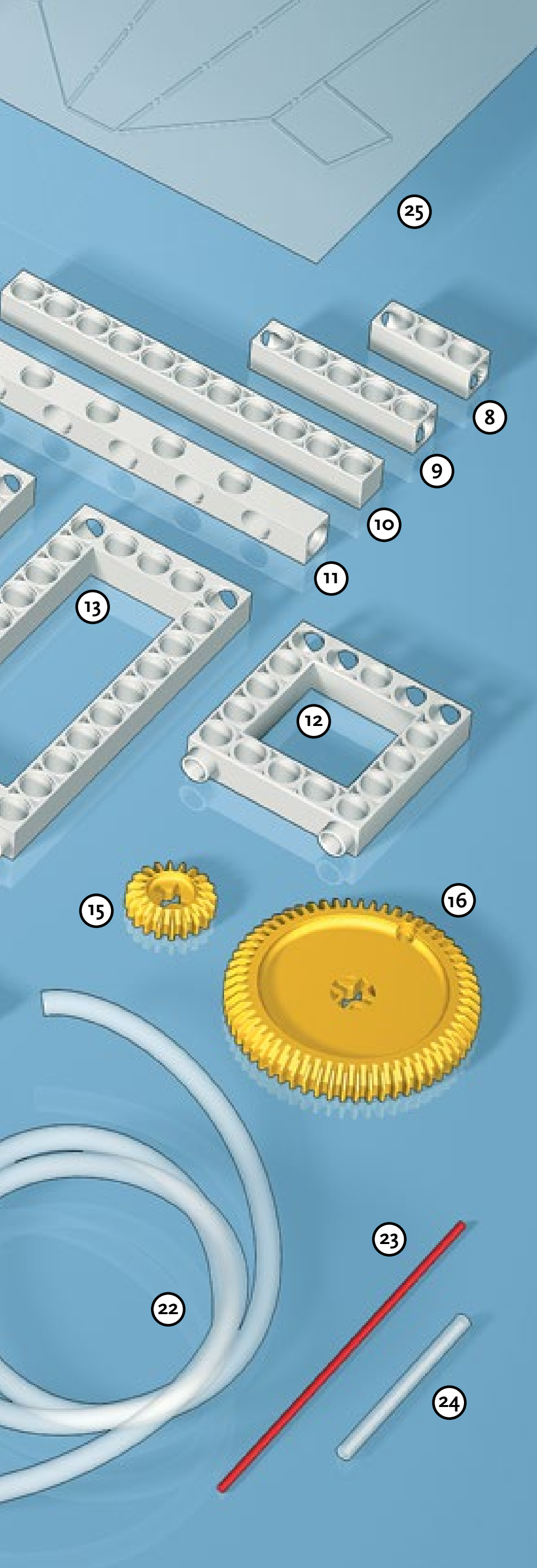
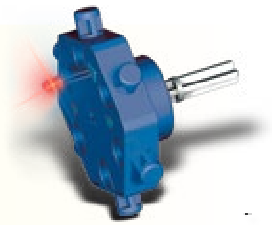


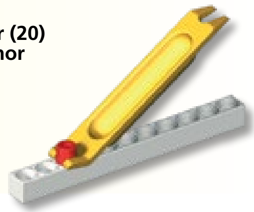
Table of Contents

Building Projects

Universal adapter (21) with LED (7): Attach the LED to the connection socket of the universal adapter with the two wires.



The anchor pin lever (20) is for removing anchor pins (4).



Additional items needed: scissors, tape, large shallow basin, pitcher or watering can, two plastic bottles (1 L water or soda bottles), drinking glass, plate, and towels.

We reserve the right to make technical changes.

The Story of Hydropower

Is water more precious than silver and gold?

All life depends on water. Without water, plants, animals, and people could not live. Most living organisms are very watery creatures: Up to four-fifths of the human body consists of this essential liquid.

It is only when the tap runs dry that a thirsty person really understands what kind of treasure pours out of the faucet every day. Is this inconspicuous, inexpensive wetness not more precious than all the jewels and treasure hoards of the world piled together? Wouldn't the richest person in the world lay all his money on the table in order to keep from dying of thirst? Unfortunately, not everyone has enough clean water to drink. Many children living in poor, hot countries have to walk for an hour to get water from a distant well, and then carry it all the way back home again.

You might think there would be plenty of water on our planet, since three-fourths of Earth is covered with oceans and seas. That's true, but unfortunately ocean water is salty and undrinkable. It first has to evaporate, collect in clouds, and then rain down as "fresh" water. And alas, the rain is not evenly distributed. Some countries drown in floods while others wither in the sun.

An important natural cycle involving water is occurring constantly on Earth: Water is heated by the sun, causing it to evaporate from the oceans and other bodies of water. The water vapor gathers in clouds. When it cools, it rains down again, and flows back into the oceans. This natural cycle is called the **hydrological cycle**. Without the hydrological cycle, we would not have flowing fresh water.

We don't just value water because we drink it, or because we can wash and bathe with it, or because ships need it to sail. It also provides us with energy, and it can take a lot of work off our hands.

With this kit, you will be able to use experiments and models to study the energy hidden in moving water. You will see how you can stop flowing water and "steal" energy from it in the process. And vice-versa — how you can "pump up" water with energy and get it moving. This is hydropower — from a water wheel in a little stream all the way to a high-tech turbine in a tidal power station. Let's start with the water wheel!

In the beginning was the water wheel

The first time that people used a machine for water power was probably over six thousand years ago in Mesopotamia, where Iraq is today. There, the Sumerians built a 25-meter-high paddle wheel on the Euphrates River. It was driven by the flow of the water current, and at the same time scooped water up in the air. Clever, wasn't it? Then, when the water reached its highest point, it flowed through irrigation canals to the fields and to drinking troughs for animals.

01 *Workshop*

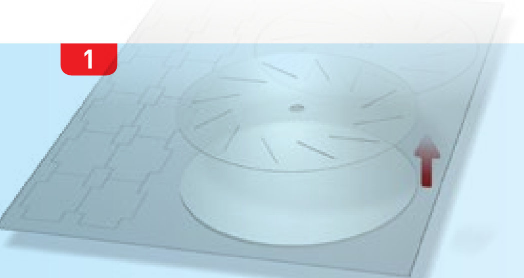
Water Wheel

For this and all other workshops in this kit, first follow the instructions to build the model, and then read and conduct the experiment immediately following the workshop to put your model in motion.

You will need:

- ☐ 2 water wheel disks (from plastic sheet)
- ☐ 12 water wheel paddles (from plastic sheet)
- ☐ 1 plastic strip to make a ring (plastic sheet)
- ☐ 2 small frames (13)
- ☐ 1 large frame (14)
- ☐ 2 large gear wheels (16)
- ☐ 1 long axle (19)
- ☐ *transparent cellophane tape*

1

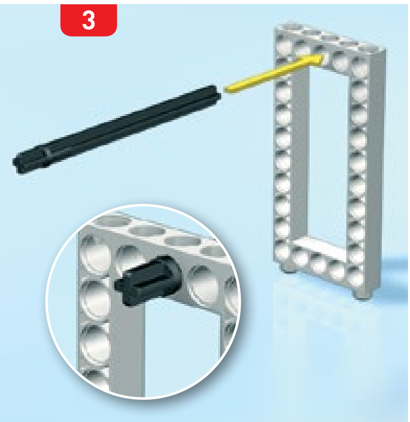


Remove the 12 blades, the two wheel disks, and the narrow strip from the plastic sheet.

2

Roll the strip into a ring and tape it. This ring should have about the same diameter as one of the large gear wheels (it won't matter if it's a couple millimeters off).

3

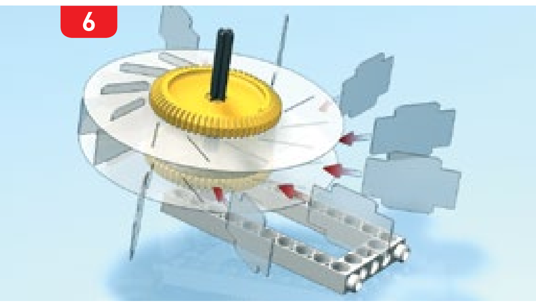


4

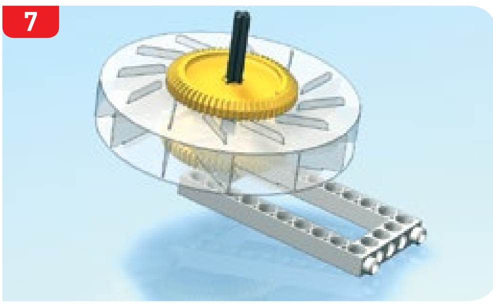
5

Pay attention to the direction of the slits!

6



7



01 *Experiment*

The weight of water drives a water wheel

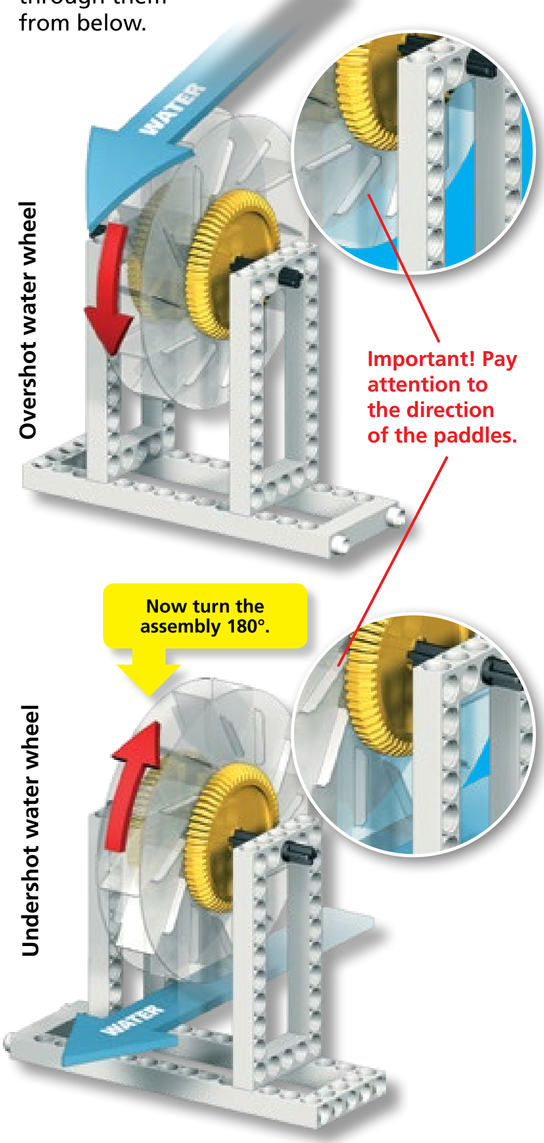
Set up your water wheel in a wide, shallow basin or plastic bin. This will allow you to catch the water that you use to power the water wheel, so that you can reuse the water over and over again. This is highly preferable to letting the water run down the drain or into the ground, as we do not want to waste any water while doing these experiments! Water is a very precious resource.

It is best to do your experiments in the sink, on a balcony, outside in your yard, or in the bathtub, to prevent "water damage" from splashes and spills.

Fill a tall, narrow drinking glass or water bottle with water and pour it over the water wheel. When you do this, hold the glass just above the wheel, because we don't want to create a strong "waterfall" — we just want the weight of the water. Watch how the paddles fill up with water, one after the other, and then empty themselves again as they drop down. Try to find the optimal location for pouring water onto the ring of paddles in order to make the wheel turn the fastest.

The weight of the water on the paddles turns the wheel and performs work as it falls. Water wheels have lent their energy to oil mills, flour mills, and sawmills. They used to be set up along streams and rivers, where the water was diverted through canals and shafts and routed onto the blades. They are still turning in a few out-of-the-way places around the world. Some have been modernized to generate electricity.

There are **overshot** and **undershot** water wheels. With overshot water wheels, the water is directed from above, while with undershot water wheels, the water runs through them from below.



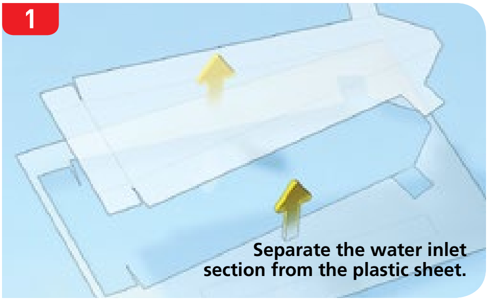
02 *Workshop*

Sawmill

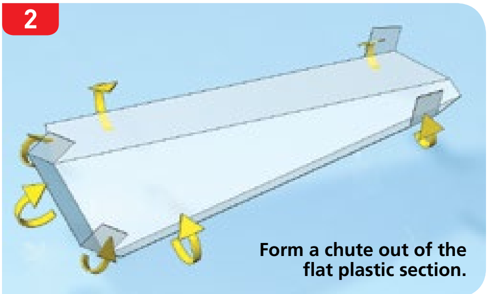
You will need:

- ☐ 1 water inlet (plastic sheet)
- ☐ 2 water wheel disks (plastic sheet)
- ☐ 12 water wheel paddles (plastic sheet)
- ☐ 1 plastic strip to make a ring (plastic sheet)
- ☐ 4 large gear wheels (16)
- ☐ 3 small gear wheels (15)
- ☐ 2 long axles (19)
- ☐ 2 large frames (14)
- ☐ 2 small frames (13)
- ☐ 1 short rod (10)
- ☐ 4 long rods (11)
- ☐ 4 5-hole rods (9)
- ☐ 2 3-hole rods (8)
- ☐ 1 washer (6)
- ☐ 2 shaft plugs (2)
- ☐ 1 shaft pin (3)
- ☐ 1 joint pin (1)
- ☐ 21 anchor pins (4)

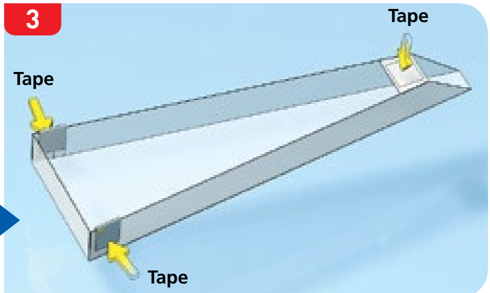
1


Separate the water inlet section from the plastic sheet.

