

# REMOTE-CONTROL MACHINES



THAMES & KOSMOS





## Safety Information

**WARNING.** Only for use by children aged 8 years and older. Instructions for parents or other supervising adults are included and have to be observed. Keep packaging and instructions as they contain important information.

**WARNING.** Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Store the experiment material and assembled models out of the reach of small children.

## Safety for Experiments with Batteries

- >>> The wires are not to be inserted into socket-outlets. Never perform experiments using household current! The high voltage can be extremely dangerous or fatal!
- >>> To operate the models, you will need six AAA batteries (1.5-volt, type AAA/LR03) or six AAA rechargeable batteries (1.2-volt, min. 1100 mAh), which could not be included in the kit due to their limited shelf life.
- >>> The supply terminals are not to be short-circuited. A short circuit can cause the wires to overheat and the batteries to explode.
- >>> Different types of batteries or new and used batteries are not to be mixed.
- >>> Do not mix old and new batteries.
- >>> Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.
- >>> Batteries are to be inserted with the correct polarity. Press them gently into the battery compartment. See page 2.
- >>> Always close battery compartments with the lid.
- >>> Non-rechargeable batteries are not to be recharged. They could explode!
- >>> Rechargeable batteries are only to be charged under adult supervision.
- >>> Rechargeable batteries are to be removed from the toy before being charged.
- >>> Exhausted batteries are to be removed from the toy.
- >>> Dispose of used batteries in accordance with environmental provisions, not in the household trash.
- >>> Be sure not to bring batteries into contact with coins, keys, or other metal objects.
- >>> Avoid deforming the batteries.

As all of the experiments use batteries, have an adult check the experiments or models before use to make sure they are assembled properly. Always operate the motorized models under adult supervision.

After you are done experimenting, remove the batteries from the battery compartments. Note the safety information accompanying the individual experiments or models!

## 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.

## Dear Parents,

Before starting the experiments, read through the instruction manual together with your child and discuss the safety information. Check to make sure the models have been assembled correctly, and assist your child with the experiments. **We hope you and your child have a lot of fun with the experiments!**

## FCC Part 15 Statement

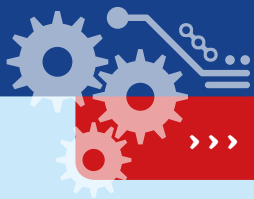
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

**NOTE:** This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.





## >>> KIT CONTENTS

**GOOD TO KNOW!** If you are missing any parts, please contact Thames & Kosmos customer service.  
 US: techsupport@thamesandkosmos.com  
 UK: techsupport@thamesandkosmos.co.uk

### What's inside your experiment kit:



**You will also need:**

6 x AAA batteries (1.5-volt, type AAA/LR03) or  
 6 x AAA rechargeable batteries (1.2-volt, min. 1100 mAh)

### Checklist: Find – Inspect – Check off

✓	No.	Description	Qty.	Item No.
<input type="checkbox"/>	1	Joint pin	14	1156-W10-A1R
<input type="checkbox"/>	2	Axle lock	4	3620-W10-A1D
<input type="checkbox"/>	3	Shaft plug	5	7026-W10-H1R
<input type="checkbox"/>	4	Shaft pin	6	7026-W10-J3R
<input type="checkbox"/>	5	3-hole rod	2	7026-W10-Q1W
<input type="checkbox"/>	6	3-hole cross rod	9	7026-W10-X1W
<input type="checkbox"/>	7	3-hole dual rod	4	7061-W10-R1D
<input type="checkbox"/>	8	3-hole wide rounded rod, black	4	7404-W10-C1D
<input type="checkbox"/>	9	3-hole wide rounded rod, white	2	7404-W10-C1W
<input type="checkbox"/>	10	Cross rod with pegs	1	7404-W10-B1S
<input type="checkbox"/>	11	5-hole rod, white	5	7413-W10-K2W
<input type="checkbox"/>	12	5-hole rod, black	2	7413-W10-K2D
<input type="checkbox"/>	13	5-hole cross rod, black	4	7413-W10-K3D
<input type="checkbox"/>	14	5-hole dual rod B, white	4	7026-W10-S2W
<input type="checkbox"/>	15	5-hole dual rod C, white	1	7026-W10-S3W
<input type="checkbox"/>	16	5-hole dual rod C, black	4	7026-W10-S3D
<input type="checkbox"/>	17	7-hole wide rounded rod, black	4	7404-W10-C2D
<input type="checkbox"/>	18	7-hole wide rounded rod, white	6	7404-W10-C2W
<input type="checkbox"/>	19	7-hole flat rounded rod, black	4	7404-W10-C3D
<input type="checkbox"/>	20	7-hole flat rounded rod, white	6	7404-W10-C3W
<input type="checkbox"/>	21	11-hole rod	4	7026-W10-C1D
<input type="checkbox"/>	22	Diagonal connector	4	7404-W10-B2S
<input type="checkbox"/>	23	Short frame	2	7413-W10-I1W
<input type="checkbox"/>	24	Curved rod	2	7061-W10-V1D
<input type="checkbox"/>	25	Square frame A	1	7026-W10-V1W
<input type="checkbox"/>	26	Square frame B	4	7026-W10-T2W
<input type="checkbox"/>	27	Trapezoidal block	1	7061-W10-L1W
<input type="checkbox"/>	28	30-mm axle	8	7413-W10-N1D

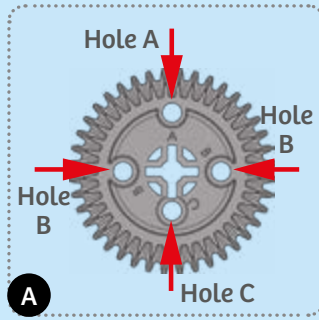
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<input type="checkbox"/>	29	35-mm axle	4	7413-W10-O1D
<input type="checkbox"/>	30	70-mm axle	2	7061-W10-Q1D
<input type="checkbox"/>	31	90-degree converter X, black	2	7061-W10-J1D
<input type="checkbox"/>	32	90-degree converter X, white	2	7061-W10-J1W
<input type="checkbox"/>	33	90-degree converter Y, black	2	7061-W10-J2D
<input type="checkbox"/>	34	90-degree converter Y, white	4	7061-W10-J2W
<input type="checkbox"/>	35	Flat triangle	4	7128-W10-A2S
<input type="checkbox"/>	36	Small gear	11	7026-W10-D2S
<input type="checkbox"/>	37	Large gear with holes	1	7026-W10-W5S
<input type="checkbox"/>	38	Worm	1	7344-W10-A1W
<input type="checkbox"/>	39	Wheel	6	7392-W10-H1W
<input type="checkbox"/>	40	Tire, hard plastic	4	7392-W10-G1S
<input type="checkbox"/>	41	Tire, rubbery plastic	2	7413-W10-D1S
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<input type="checkbox"/>	43	20-mm tube	2	7400-W10-G2D
<input type="checkbox"/>	44	Short anchor pin	9	880-W10-M1B
<input type="checkbox"/>	45	Anchor pin	46	7061-W10-C1R
<input type="checkbox"/>	46	Two-to-one converter	10	7061-W10-G1D
<input type="checkbox"/>	47	Washer	4	R12-3620
<input type="checkbox"/>	48	Anchor pin lever	1	7061-W10-B1Y
<input type="checkbox"/>	49	Medium gear	4	7346-W10-C1S
<input type="checkbox"/>	50	Motor unit	2	7400-W85-A
<input type="checkbox"/>	51	IR remote control unit	1	7337-W85-A1
<input type="checkbox"/>	52	IR motor unit	1	7337-W85-B1
<input type="checkbox"/>	53	80-mm tube	1	7337-W16-A1D
<input type="checkbox"/>	54	Sensor box front	1	7337-W10-A2W
<input type="checkbox"/>	55	Sensor box back	1	7337-W10-A3W
<input type="checkbox"/>	56	Sensor box eye stickers	1	R20-7337



Here are a few tips for assembling and using the models. Read them carefully before starting.

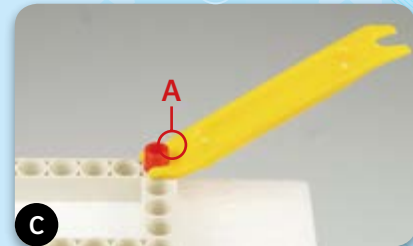
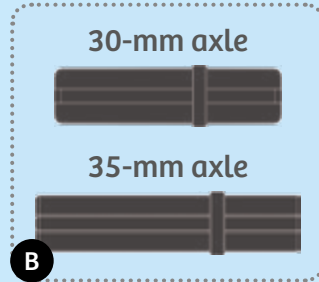
**A. Gear hole alignment**

Pay close attention to the alignment of the holes in the gear wheels. Make sure that you insert the shaft pins into the correct holes and that the gears are oriented exactly as shown in relation to each other and to the model.



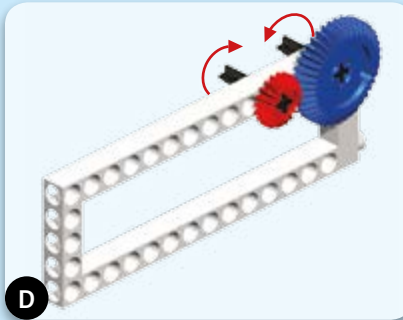
**B. 30-mm and 35-mm axles**

Make sure you use the correct axles. The 30-mm and 35-mm axles look very similar, so the assembly instructions indicate which one to use with a 1:1 scale image.



**C. The part separator tool**

In the box, you will find a little yellow tool called the anchor pin lever. End A of the part separator tool makes it easy to remove anchor pins from the frames.