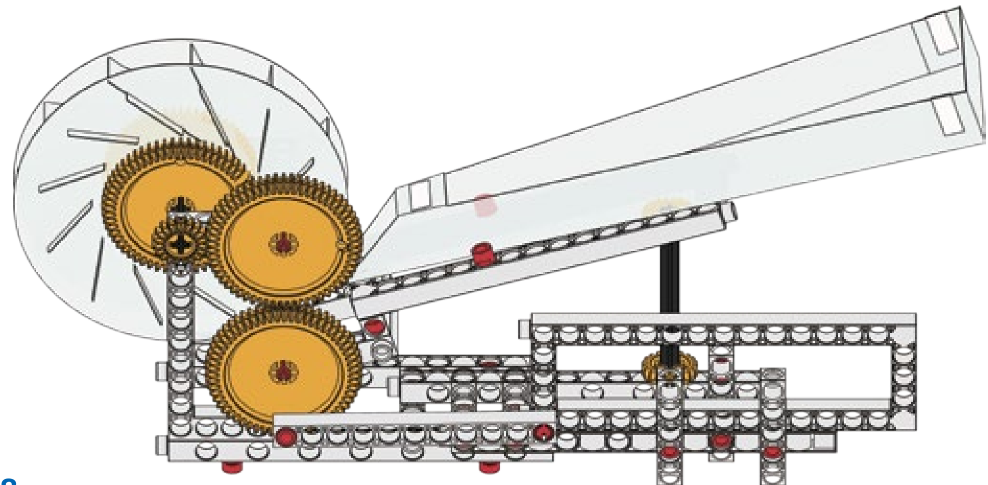
2

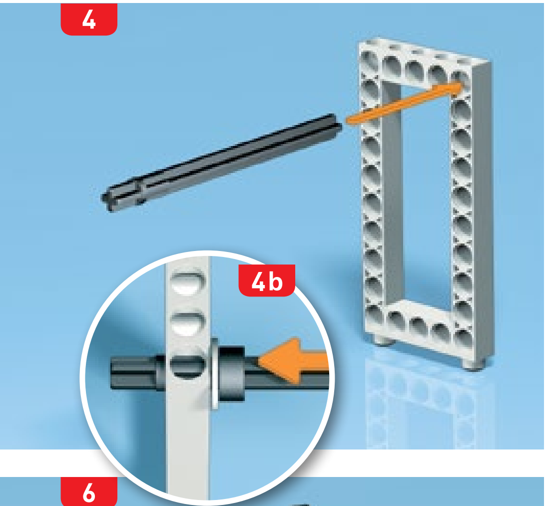

Form a chute out of the flat plastic section.

3



Use tape to secure the two flaps on the long edge to the sides of the chute, and to secure the two flaps on the narrow edge to each other, as shown here.



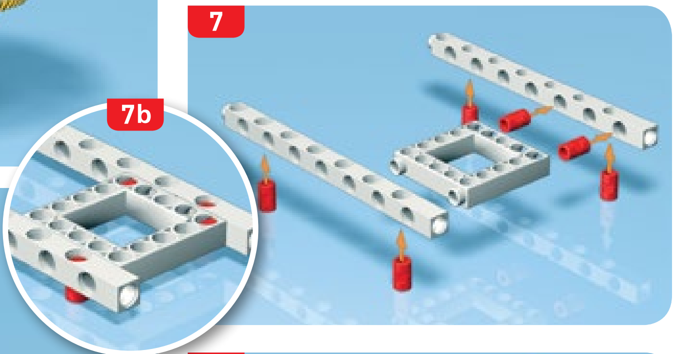


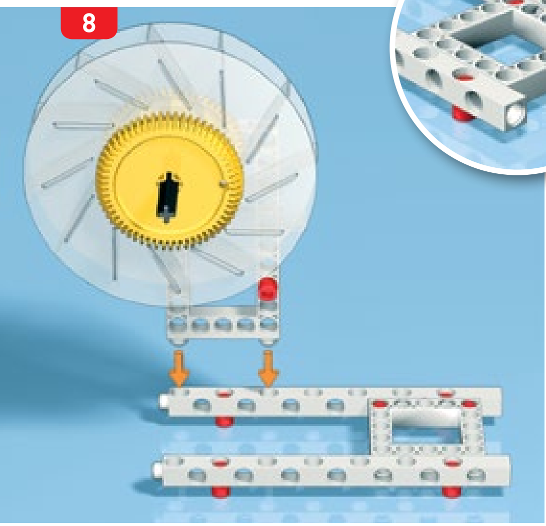
You can pull the assembled water wheel off the axle and stick it back on again. You may have to do this if the paddle direction is wrong.

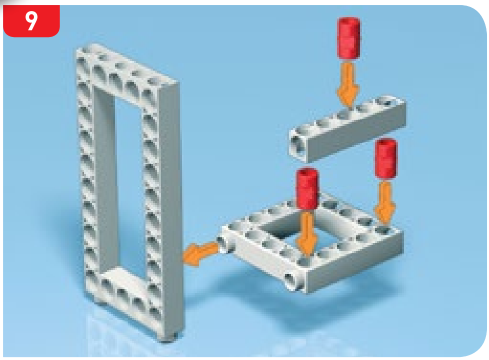
When removing the water wheel, press the two gear wheels tightly together so that the paddles don't fall out. Then carefully remove the axle.

Be careful not to twist the water wheel disks and gears, or to crush them.

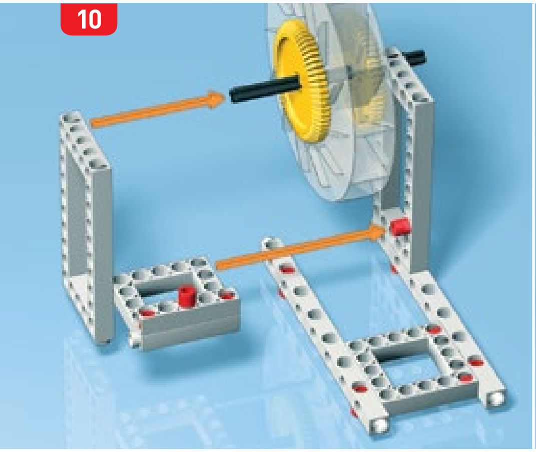
If the water wheel falls apart, you will have to reassemble it with the instructions on page 6.

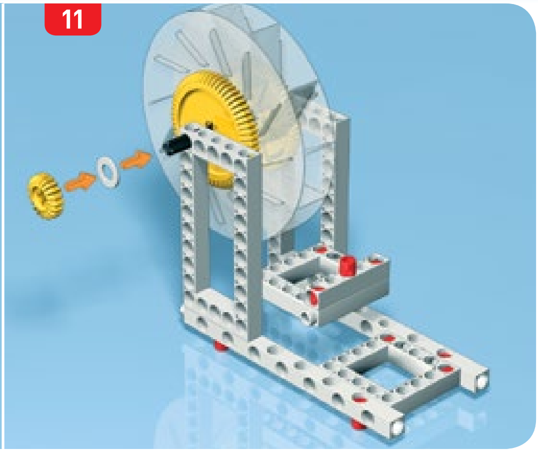


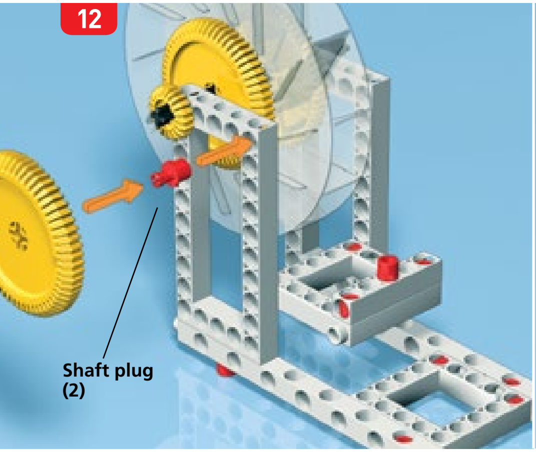


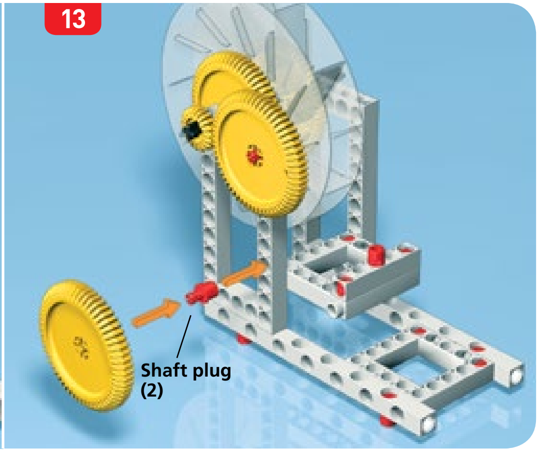


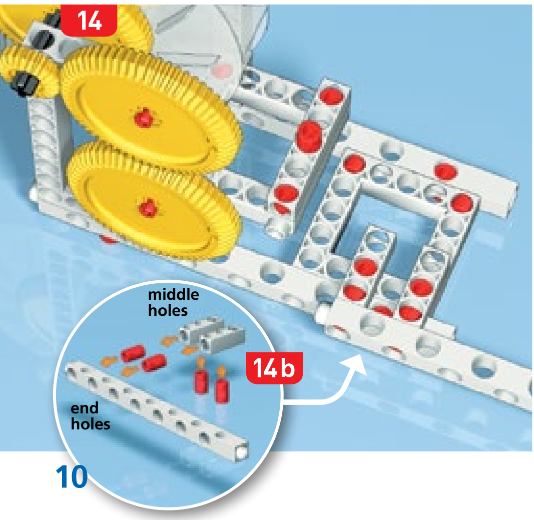
Hydropower Sawmill

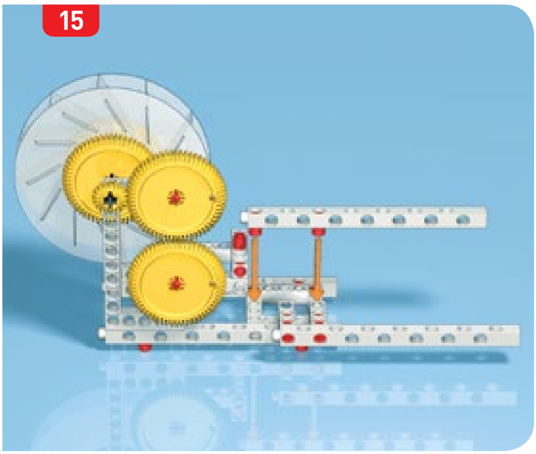








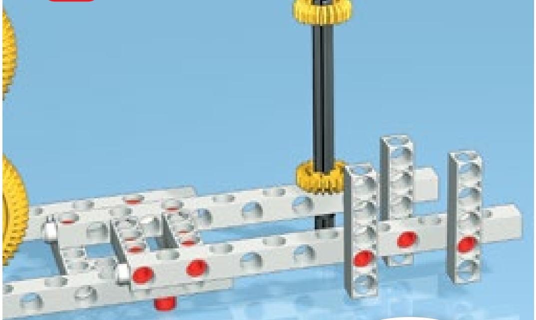




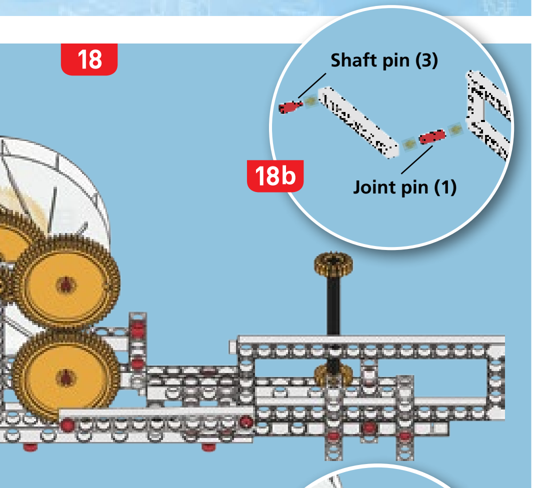
Hydropower Sawmill

16

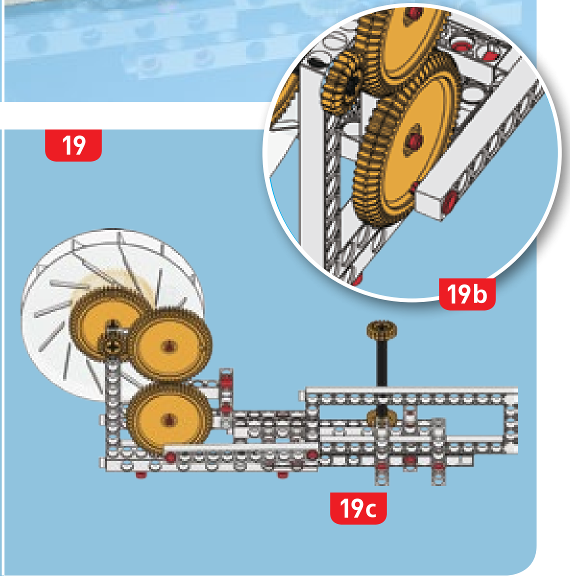
17



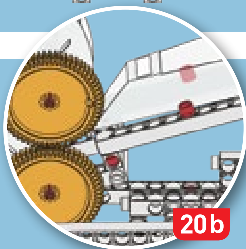
18



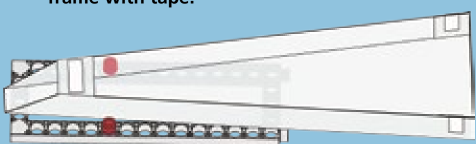
19



20

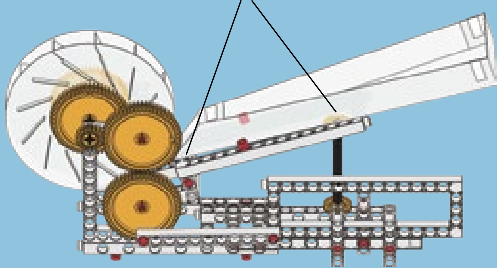


Secure the water chute to the large frame with tape.



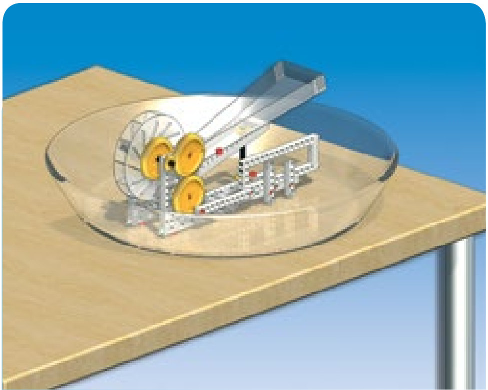
21

Secure the water chute and frame assembly to the rest of the structure with tape.



02 *Experiment*

Putting the sawmill to the test



Set up your sawmill in a wide, shallow basin or plastic bin, as before. It is best to do your experiments in the sink, on a balcony, outside in your yard, or in the bathtub, to prevent "water damage" from splashes and spills.

Pour water from a large pitcher or a watering can into the inlet of the chute, varying the quantity of water as you do this. Try stopping the rod with your finger as it slides, in order to get a feel for its force.

When you stop the rod, you will see that the more water falling on the wheel per second, the more power is produced at the end of its journey. Machines that are driven by the flow of fluids (liquids or gases) are categorized as **turbomachinery**.

Machines that work the other way around, by setting a flowing mass in motion (such as pumps, fans, jet engines, and ship propellers), are also called turbomachines.

Water's sticking power

It's hard to believe, but water can stick like glue. It can even be downright clingy. You can easily see this by looking at how the water's surface climbs up the side of a water glass: If you look closely at the spot where the water meets the edge of the glass, you will see the water curves upward at the edge.

Why does it do that? The water molecules hold onto each other with a special bonding force, just as if they had tiny arms. The attraction of water molecules to each other is called **cohesion**.

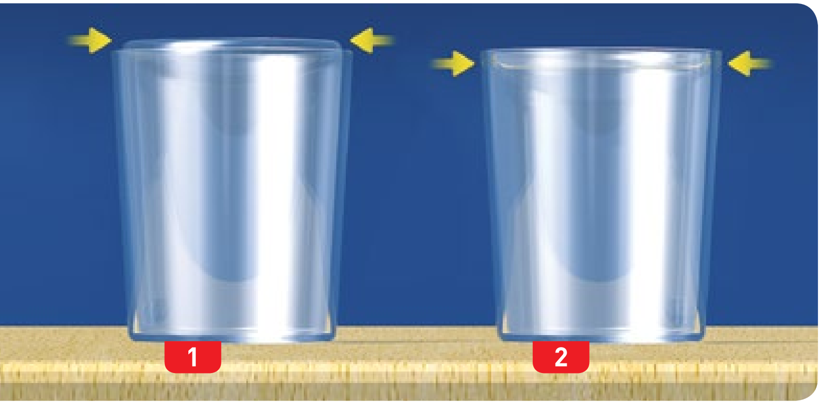
At the water's edge, however, neighboring water molecules are missing, giving rise to another force of attraction. Instead of just reaching into empty space, the molecules attach themselves to the side of the glass. The attraction of water molecules to other objects is called **adhesion**.

Adhesion and cohesion come into play at the water's surface, where the little arms produce a force known as **surface tension**. In the next experiment, we see surface tension in action.

03 *Experiment*

Water arches its back — surface tension

The Surface Tension of Water



Carefully fill a glass with water up to just above the rim. It will bulge upward. The water molecules' cohesion holds the water together so strongly that it won't flow over the edge.

Now pour off a little water and watch where the water touches the edge of the glass. Here, the "skin" of the water pushes it upward at the edges, because of adhesion.

Surface tension works like a magnet, with the molecules attaching themselves to each other and to other solid objects. If they don't find any, as in an overfilled glass, then they respond to the tension by bulging up. In the second glass, the surface curves up the side of the glass as if it were magnetized, until gravity and surface tension balance each other out. Imagine the water glass getting narrower and narrower, until it becomes a very thin tube and the curved edges of the water meet. Then, the water would just keep rising higher and wouldn't stop. This is what happens when, for example, you dip the end of a piece of wool or cotton cloth into some water: The water climbs upward through the fine hair-thin tubes, or capillaries, of the dry fabric.

Try this simple experiment: Dip one corner of a cloth handkerchief into a glass filled with water, and you will see how the moisture gradually climbs up the cloth.

You can easily construct a plant-watering system that works by this principle. Just get a bucket of water, suspend one end of a thick piece of yarn in the water, and put the other end in a planted flowerpot. Then, wait for the water from the bucket to travel through the yarn into the flowerpot.

Water Column

The physical phenomenon of water climbing against gravity in a narrow space, which is caused by adhesion, is called **capillary action**.

By the way, you can greatly reduce the surface tension of water with a few drops of household dishwashing soap, as the next experiment will show.

Water Column

You have probably seen towers used for storing water, which flows out of them in pipes all the way to the taps of your house or apartment.

You can see how this works with a simple experimental apparatus.

Water tower for storing drinking water

03 ***Workshop***

Water Tower

You will need:

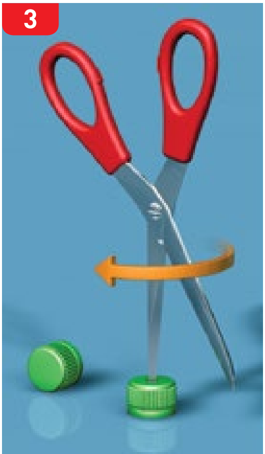
- ☐ 8 anchor pins (4)
- ☐ 4 long rods (11)
- ☐ 2 5-hole frames (12)
- ☐ 2 small frames (13)
- ☐ 2 large frames (14)
- ☐ a section of the thick tube (22) about 25 cm in length
- ☐ *2 plastic drink bottles with a volume of 0.75 or 1.0 liter, and two screw-top caps*

Start with the two plastic drink bottles (e.g., 1-liter water or soda bottles and the screw-top lids that go with them). Cut off

Water Tower

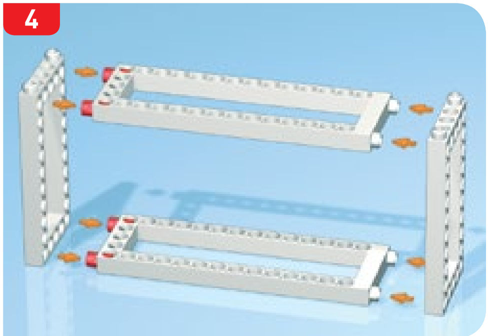
the bottom of each bottle with a pair of household scissors.

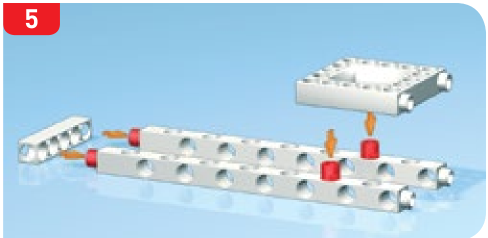
You will then have to punch a hole in each of the screw-top lids. Have an adult do this for you. It's easy to do with the tip of a pair of scissors, turning the blade like a drill. Of course, it's even easier with an actual drill from the toolbox.

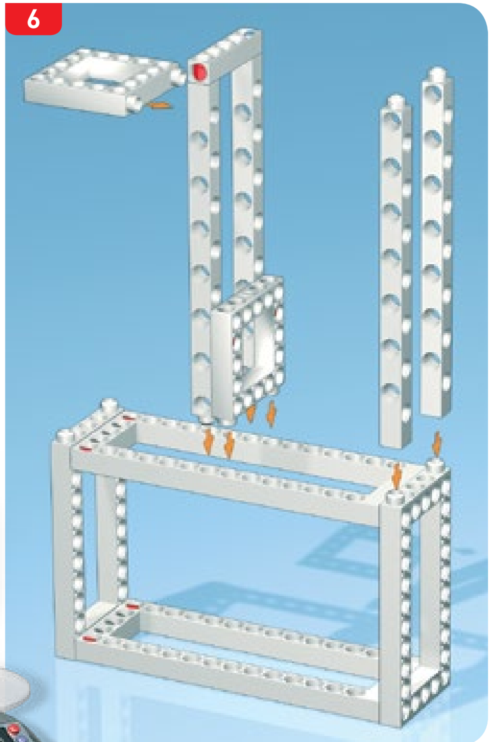


Caution! Don't injure yourself — please work very carefully.

For the hole, select a diameter that allows you to push the thick tube through the hole but at the same time maintain a fairly tight seal — in other words, about 5.5 millimeters across. Do this by repeated checking the hole. Be careful not to make the hole too big, or all the water will spill out! Inserting the tube will be easiest if you cut the end of the tube at an angle.



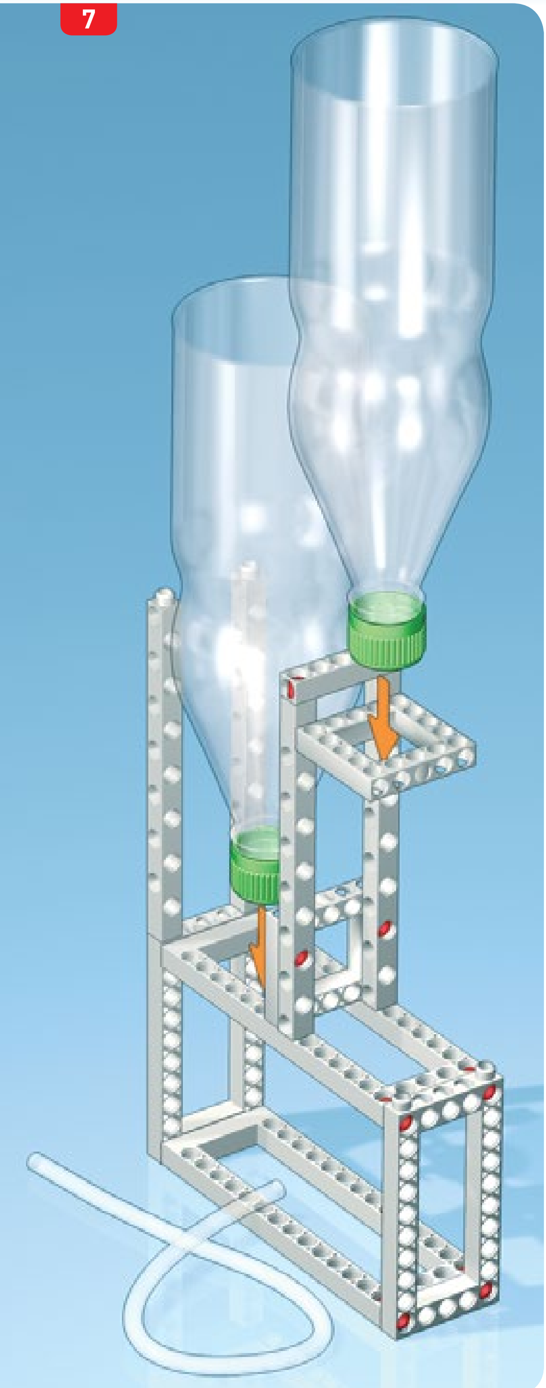




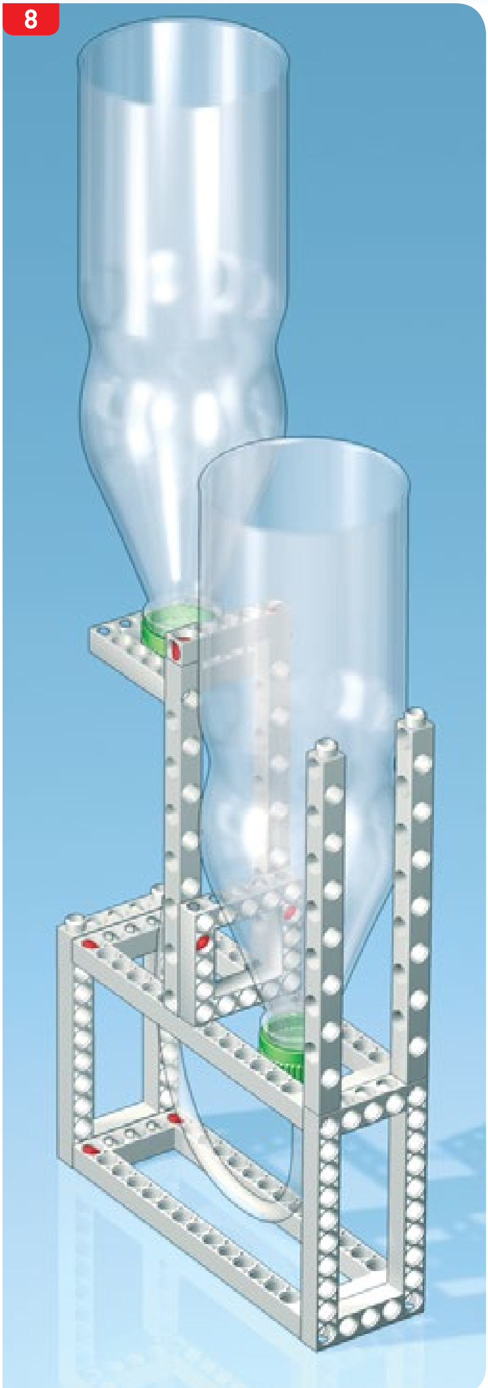
By the way, if you are working with non-reusable PET bottles, you can still recycle the bottles after you cut them — all such bottles are shredded and reused as a raw material for other

Caution!
Water is heavy. One liter weighs one kilogram (2.2 pounds) at 20 °C (68 °F)! Since the experimental setups are quite tall, you should only put a little water into the bottles.