**D. Gear wheels**

The models will often have several gear wheels installed in a row. In order for the models to work well, these gears will have to mesh well. Otherwise, the force from one gear wheel won't be properly transferred to the next.

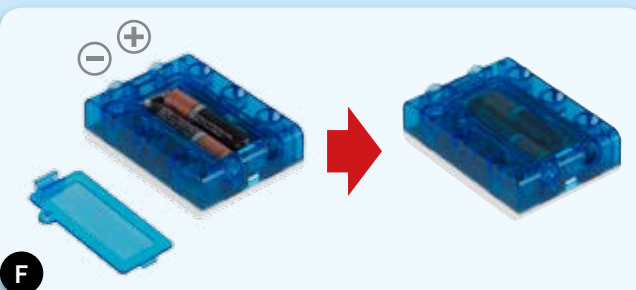
**E. Batteries in IR motor unit**

Insert the batteries according to their indicated plus-minus polarity and close the compartment with the transparent cover.



**F. Batteries in IR remote control unit**

Open the battery compartment by unscrewing the screw and removing the cover. Insert two batteries, paying attention to the polarity indicated in the compartment and on the batteries. Close the compartment again and reinsert the screw to secure it.



**G. Using the IR remote control**

To control a model, turn on both the motor unit and the remote control unit by moving their switches from the "off" position (0) to any of the four channels (1-4). The motor unit and the remote control must be set to the same channel to communicate. The channels enable you to use up to four models (sold separately) at the same time in the same space.



**IMPORTANT!**

Make sure your remote control unit and your motor unit are both set to the same channel (1-4) or else they will not work. When the remote control and motor are not in use, turn them off by setting their switches to "0" so as to not drain the batteries.

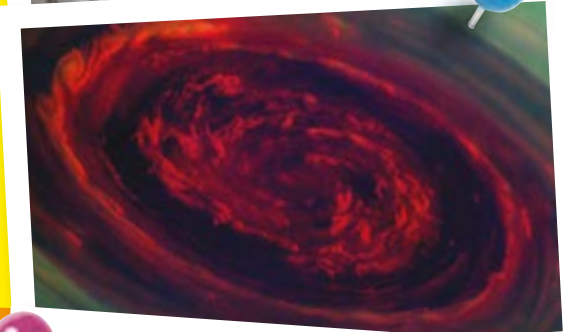
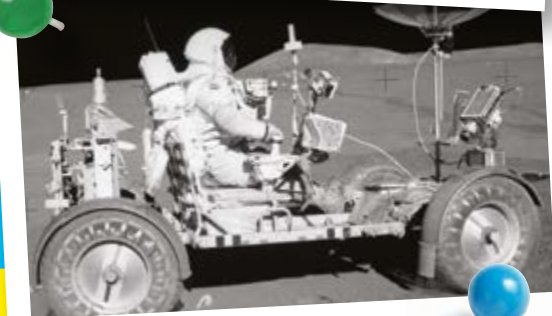




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### TIP!

You will find additional information in the “Check it out” sections on pages 14-18, 25, 32, 40, 53, 59, 79, and 80.



### TIP!

Above each set of assembly instructions, you will find a red bar:

>>> It shows you the difficulty level for the model's assembly:

● ● ● ● ●	● ● ● ● ●	● ● ● ● ●
easy	medium	hard

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# Exploring Space with Machines and Robots

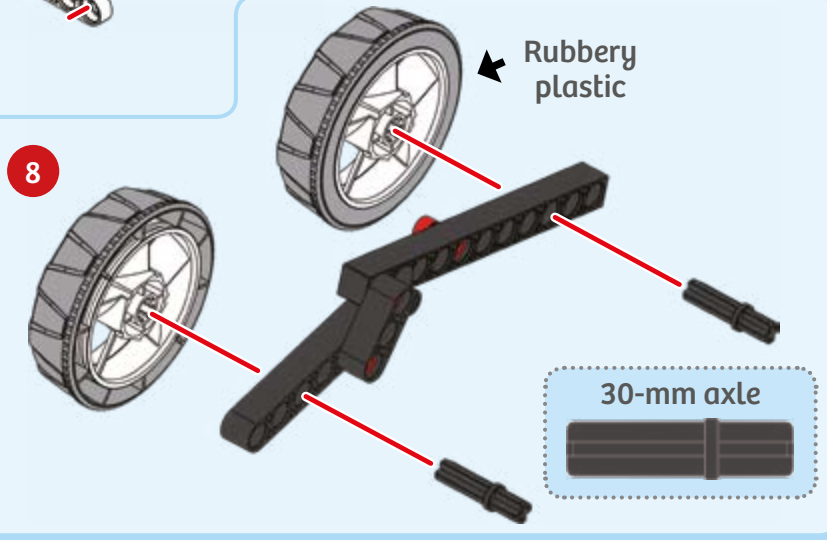
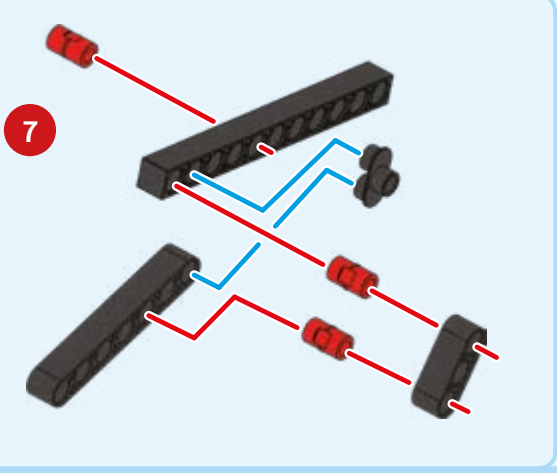
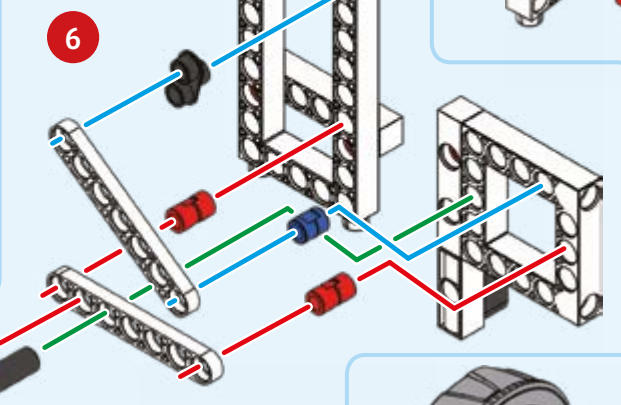
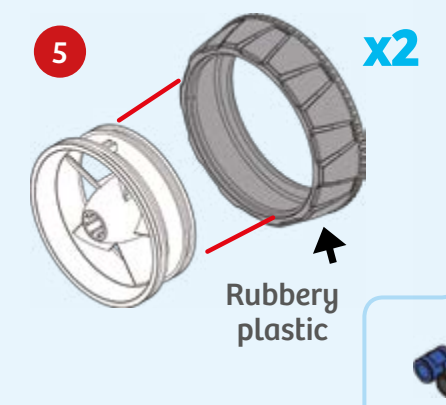
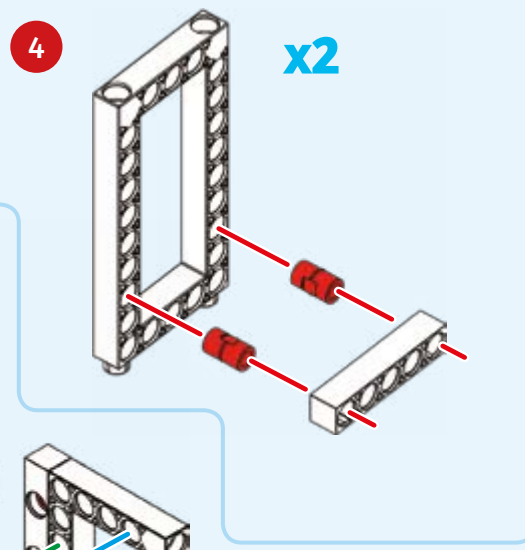
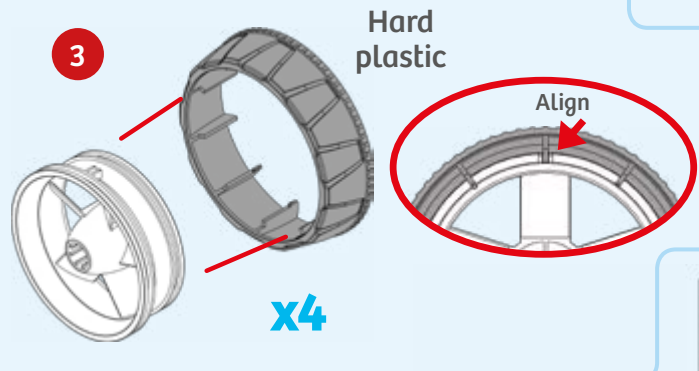
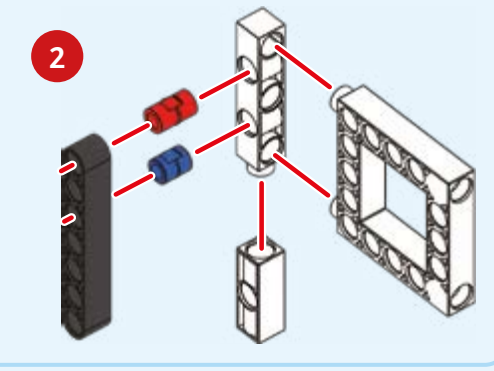
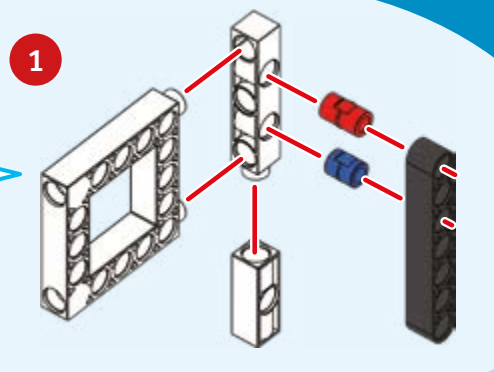
Robots are mechanical agents controlled by computer programs. They can be programmed to perform all sorts of tasks and movements. Robots can assemble cars, play soccer, wash windows, vacuum floors, fly planes, map terrain, climb mountains, entertain people, cook dinner — the list goes on and on. And now, robots are increasingly used in extraterrestrial exploration.