7



8



Communicating Vessels

04 *Experiment*

Speed up water!

Fill the bottles with water as shown in the picture below by carefully pouring water into the upper bottle. As you can see, the water flows very slowly through the thin tube.

By adding a squirt of dishwashing liquid, you can increase the flow rate. As you saw in your experiment, the water molecules “hold tightly” onto one another. The dishwashing liquid prevents this to some degree, so the water glides more easily and quickly through the tube.

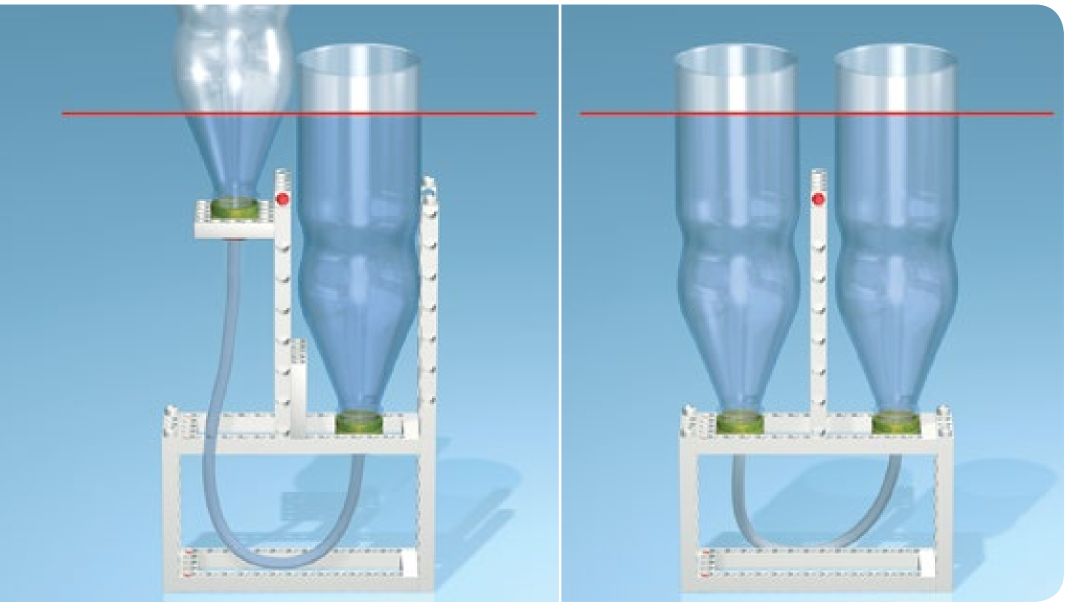
After the water has flowed slowly from one bottle to the other through the tube, the water levels in both bottles should be the same — but why is that?

Physicists have a name for a system of connected tubes or containers in which the water levels in all of the vessels or containers are equally high. It is called a system of **communicating vessels**.

If you move one bottle lower, as shown in the picture below, the water will start flowing again. But soon the water levels will even out and be the same again in both bottles.

Water fountain and water pressure

You have seen that the water level in containers connected by pipes or tubes will always be the same. But what happens if one of the containers is much higher than the water outlet? We will investigate this in the fountain experiment.



In a system of communicating vessels, the water levels in all of the vessels or containers will be equally high. Even though the bottles are at different heights in the setup shown on the left, the water levels (indicated by the red line) are still the same in both bottles.

04 ***Workshop***

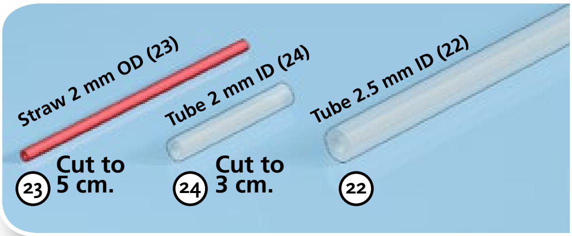
Fountain

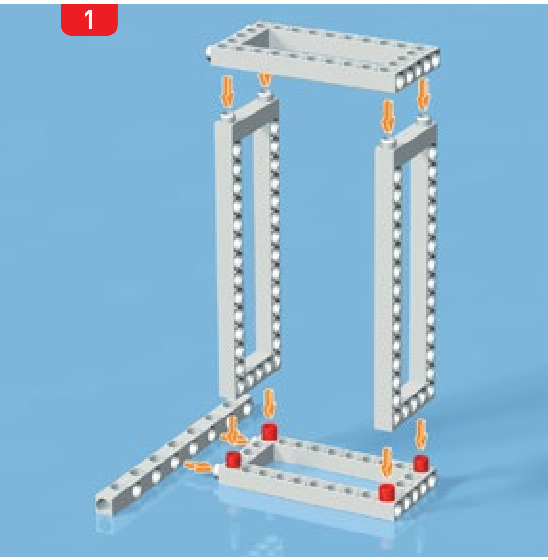
You will need:

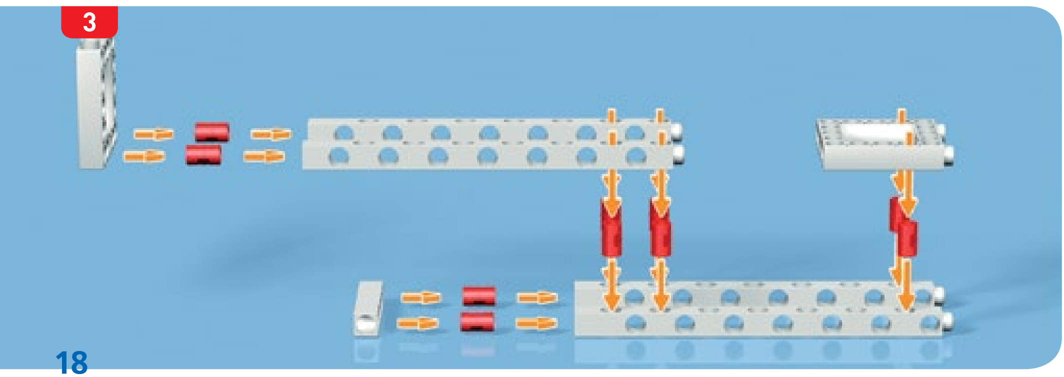
- ☐ 17 anchor pins (4)
- ☐ 1 3-hole rod (8)
- ☐ 4 long rods (11)
- ☐ 2 small frames (13)
- ☐ 2 large frames (14)
- ☐ 1 tube (22)
- ☐ 1 section of the red straw (23)
- ☐ 1 section of the narrow tubing (24)

First, cut a 5-cm length of the red straw (23). Then, cut a 3-cm length of the narrow tube section (24), making the cut at an angle.

Next, assemble the framework of the fountain as shown.

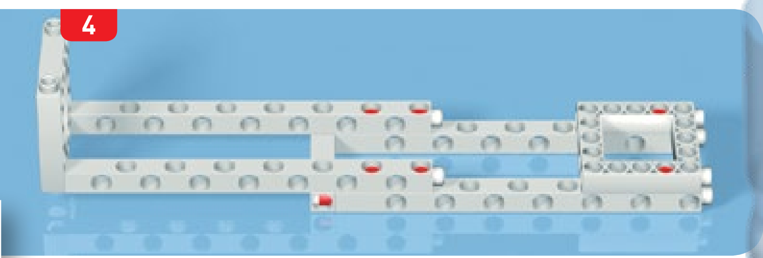




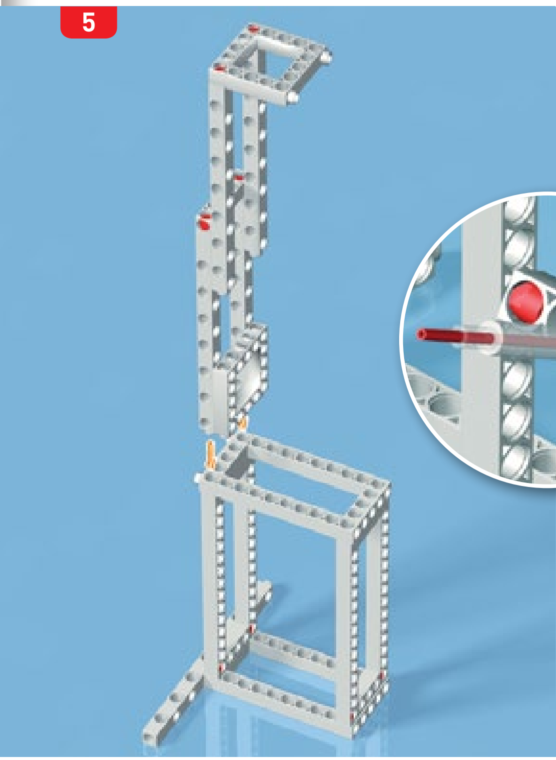


Fountain

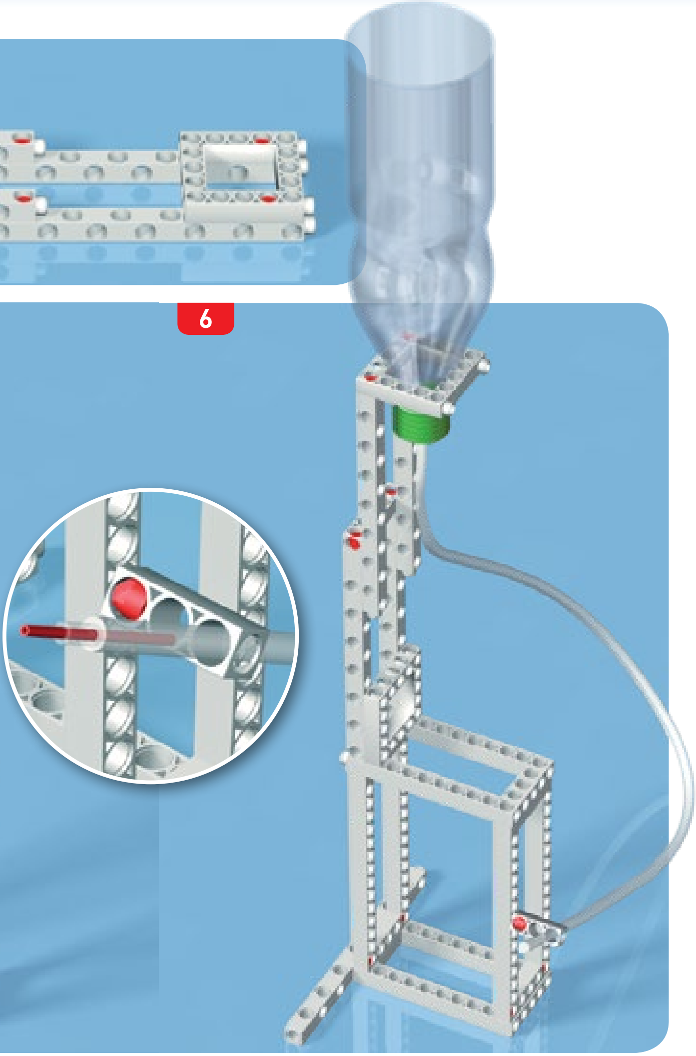
4



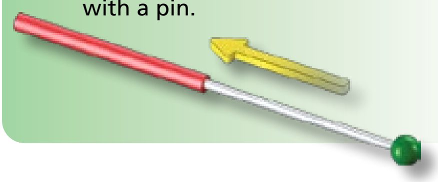
5



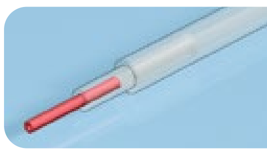
6



Important!
If the end of the straw gets compressed together when you cut it, open it again with a pin.



Then, insert the narrow tube section (24) into the thicker tube (22) with the angled end first. You may have to wet it first, and twist it while pushing it, to get it in. Insert the red straw (23) into the narrow tube until it also enters the thicker tube.
It should be a tight fit.
If the straw doesn't fit tightly, you may have to wind some cellophane tape around it.



05 *Experiment*

How high does the fountain's stream go?

Set up your fountain outside or in a bathtub. Pour water into the reservoir bottle on your fountain. Make sure the fountain nozzle is pointed away from you and others.

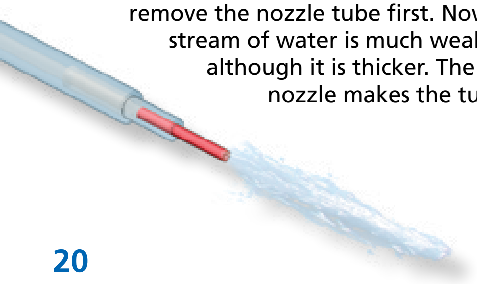
In theory, the fountain's stream should rise up to the level of the water in the storage bottle. But in fact, it falls back down before it reaches that level. Why? The principle of communicating vessels only applies to resting water in the vessels. Also, the propelled water in the fountain rubs against the walls of the tube, the nozzle, and the outlet as it moves. That uses up energy.

And what is the nozzle for? Let's find out.

06 *Experiment*

The nozzle does it

Repeat the last experiment, but this time remove the nozzle tube first. Now, the stream of water is much weaker, although it is thicker. The nozzle makes the tube narrower, but the same quantity of water still has to move through it per second as through the thicker tube, so the water has to move faster. Thus, the water moves faster and stronger through the thinner tube, and slower and weaker through the thicker tube.



Hammer Mill

The flow of water drives machines

As your water wheel experiment showed, flowing water can perform work. With the water wheel, however, it was just the weight of the water that was doing the work.

The next experiment will show you why, throughout history, so many towns have been located along rivers. The river water could be used to transport heavy cargoes on rafts and ships. But the flowing water was also put to work to drive machines. Along with the familiar sawmill, hydropower drove machines for spinning, weaving, and lots of other things. In the next experiment, we will build a hammer mill, which is a machine used for finishing iron hardware.

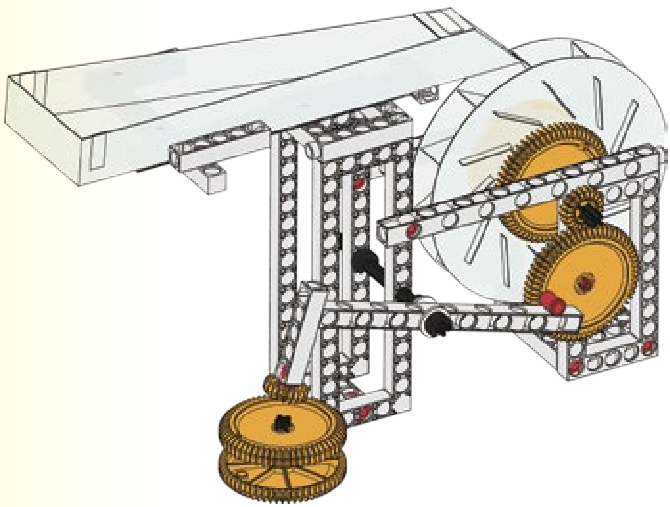
When building your hammer mill, make sure that the water wheel is correctly assembled. The water paddles have to be pointed toward the water outlet, so the individual chambers fill properly with water. If the paddles point in the wrong direction, the flowing water won't produce enough energy, and the rotation rate will drop.

05 ***Workshop***

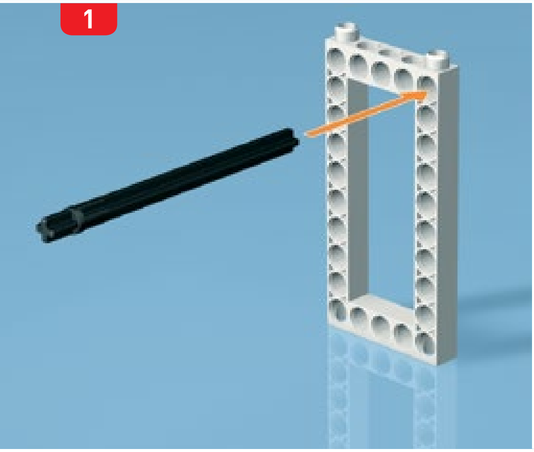
Hammer Mill

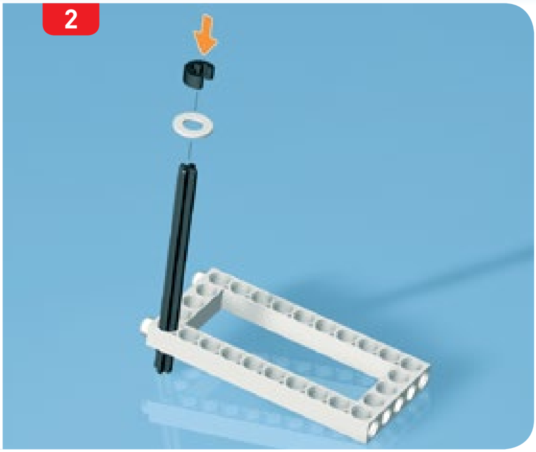
You will need:

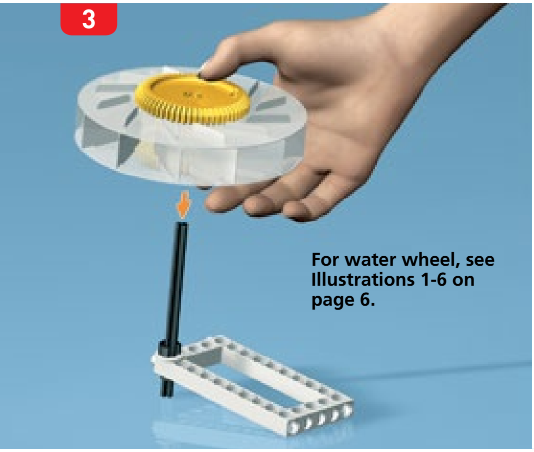
- ☐ 1 water inlet (plastic sheet)
- ☐ 2 water wheel disks (plastic sheet)
- ☐ 12 water wheel paddles (plastic sheet)
- ☐ 1 plastic strip (plastic sheet)
- ☐ 2 shaft plugs (2)
- ☐ 1 shaft pin (3)
- ☐ 10 anchor pins (4)
- ☐ 3 axle locks (5)
- ☐ 4 washers (6)
- ☐ 2 3-hole rods (8)
- ☐ 3 5-hole rods (9)
- ☐ 1 short rod (10)
- ☐ 4 long rods (11)
- ☐ 2 5-hole frames (12)
- ☐ 2 small frames (13)
- ☐ 2 large frames (14)
- ☐ 2 small gear wheels (15)
- ☐ 5 large gear wheels (16)
- ☐ 1 short axle (17)
- ☐ 2 long axles (19)