In this kit, you will build ten models of real and imaginary robots that perform their duties in outer space and on other planets.



MARS ROVER

- 1 14x 2 4x 3 5x 4 1x 5 2x 6 9x 7 4x 8 4x 10 1x 11 4x 12 2x 14 3x 15 1x
- 16 4x 17 4x 18 4x 19 4x 20 6x 21 4x 22 4x 23 2x 25 1x 26 4x 27 1x
- 28 8x 29 4x 30 2x 31 2x 32 2x 33 2x 34 2x 35 4x 36 9x 37 1x 38 1x 39 6x 40 4x 41 2x
- 42 6x 43 2x 44 9x 45 46x 46 10x 47 4x 49 3x 50 2x 51 1x 52 1x 53 1x 54 1x 55 1x 56 1x

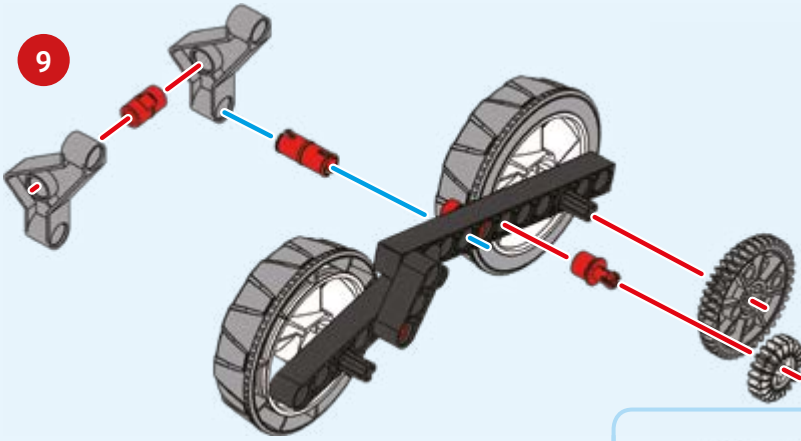




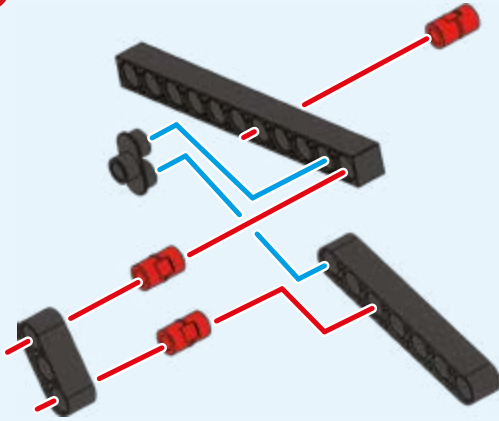


# MARS ROVER

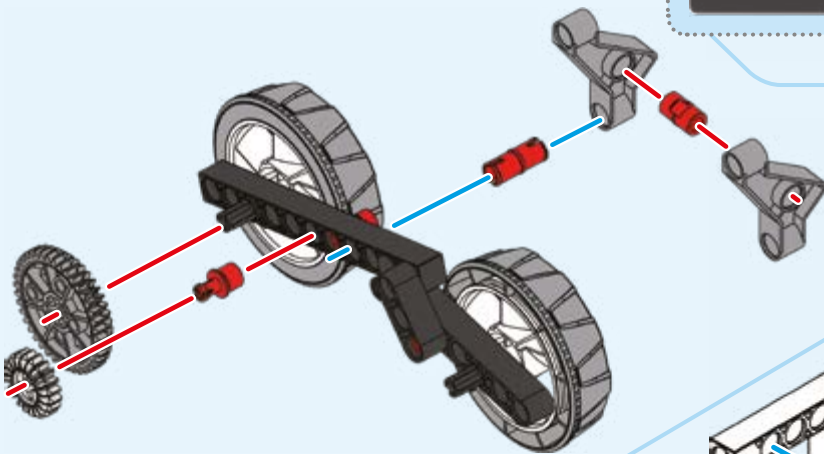
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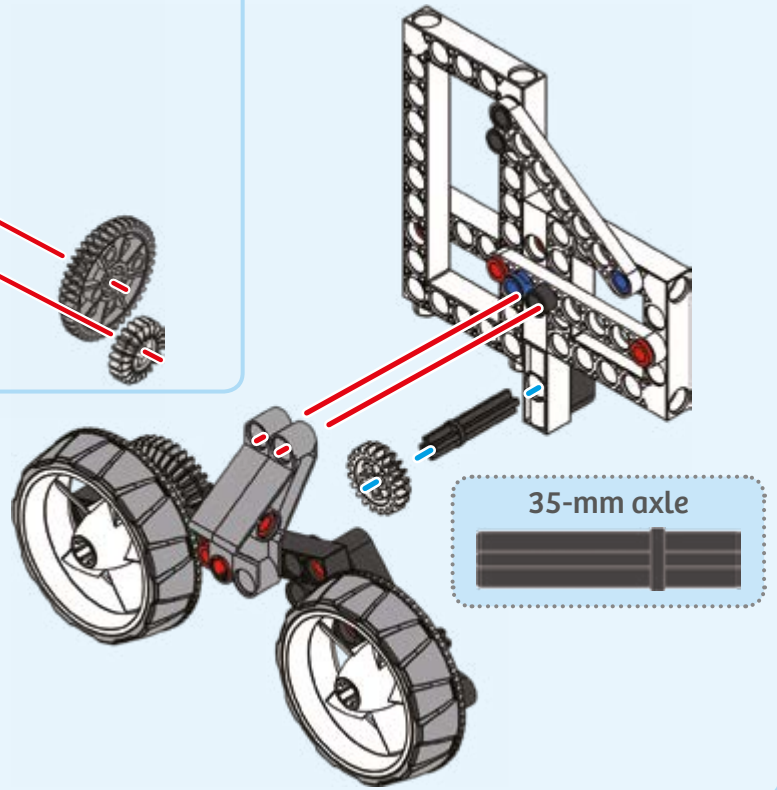
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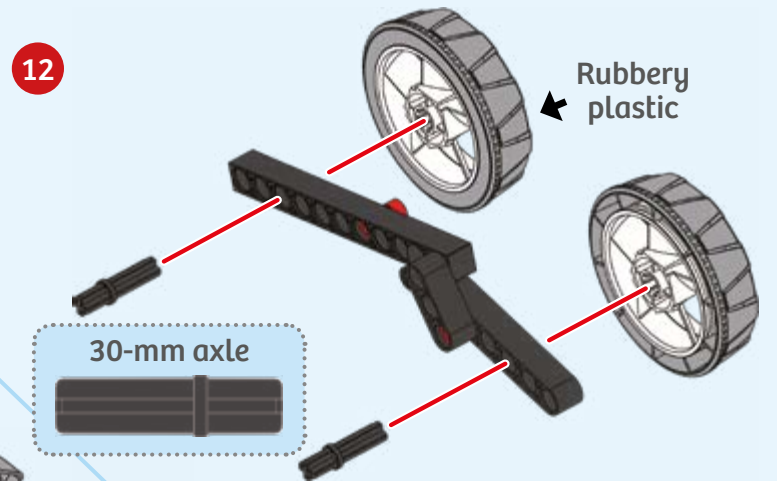
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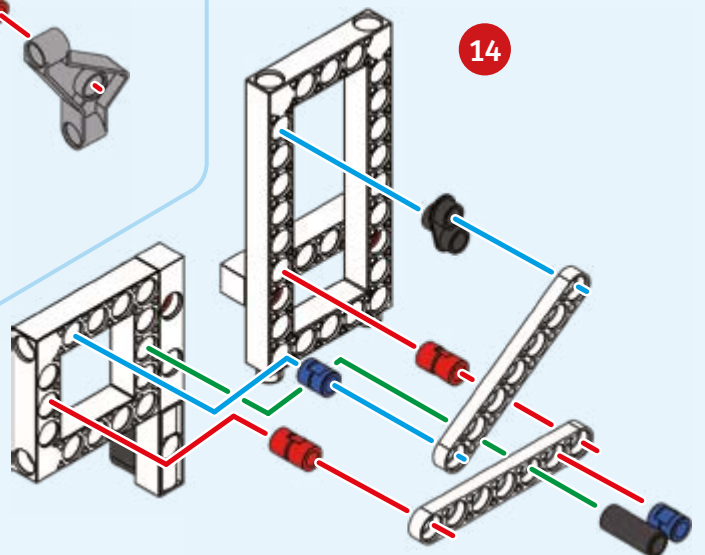
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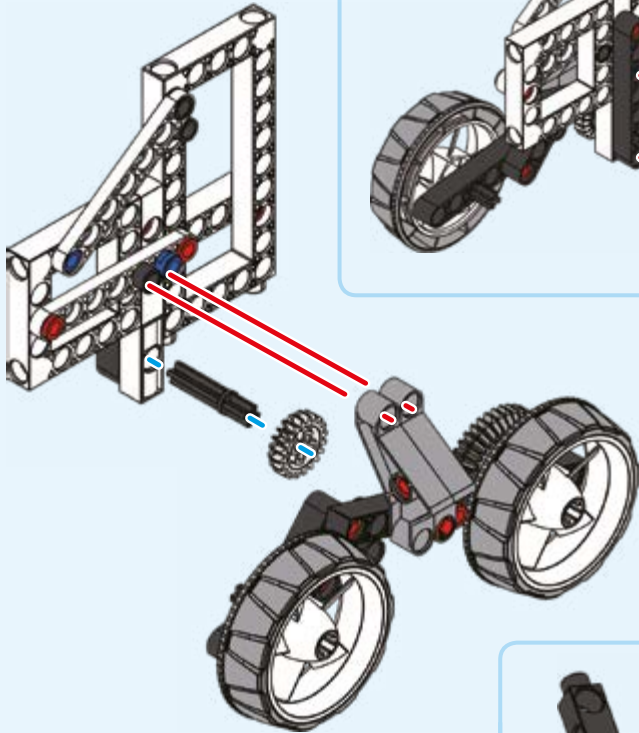
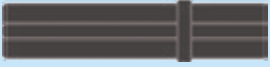