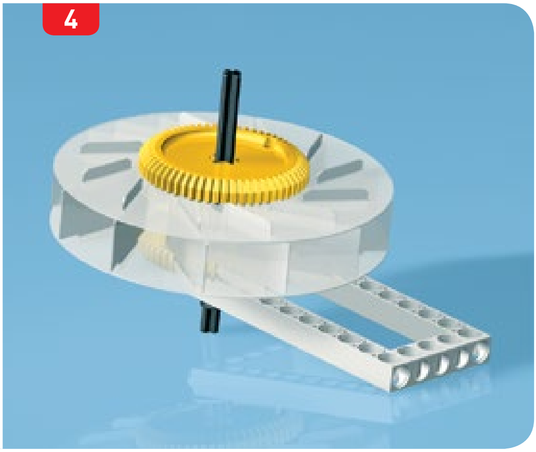


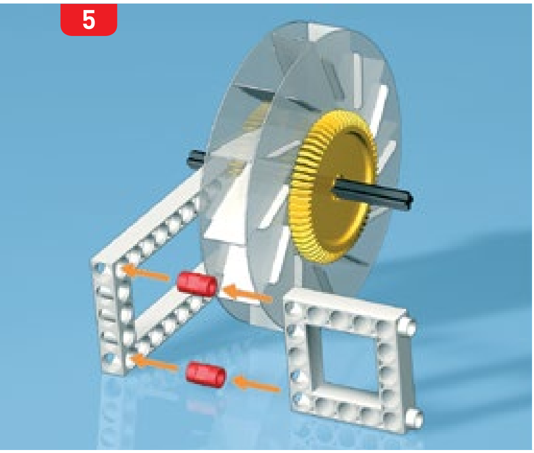
Hammer Mill

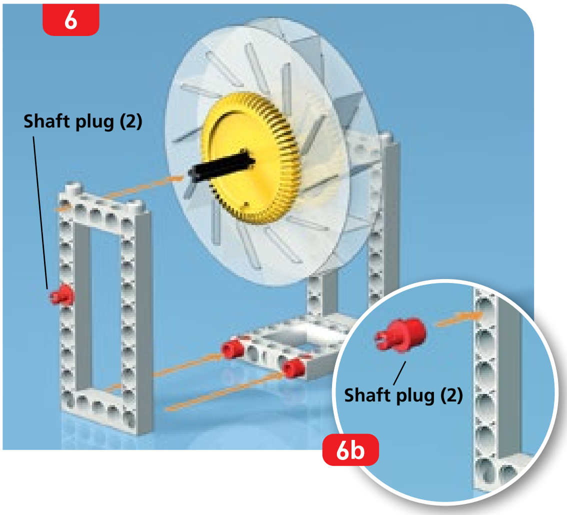

1

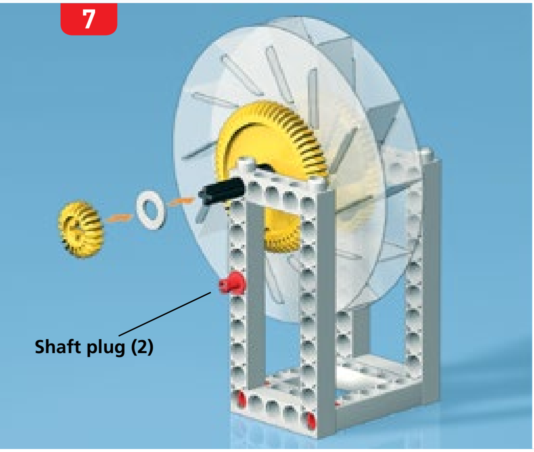

2

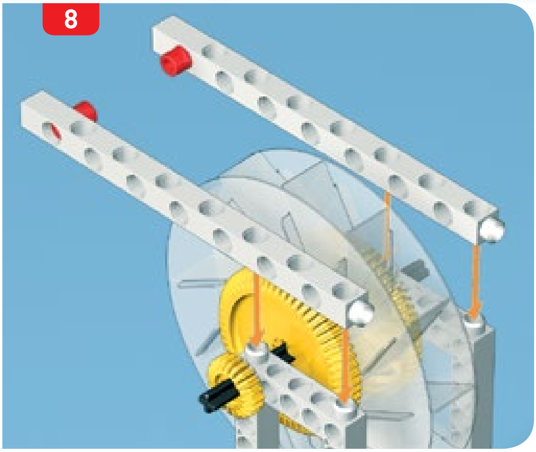

3
For water wheel, see Illustrations 1-6 on page 6.

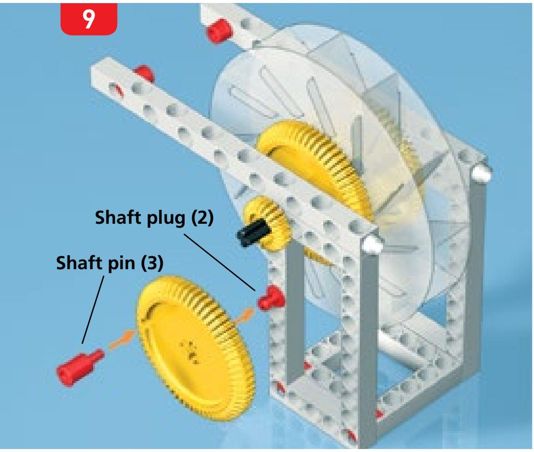

4

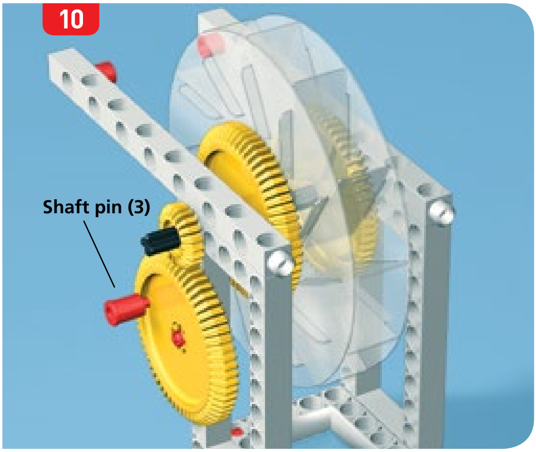

5

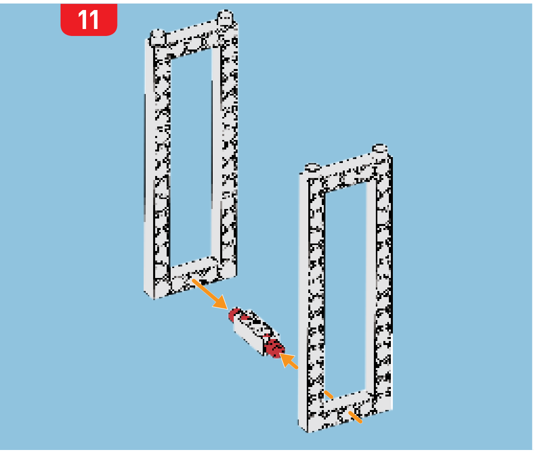

6
Shaft plug (2)
Shaft plug (2)
6b

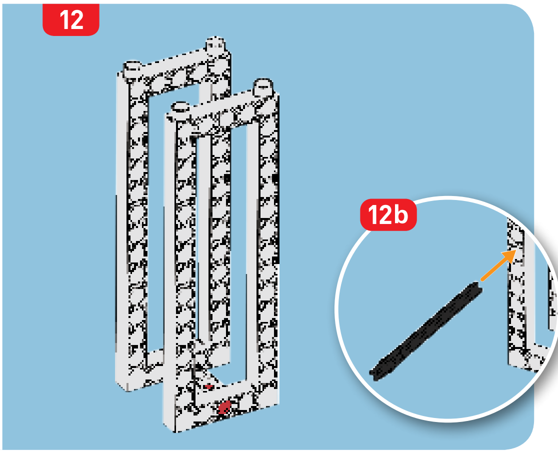

7
Shaft plug (2)


8

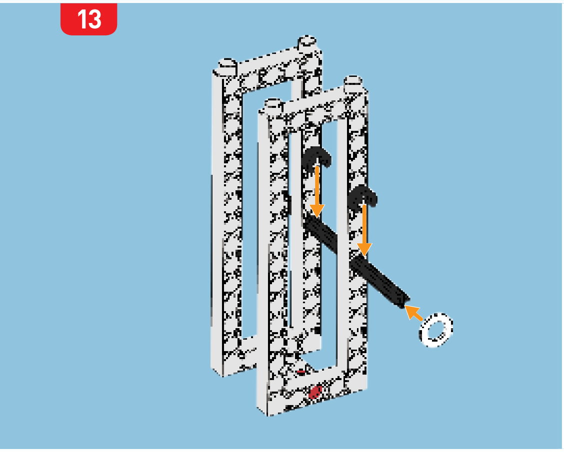

9
Shaft plug (2)
Shaft pin (3)

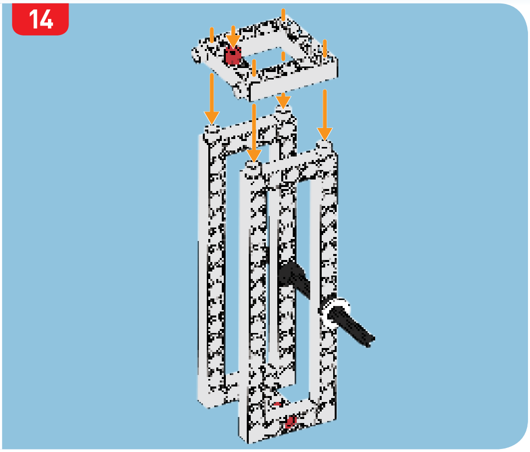

10
Shaft pin (3)

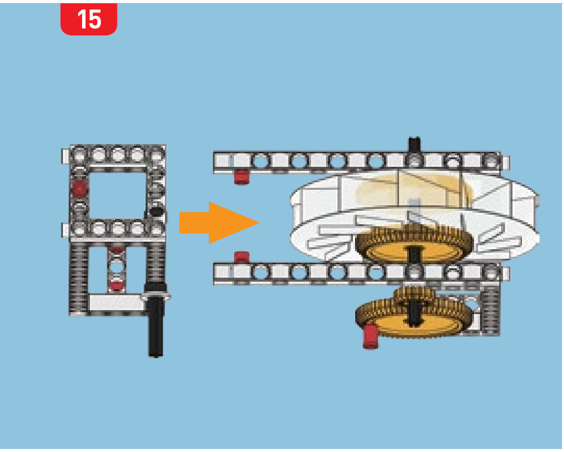

11

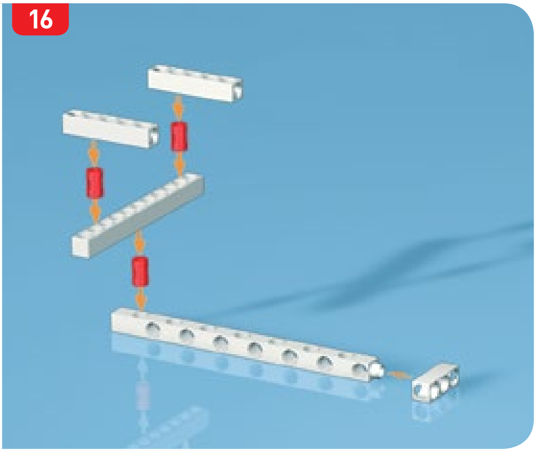

12
12b

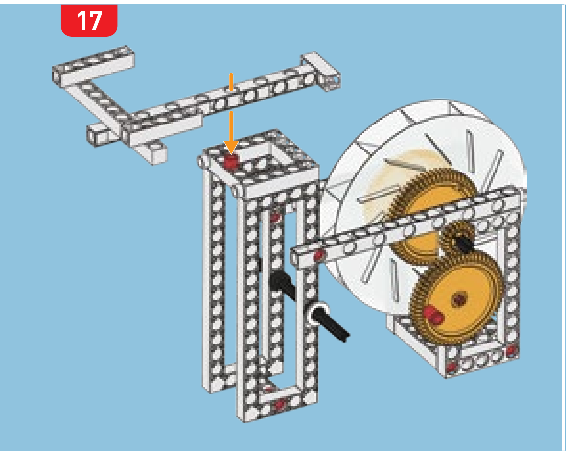
Hammer Mill

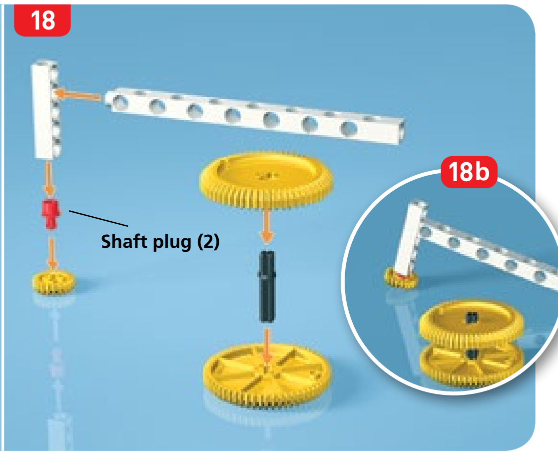


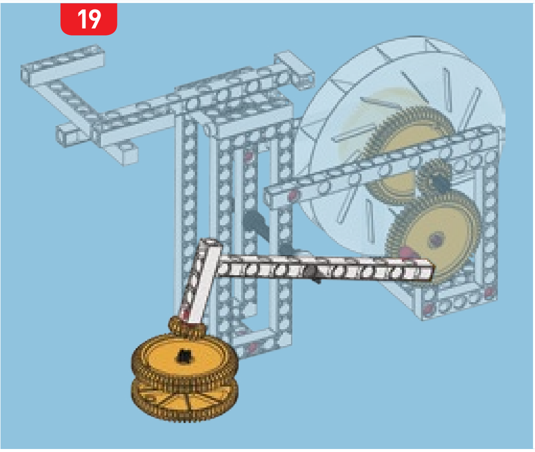


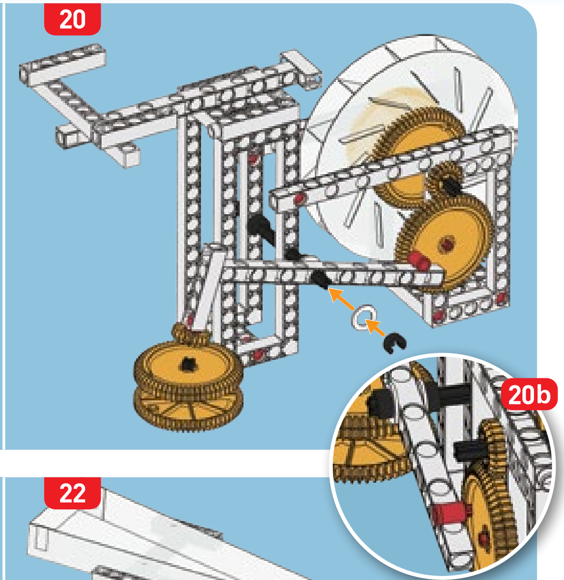


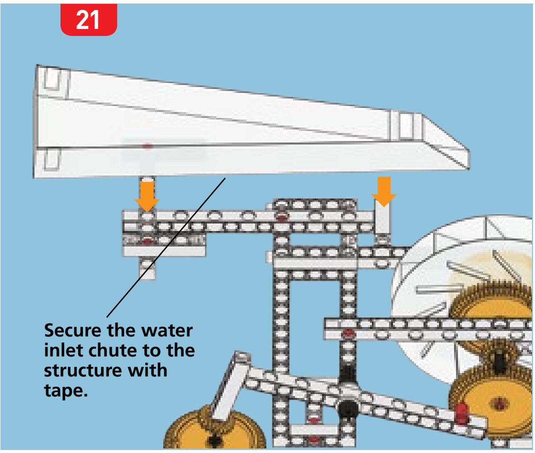


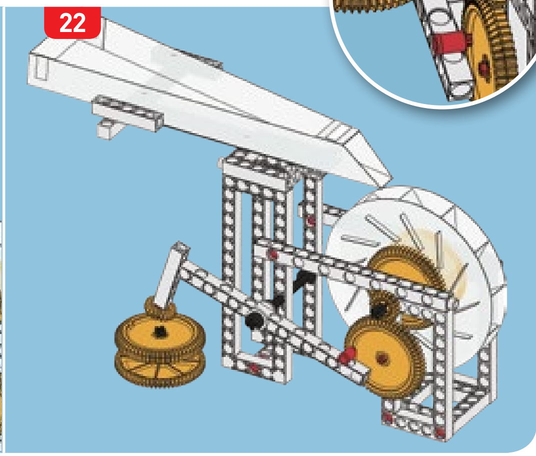


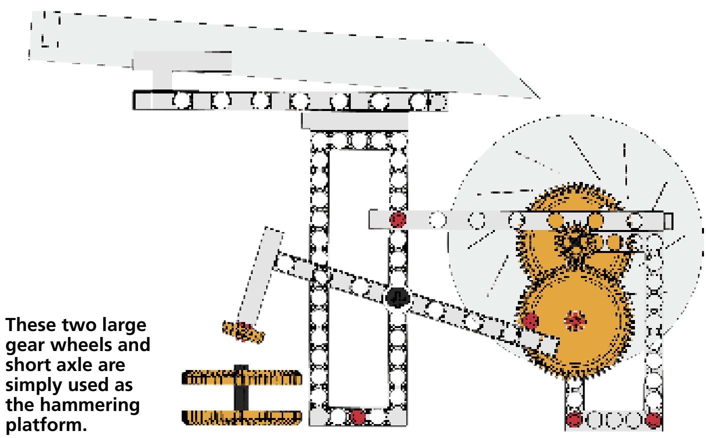


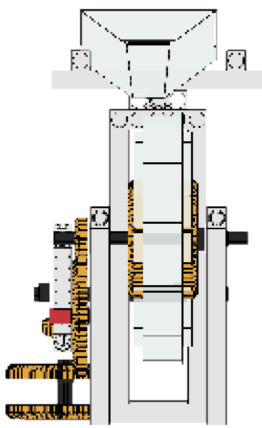

19


20
20b


21
Secure the water inlet chute to the structure with tape.


22

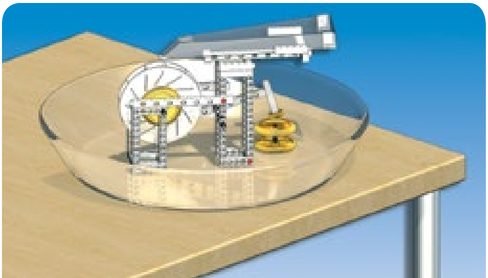

These two large gear wheels and short axle are simply used as the hammering platform.



From Water to Electricity

07 *Experiment*

More water, more energy

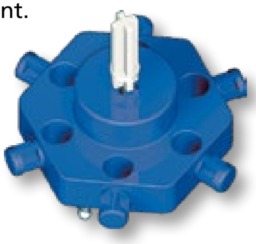


Set up your hammer mill in a wide, shallow basin or plastic bin, as before. It is best to do your experiments in the sink, on a balcony, outside in your yard, or in the bathtub, to prevent "water damage" from splashes and spills.

Pour water into the inlet chute to start your hammer mill. You can raise the rotation rate of the water wheel by adjusting the water inlet — more water or a steeper angle of the chute yields a higher rotation rate. In this way, you can significantly increase the number of times your hammer strikes in a given time period.

From water to electricity

Hydropower plants use the energy of flowing water too. In high-elevation reservoirs, rainwater and runoff from melting snow are collected and routed downhill through a conduit to a propeller (turbine) in the valley. The turbine turns a large dynamo (generator), which produces electrical current.



In order to create dammed reservoirs, valuable land and towns often have to be flooded. Entire ecosystems and major species habitats are adversely affected, even lost entirely in the construction of hydropower dams. For this reason there is some contention over the environmental sustainability of large hydropower projects. On the other hand, this means of producing electricity does not involve the combustion of heating oil, gas, or coal in thermal power plants, which contribute to global warming. Therefore, each kilowatt hour of electricity generated from a hydropower plant is pollution-free energy.

There are ways to reduce the environmental impact of hydropower generation, especially with small scale or existing dam structures. The Low Impact Hydropower Institute has a certification program designed to help identify dams that are minimizing their environmental impact by meeting criteria in the following eight areas: river flows, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resources protection, recreation, and facilities recommended for removal. Clean Water Action, a national organization with over 1.2 million members in the United States, supports low impact hydropower as a renewable energy source.

Hydropower plant with penstock pipes

A high-pressure stream of water drives this Pelton turbine in a power plant.

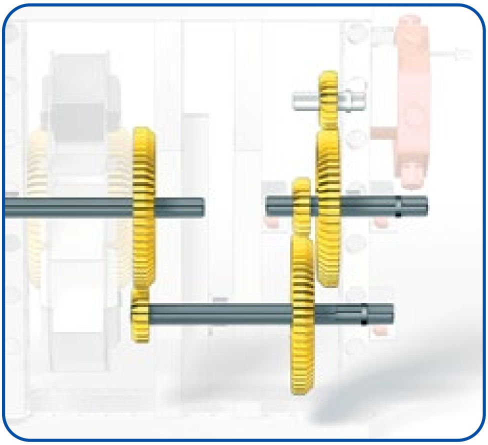
06 *Workshop*

Water Wheel with Generator

You will need:

- ☐ 3 large gear wheels (16)
- ☐ 3 small gear wheels (15)
- ☐ 18 anchor pins (4)
- ☐ 6 long rods (11)
- ☐ 2 large frames (14)
- ☐ 1 small frame (13)
- ☐ 3 5-hole frames (12)
- ☐ 5 5-hole rods (9)
- ☐ 7 washers (6)
- ☐ 1 medium axle (18)
- ☐ 2 long axles (19)
- ☐ Fully assembled generator unit, blue (21)
- ☐ 1 LED (7)
- ☐ 6 blue turbine buckets (27)
- ☐ 6 button pins (28)
- ☐ 6 3-hole dual rods (29)
- ☐ Universal adapter, assembled, red (30)

This model uses a different water wheel than the one previously used in this manual. You will now be using the light blue hard plastic water wheel assembly.



As you saw in the previous experiments, your water wheel can drive small machines, exploiting the flow of water to create mechanically usable energy. So, for example, with the hammer mill you just built, if you want to forge some metal hardware, you would be doing this not with an exhaust-producing engine, such as a gas engine, but with emissions-free, renewable hydropower. But our water wheel can also produce electricity. That's what we'll be doing next.

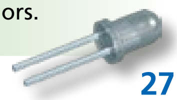
In order to generate electricity from the spinning water wheel, you will use a generator. The generator's axle has to turn very quickly for it to work, so you will build a transmission to make it spin faster. You will be assembling a three-stage transmission (see diagram below), with each gear having a transmission ratio of 1 to 3. That means that when the water wheel is turning at a rate of 100 rotations per minute, the generator shaft will be turning at a rate of 900 rotations per minute.

You can try it without water to see if the LED lights up. To do this, give the water wheel a little spin. Pay attention to the rotation direction: Looking at the assembly from the water wheel side, you will have to push the water wheel downward on the right side.

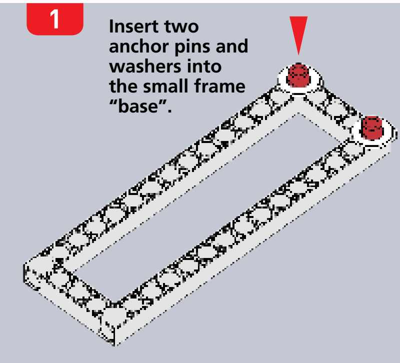
If the LED lights up, everything is working. If not, you will have to insert the LED the other way around. Unlike light bulbs, LEDs are polarized, meaning that they have a plus and a minus pole, and they only work with the current flowing in one direction.

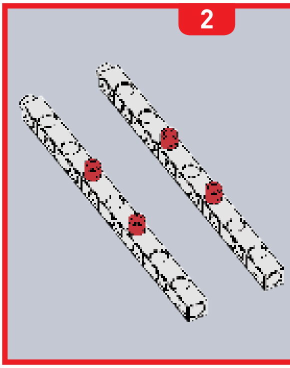
Be sure that the individual gears turn smoothly and, in particular, that the turbine wheel is installed correctly.

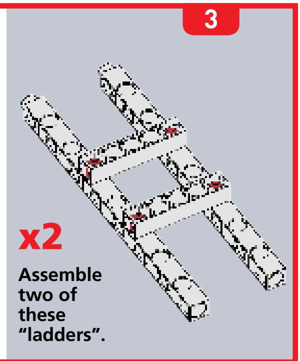
By the way:
A light-emitting diode (LED), also known as a luminescent diode, is an electronic assembly component. If an electric current flows through the LED, it lights up. LEDs come in a variety of colors.

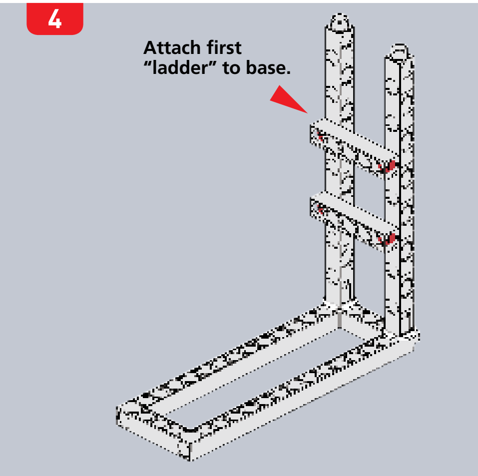


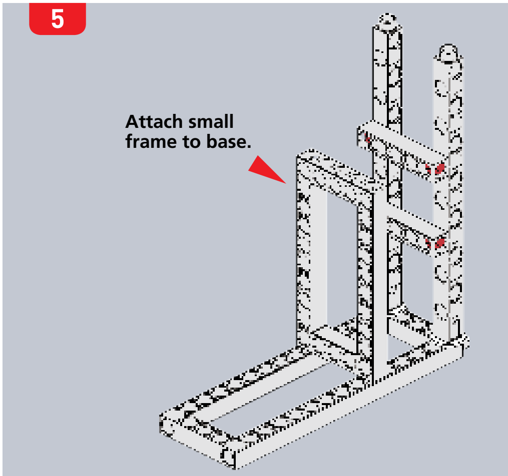
Water Wheel with Generator

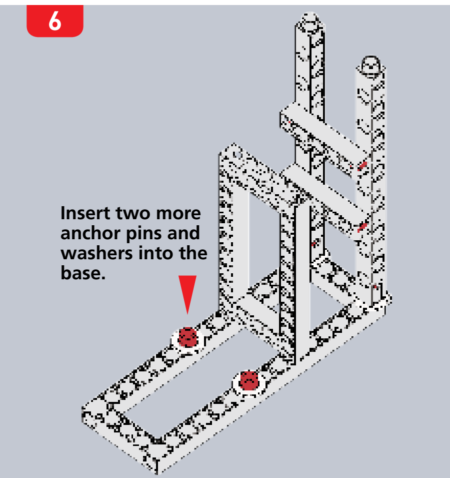


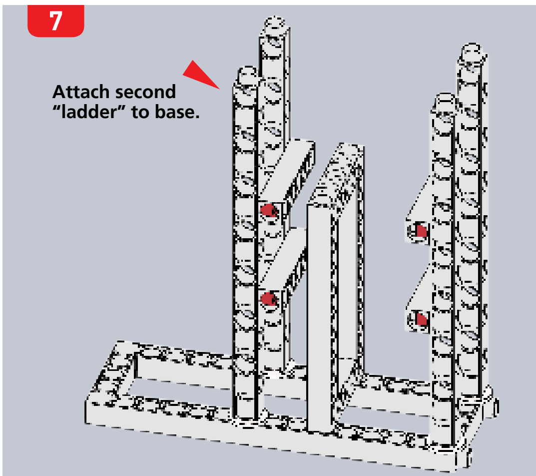




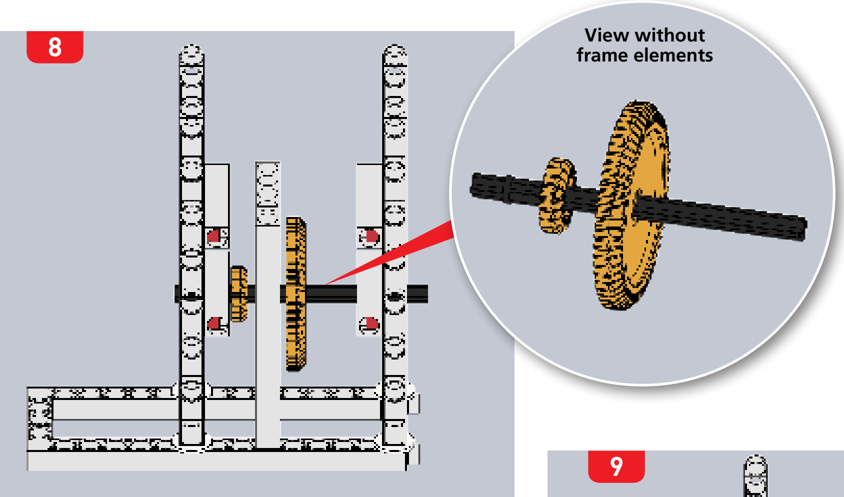






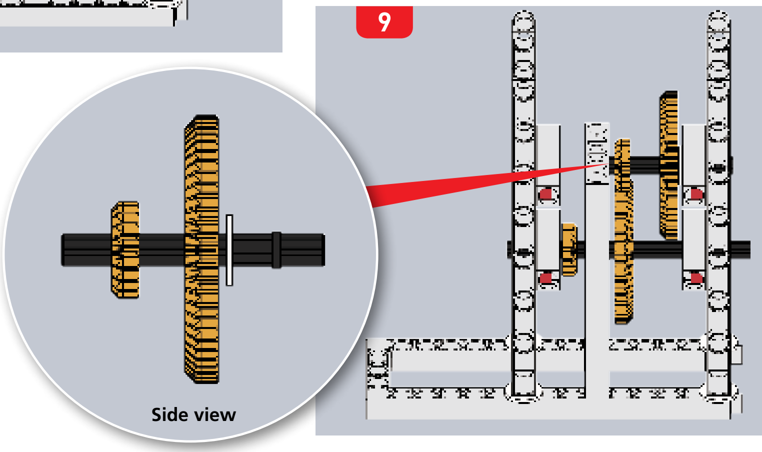


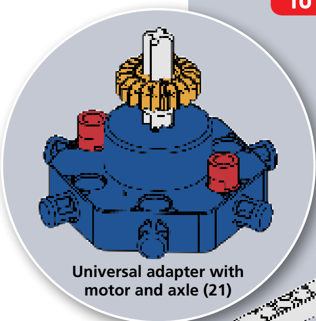
Water Wheel with Generator



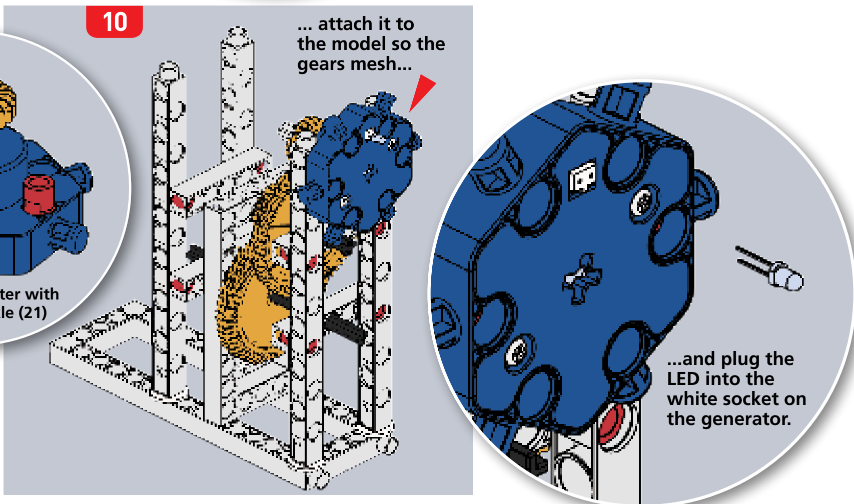
Assemble a long axle with small and large gears in place, first holding the gears in position as you slide the axle through them and the rods. (You cannot assemble the axle and gears first, and then insert it.)

Assemble this medium axle with small gear, large gear, and washer in place. Make sure the large gear on the first axle meshes with the small gear on the second.



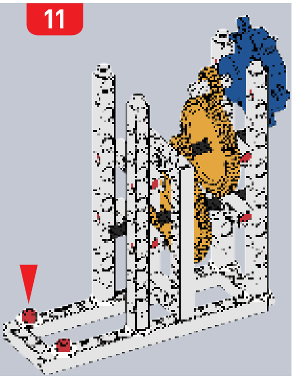


Attach two anchor pins and a small gear wheel to the blue generator unit...



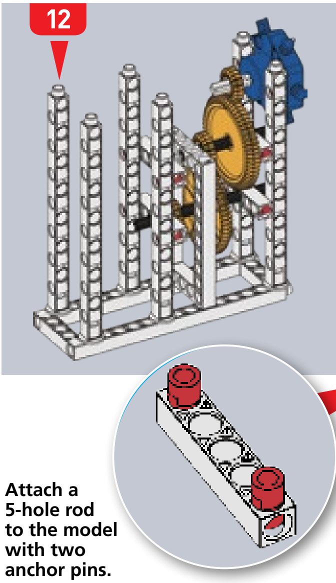
Water Wheel with Generator

11



Insert two more anchor pins and washers into the base.