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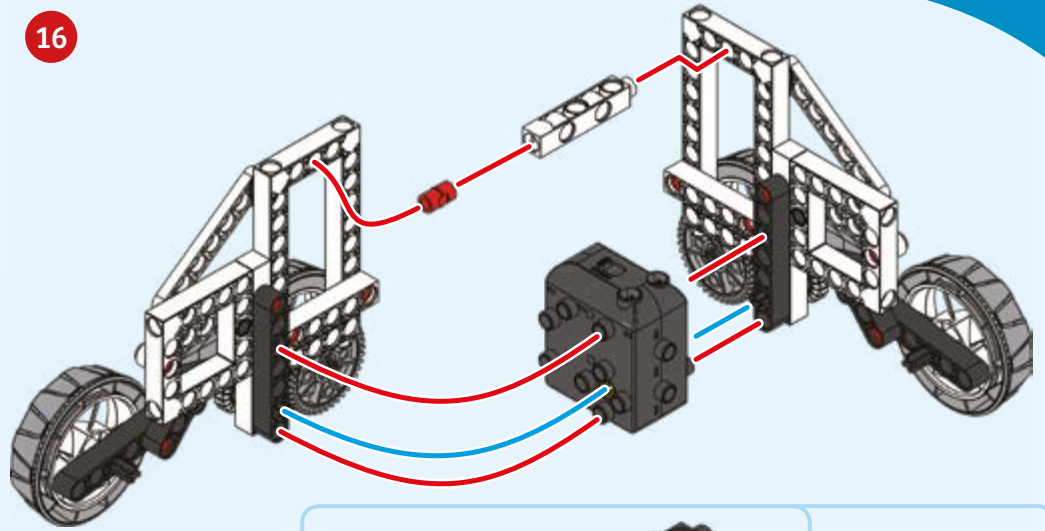


15

35-mm axle

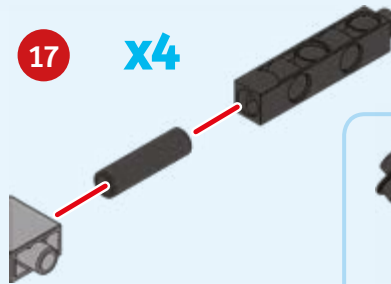


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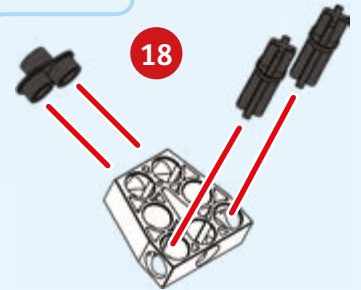


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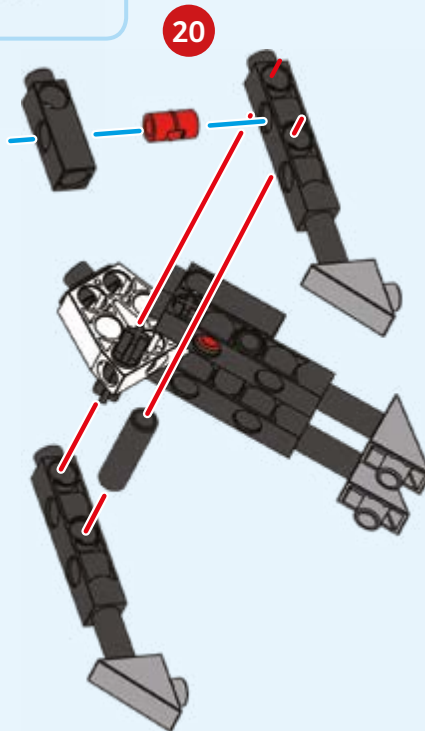
x4



18



20

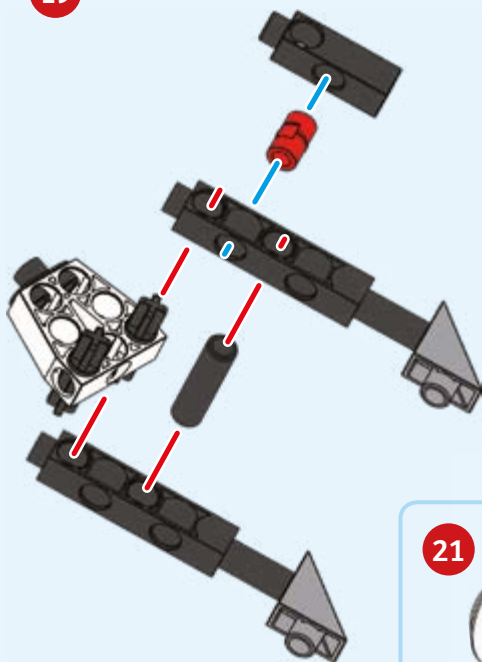


30-mm axle

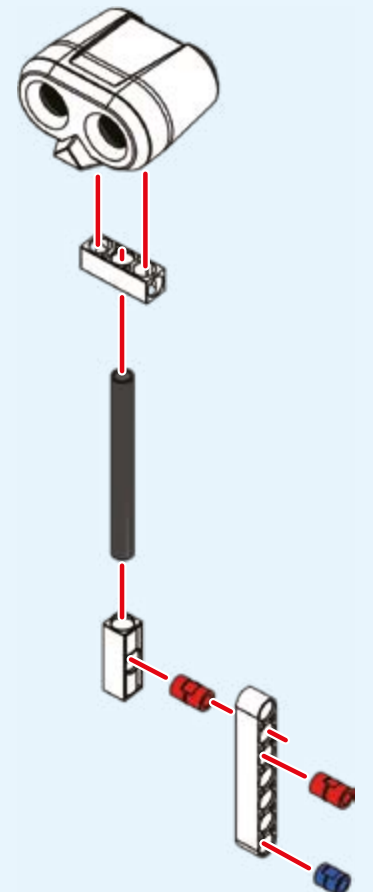
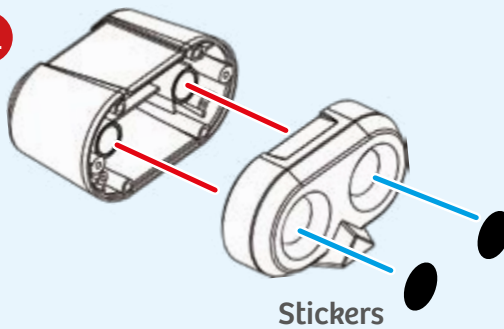
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21