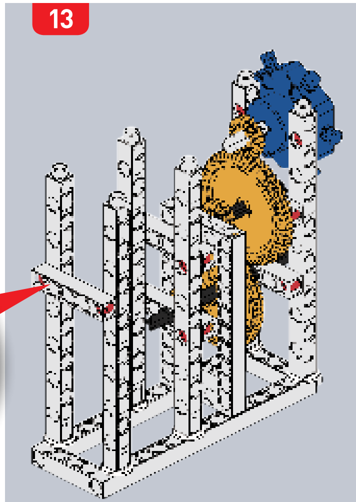
12



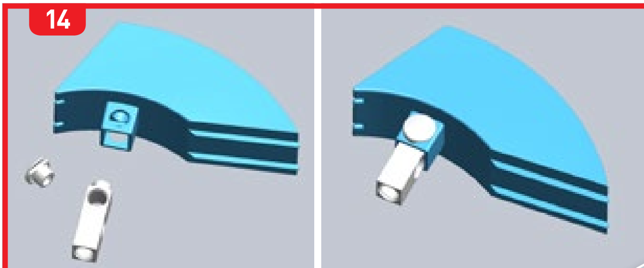
Attach a 5-hole rod to the model with two anchor pins.

13

Attach two long rods to the anchor pins.



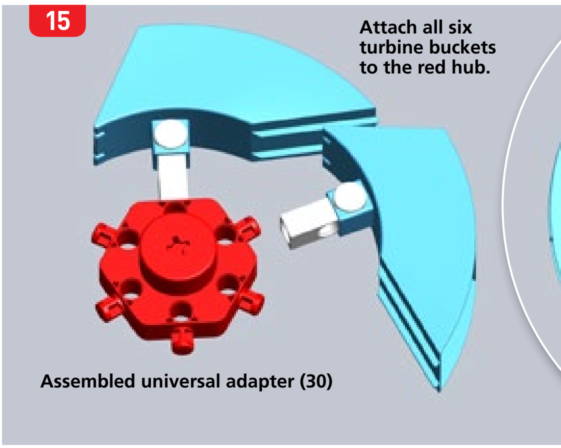
14



x6

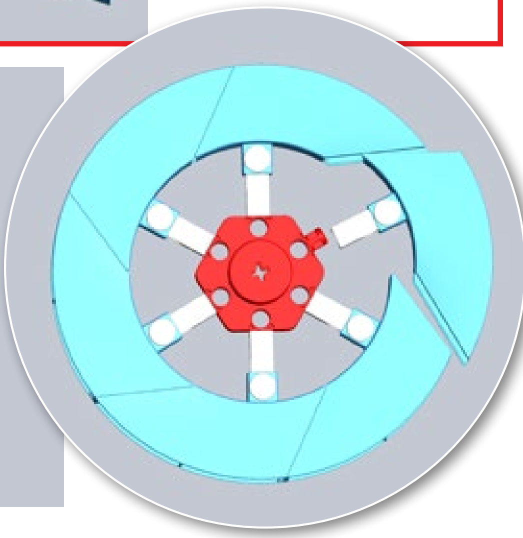
Assemble six of these turbine buckets with 3-hole dual rods and button pins.

15



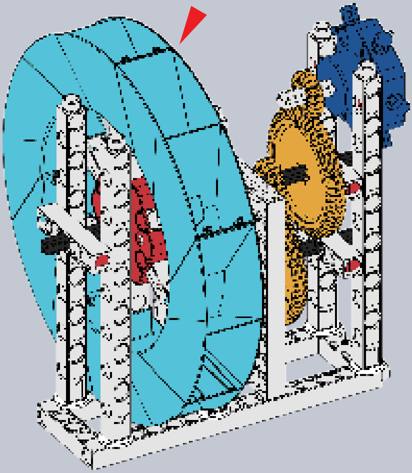
Attach all six turbine buckets to the red hub.

Assembled universal adapter (30)



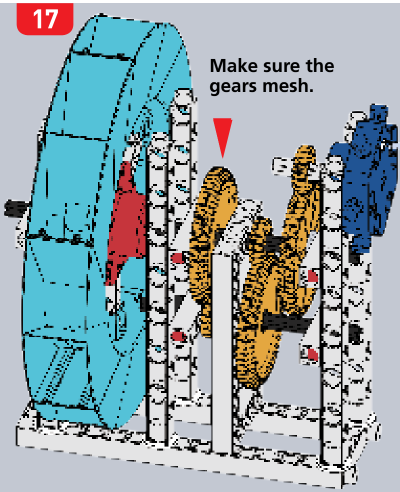
16

Attach the water wheel and a large gear wheel to the model with a long axle.



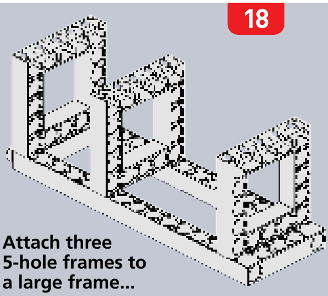
17

Make sure the gears mesh.



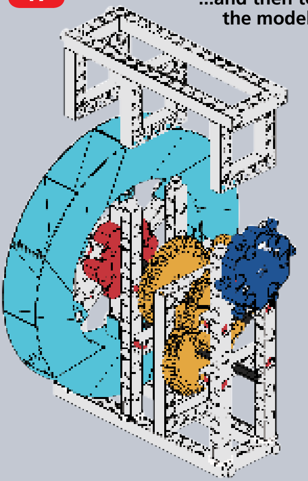
18

Attach three 5-hole frames to a large frame...



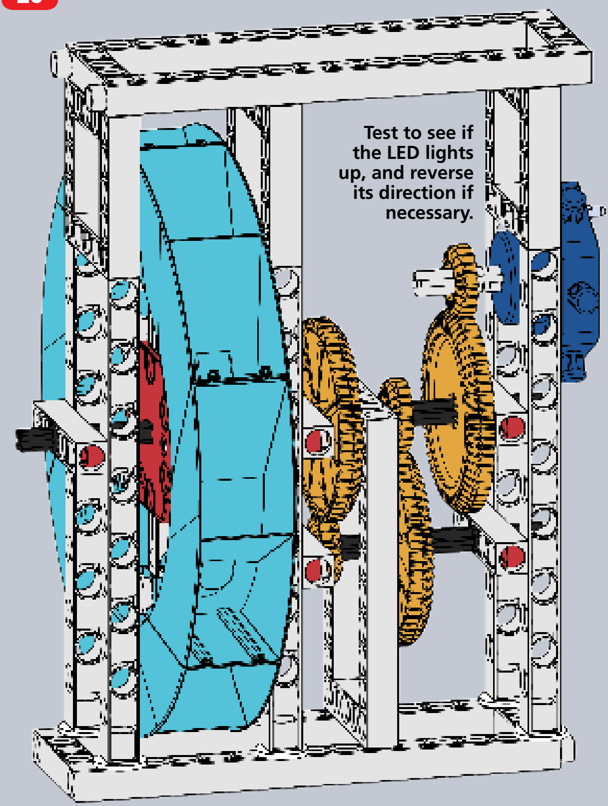
19

...and then to the model.



20

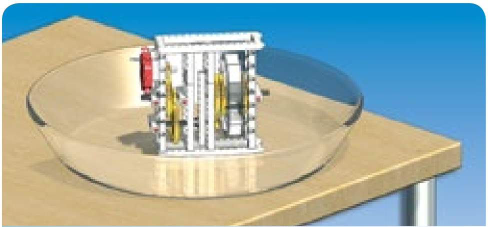
Test to see if the LED lights up, and reverse its direction if necessary.



Power from the Sea

08 *Experiment*

The water wheel makes the LED light up



Set up your water wheel in a wide, shallow basin or plastic bin, as before. It is best to do your experiments in the sink, on a balcony, outside in your yard, or in the bathtub, to prevent “water damage” from splashes and spills.

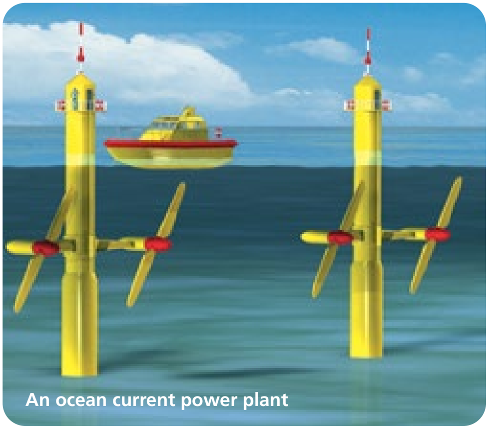
Because more water is needed for a water wheel that will be driving an electrical generator, you will want to do this experiment with a hose or a watering can. Pour the stream of water directly onto the paddles of the water wheel.

This dynamo on a bicycle wheel generates enough electricity to power the bicycle’s light, so there is never a need for batteries.

To produce electricity, the generator requires a high rotation speed. If you have a bicycle with a generator-powered light, then you are already familiar with generators — with a bicycle light, it is called a “dynamo.”

Power from ocean currents

An ocean current power plant, like a windmill in the water, uses the flow of the ocean’s current to turn a generator to produce electric current.



An ocean current power plant

Power from the waves

The rise and fall of ocean waves also holds energy. Between the crest of one wave and the trough before the next one, masses of water are lifted up and lowered again. Waves are created when wind pushes along the water’s surface. And wind created when the sun warms masses of water and land to different temperatures. That leads to differences in air pressure, which air currents try to equalize. So wave energy is ultimately solar energy converted into kinetic (movement) energy.

The use of ocean waves is a new, environmentally friendly technology for obtaining energy. Because this energy is inexhaustible, as with all other forms of hydropower, it is considered renewable. Countries with long coastlines and high waves (such as the United States and the British Isles) could meet much of their electricity needs with power from wave energy. Of course, a lot of beautiful coastline would have to be built up in the process, which is an important consideration.

Yet another wave-powered system uses a principle that is a little like breathing in and out: An open bottom concrete chamber is situated on the waterfront. Incoming waves push water into the chamber through the bottom. When the water is pushed into the chamber, the air above the water is compressed. The compressed air is forced into a tube where it drives a turbine (similar to how wind drives a wind turbine). The turbine is connected to a generator that generates electricity.

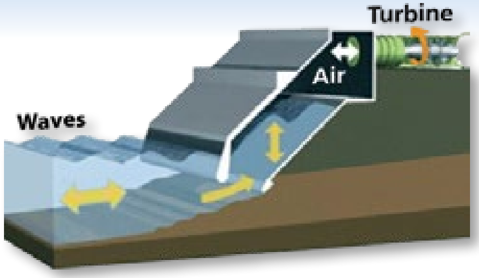


Diagram of a wave power plant.


Tidal current drives the turbines at this tidal power plant near St. Malot, France. It was built in 1969. The Rance River serves as a storage pool.

Power from the moon

The sea holds yet another kind of energy: tidal power. The tides are the rhythmic rise and fall of the surface of the ocean. The tides are actually caused by the moon. As it revolves around the Earth, its gravity pulls the oceans' waters toward it. This causes the ocean level to rise and fall at regular intervals.

On some coasts, the difference between high and low tide is particularly large. For example, on the coasts of the English-French Channel, the difference is nine to thirteen meters.

When the tide rises, a river or inlet is filled with a huge mass of incoming water. Thinking back to the fountain experiment, you will remember what happens when a large volume of water squeezes into a relatively narrow channel: It creates a fast-moving, powerful flow. Turbines placed in the middle of this flow can use both the incoming and outgoing tidal waters to generate electricity.

Test Your Knowledge of Hydropower

1. What is meant by the term "hydrological cycle?"

A. Water flows from mountains into streams and rivers.
B. Rain falls from the sky and fills up lakes and ponds.
C. Water from oceans, seas, and rivers evaporates, turns to clouds, and falls back to Earth as rain, which flows back into the oceans.

2. Why would there be no hydropower without the sun?

A. The sun pulls the water towards it.
B. Water warmed by the sun evaporates and forms clouds. When these clouds move into colder regions, the water falls back to Earth as rain or snow.
C. Warm water stores energy.

3. How can the moon help us to produce electricity?

A. The moon orbits the Earth and emits energy.
B. The attractive force of the moon produces high and low tides along the coasts. The difference between high and low water is exploited by tidal power plants.
C. Moonbeams emitted by the moon are converted by power plants into electrical energy.

4. What does the "adhesion" of water mean?

A. Water is transparent, but only lets diffracted, or bent, rays of light penetrate it.
B. Water consists of individual molecules that repel each other.
C. The force with which the individual water molecules attract each other.

5. How can water flow uphill all by itself?

A. When water is heated, it flows uphill.
B. When water is exposed to low temperatures.
C. Water climbs up very narrow tubes — also known as capillaries.

6. How could you use a piece of garden hose and water to determine that two things are at equal heights?

A. The water level is always equally high in two connected containers.
B. The water always flows to the lowest point.
C. The water flows from one height to the other.

7. What are water towers and elevated tanks used for?

A. To ensure that a certain quantity of water supply is available.
B. Water is purified in water towers and elevated tanks.
C. Water towers and elevated tanks create a system of communicating vessels with city and household plumbing.

8. How can electric power stations create large quantities of clean electricity in a short period of time?

A. Power plants use batteries to release stored up electricity.
B. Dammed water is released from pumped-storage power plants and large turbines produce electricity quickly.
C. With a lot of fuel (petroleum, diesel fuel, etc.).

9. What kind of power is in flowing water?

A. Hydropower utilizes the kinetic energy of flowing water.
B. The weight of water is utilized.
C. The loosely interconnected water molecules give off energy.

Answers:
1. C (page 4)
2. B (page 4, 32)
3. B (page 33)
4. C (page 12)
5. C (page 13)
6. A (page 17)
7. C (page 14 ff)
8. B (page 26)
9. A (page 21)

624811-02-020323