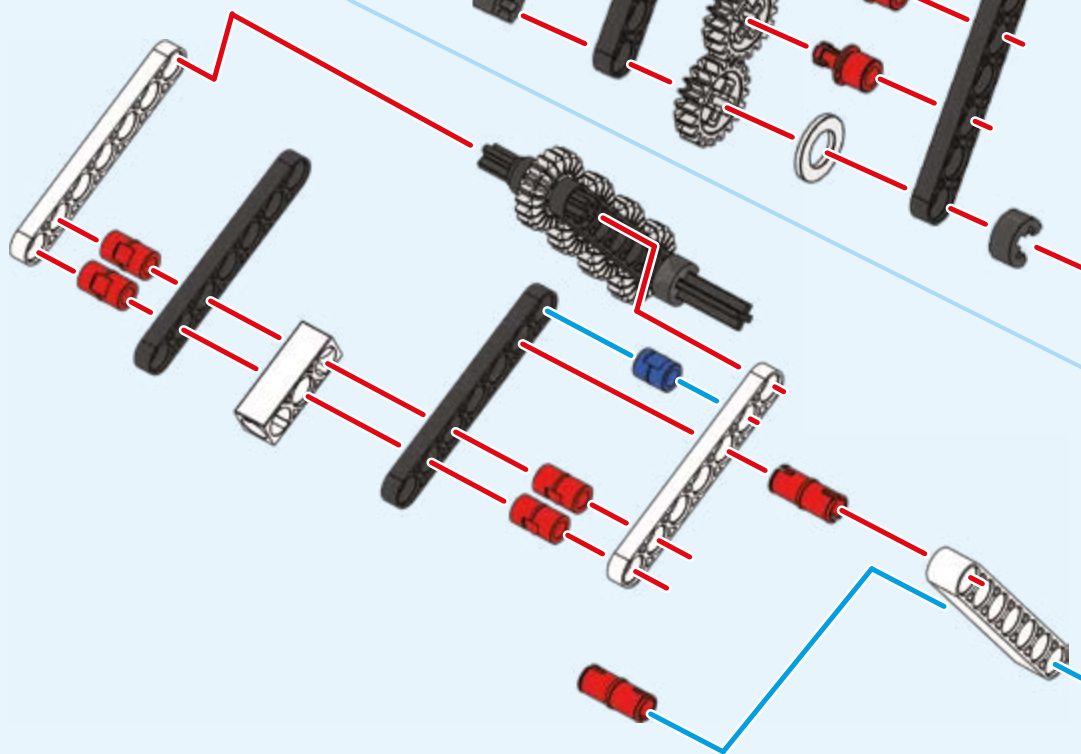


# MARS ROVER

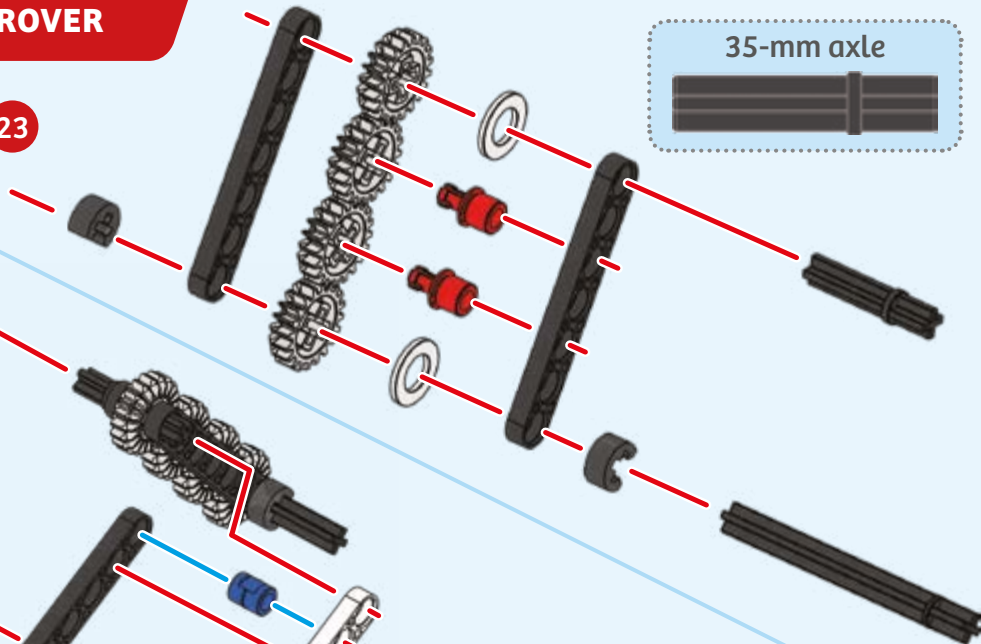
35-mm axle



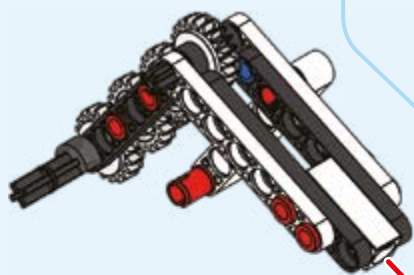
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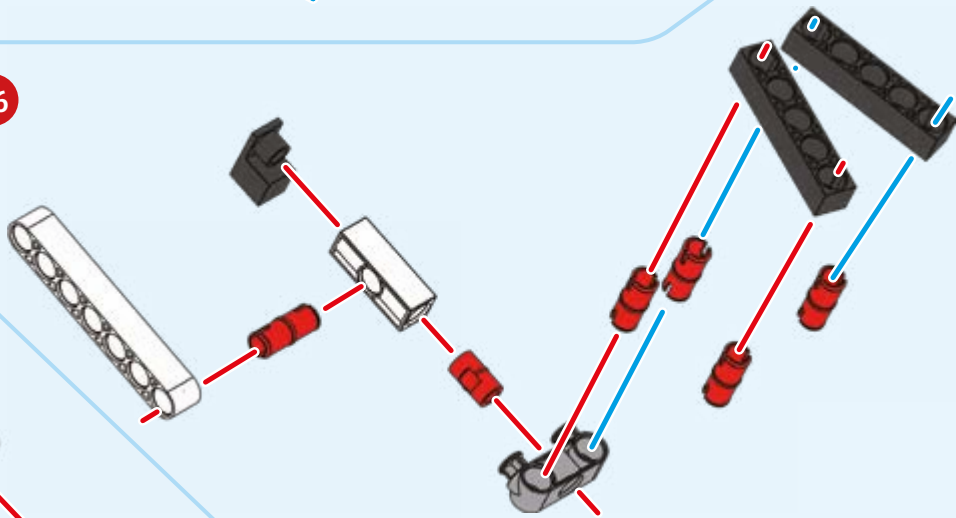
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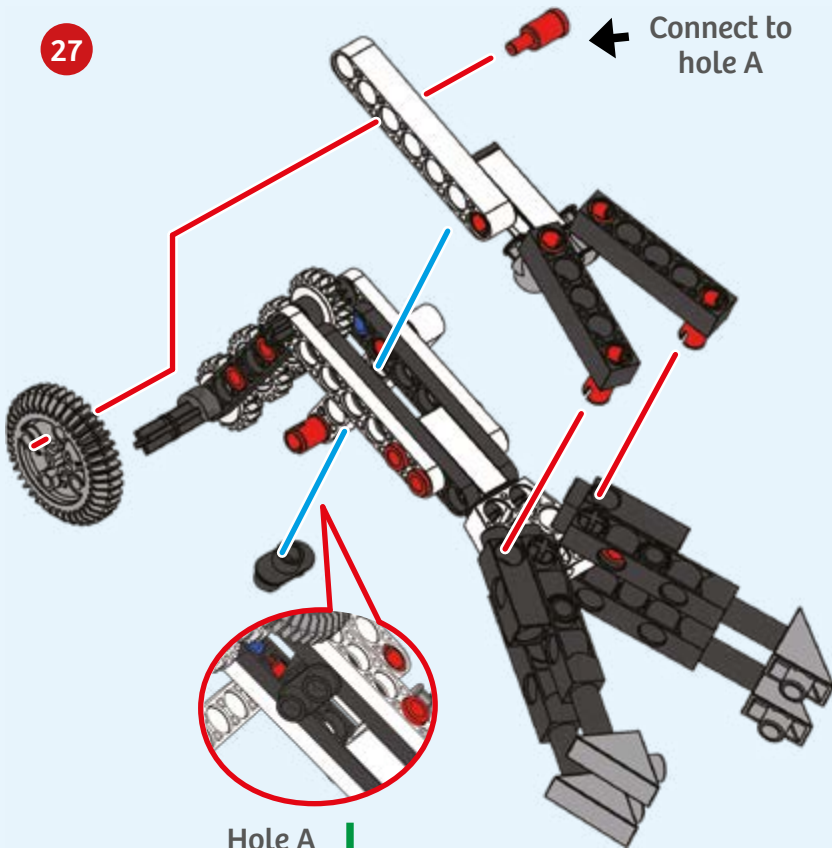
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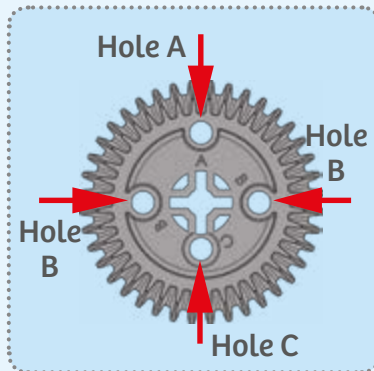
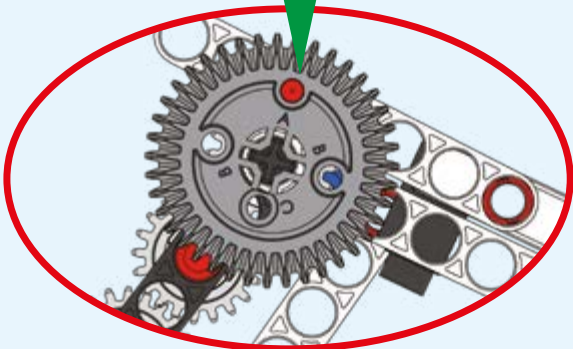


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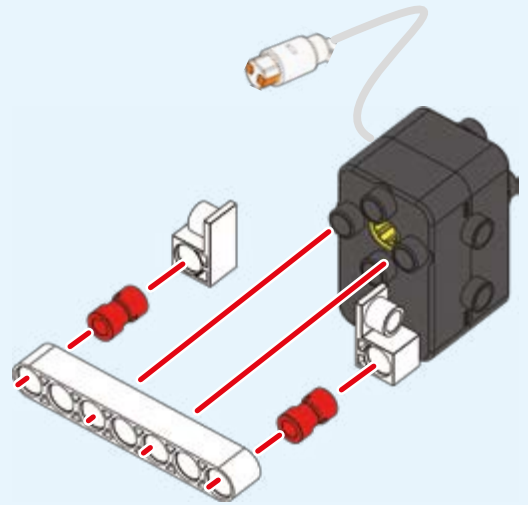


Connect to hole A

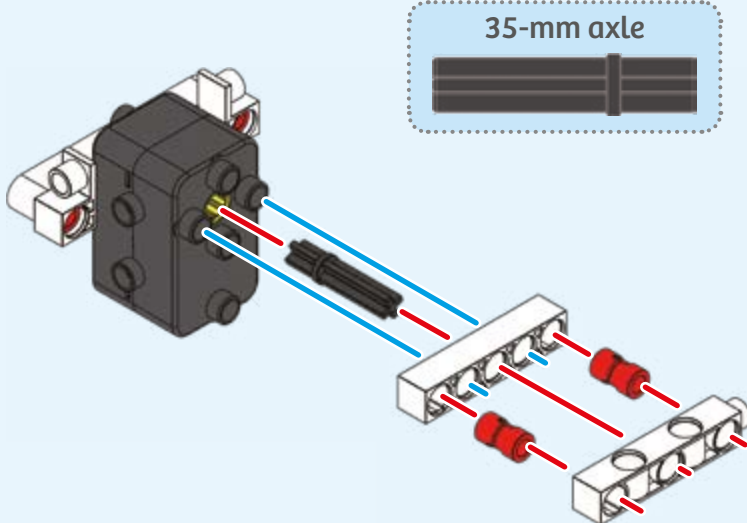
Hole A



28

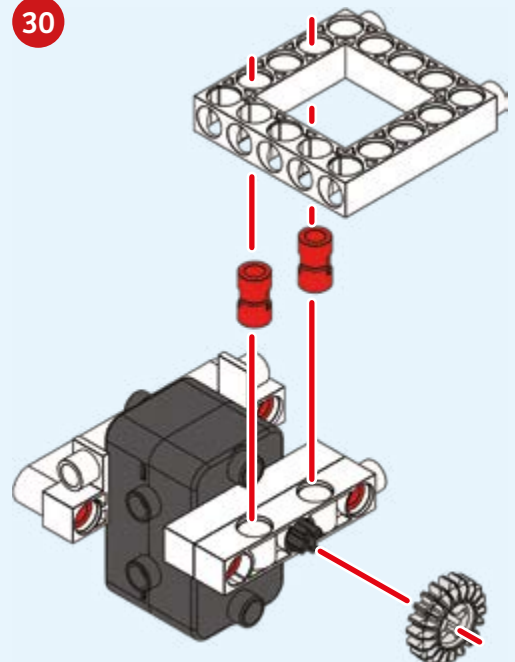


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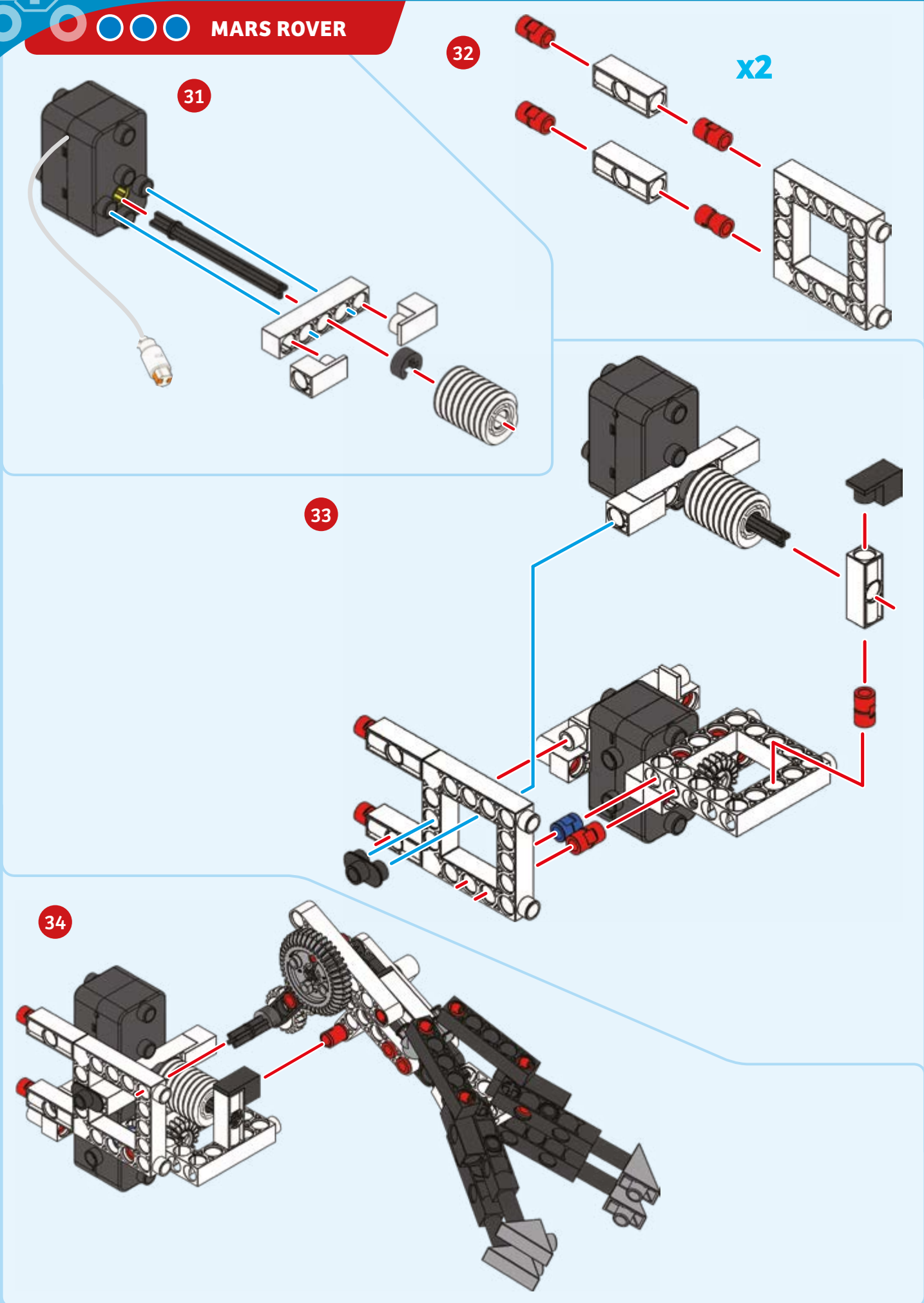


35-mm axle

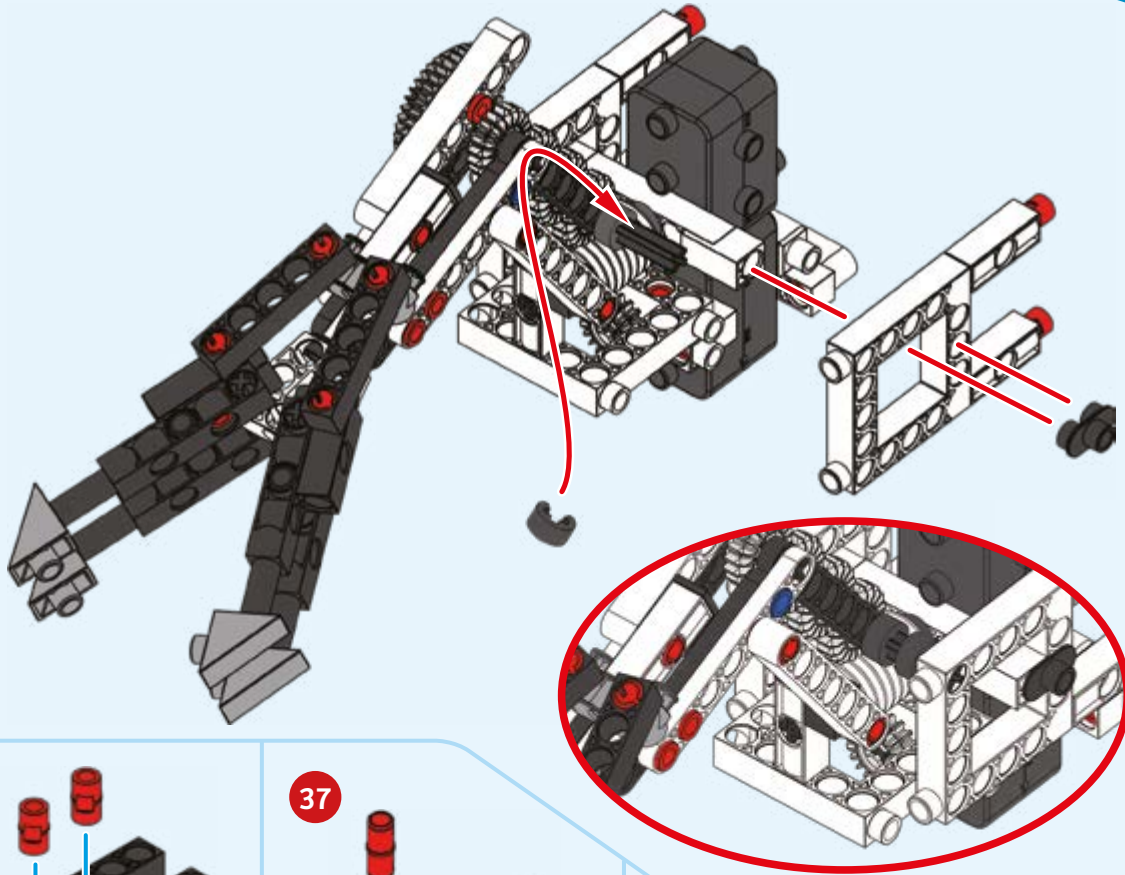
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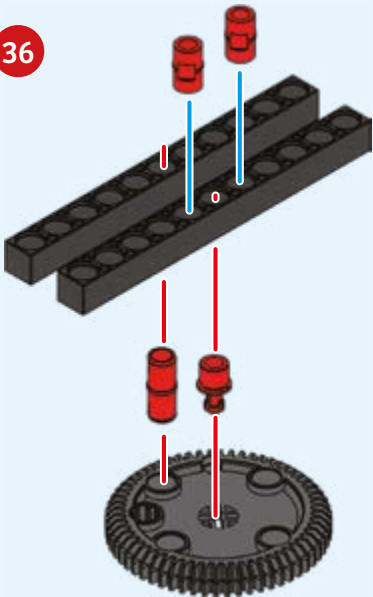




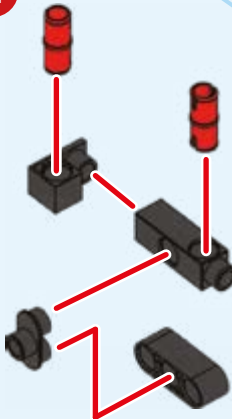
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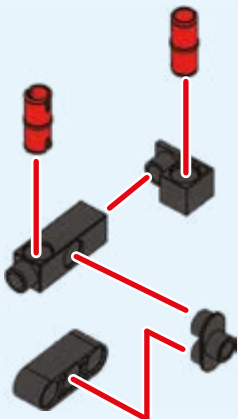
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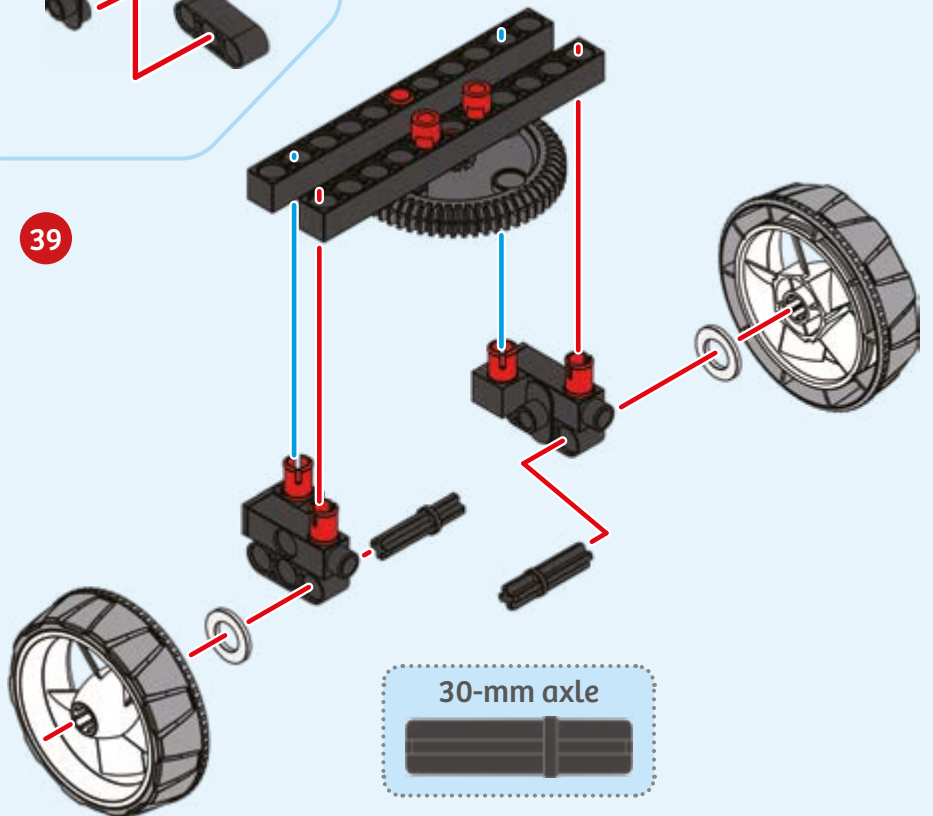
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38



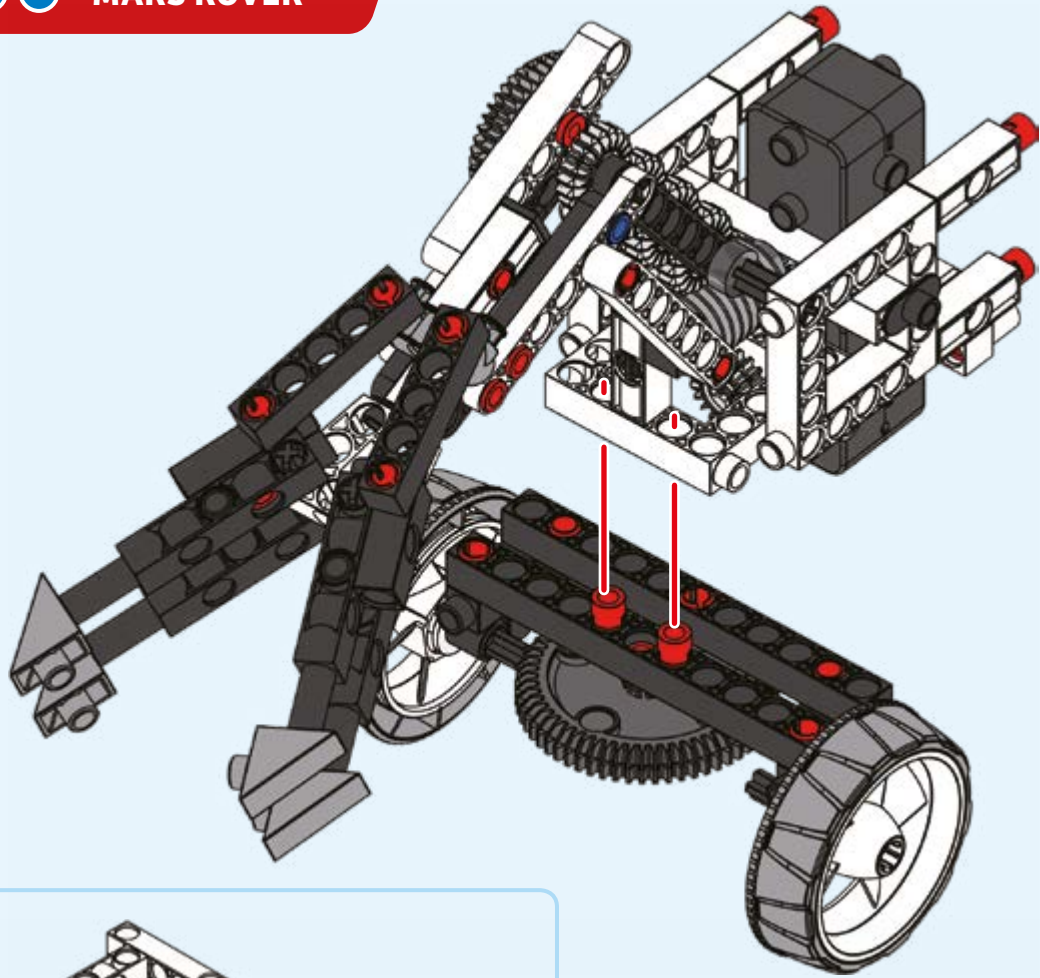
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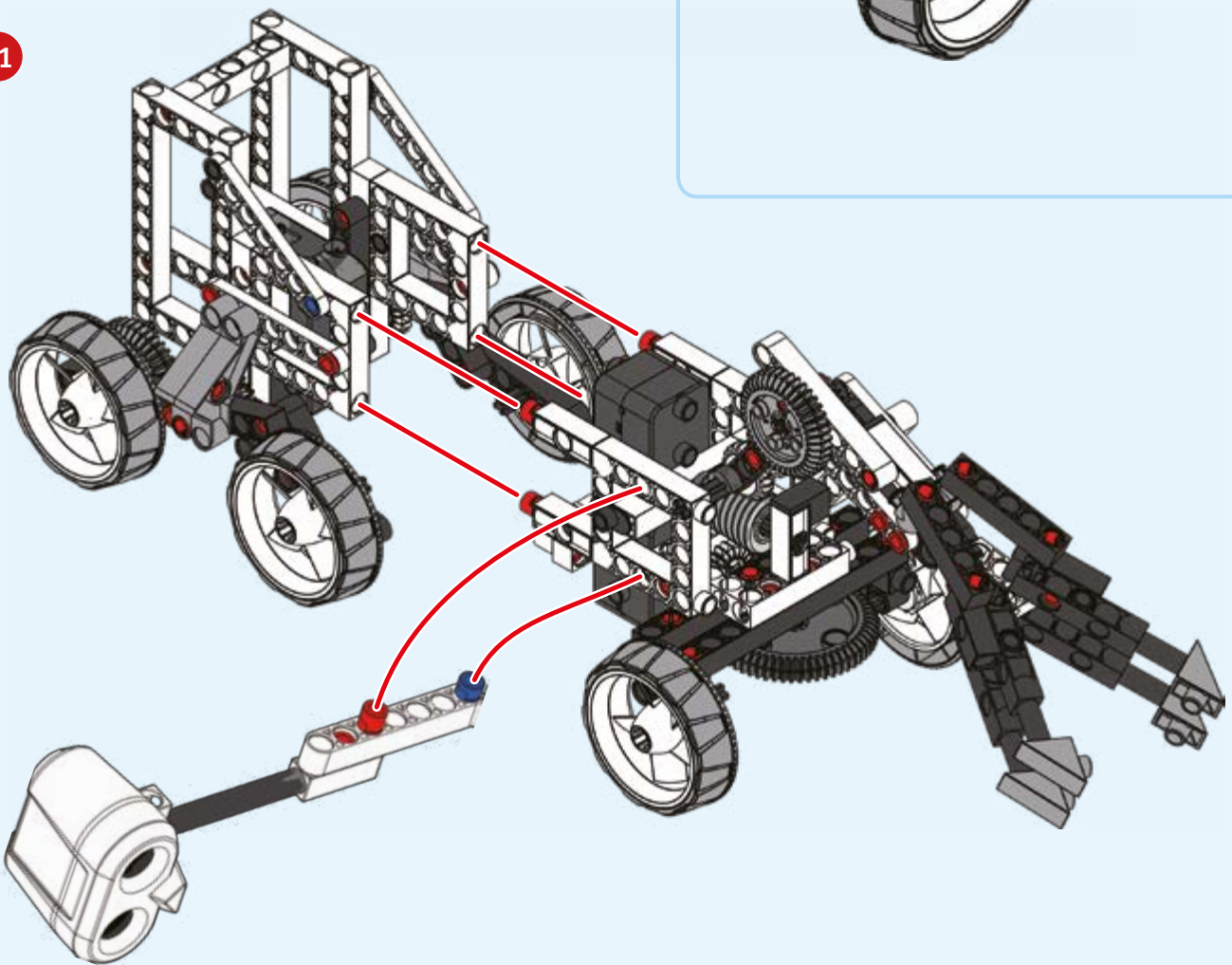




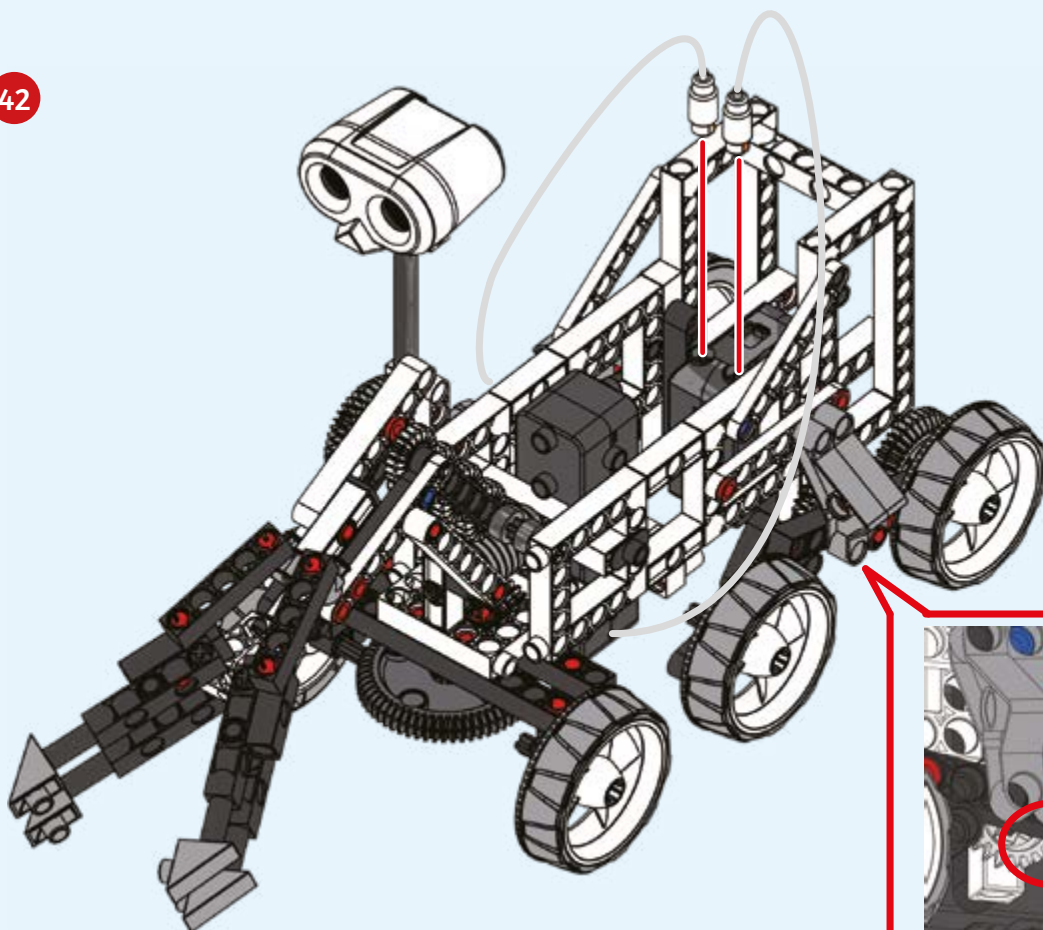
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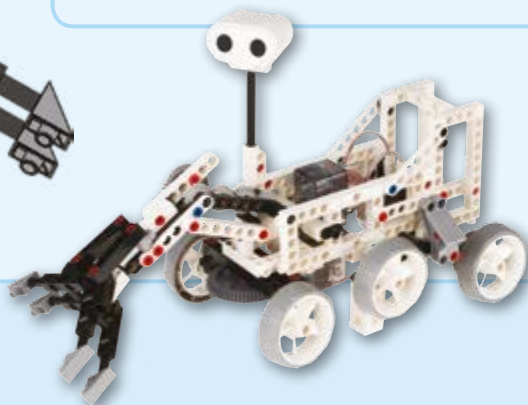
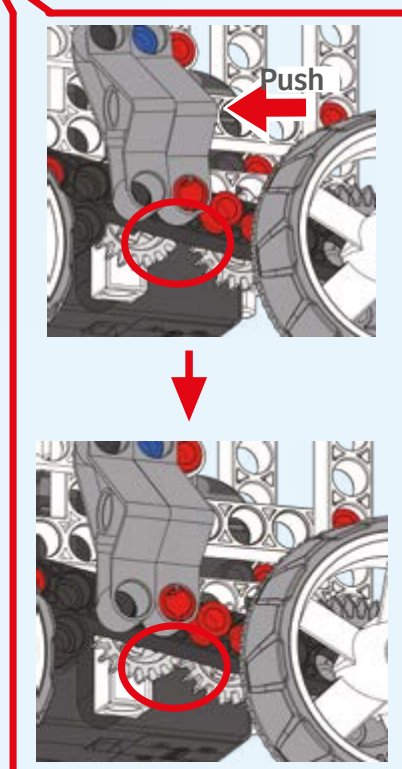
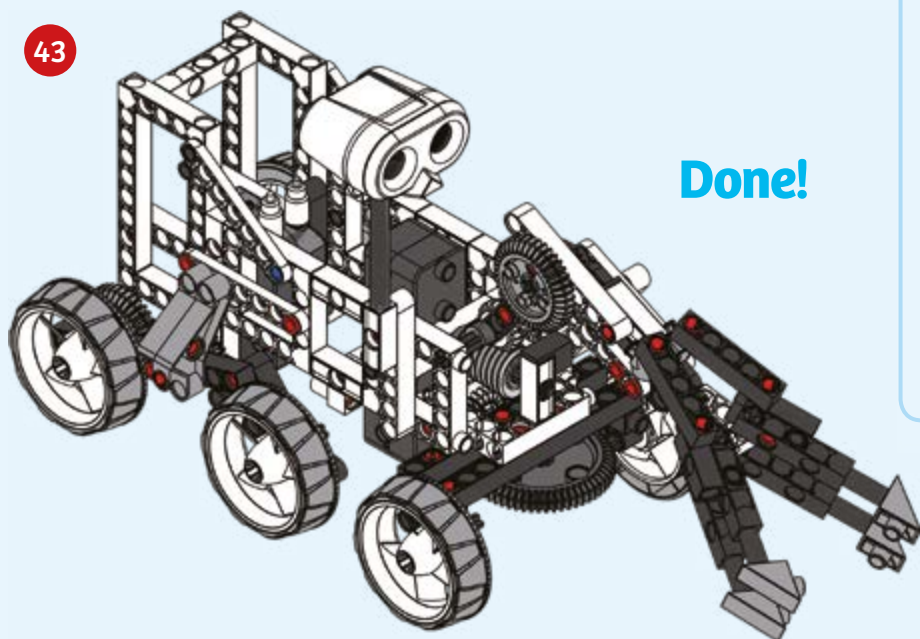
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**EXPERIMENT 1**

**Exploring "Mars"**

**HERE'S HOW**

Have a friend or family member set up a make-believe Mars landscape in a room in your house. They can gather various light objects to be

investigated and collected such as small cardboard boxes (e.g., tea boxes and matchboxes), light toys, and empty cans, and place them around the room. Turn on your model

and, while staying at least one meter away from the model at all times, try to collect all of the objects and bring them to one location for pretend-transport back to Earth!





## Curiosity Makes You Smarter

On November 26, 2011, the moment had finally arrived. The most ambitious NASA mission to date for the exploration of Mars had started: **The Mars Science Laboratory (MSL) lifted off** from Cape Canaveral on board an Atlas V 541 rocket.

The centerpiece of this Mars mission was the **Curiosity rover**. A rover is a vehicle that is controlled by radio signals sent from Earth. If it is too far away from Earth, it can also be driven autonomously. It is smart enough to steer itself toward goals and avoid obstacles. A rover such as Curiosity is equipped with a variety of measuring instruments and tools, and it can transmit its measurement results back to Earth. Curiosity's most important objective is to answer this question: Was Mars ever or might it still be habitable?



### GETTING A ROBOT TO MARS SAFELY

In order to answer that question, Curiosity first had to complete the long voyage to the planet — about 570 million kilometers. To make that journey, the rover and the MSL needed eight and a half months. On August 6, 2012, Curiosity finally landed softly on Mars.

After all, a lot of thought had gone into it. NASA engineers had designed a **"sky crane" system** to be held by retrorockets 20 meters above the Martian surface. From there, the rover was finally lowered to the surface on nylon tethers.

In order to understand this better, let's take a look at the most important elements of the Mars Science Laboratory.

The cruise stage guided the MSL during its flight to Mars. Before entering the Mars atmosphere, the module was separated from the **capsule**. The capsule protected the **rover** from the conditions of space and the Martian atmosphere as it parachuted down toward the surface.

The **heat shield** in turn provided protection against the extremely high temperatures of atmospheric entry. After the heat shield and capsule had completed their tasks, they were cut loose. At that point, the freed **descent stage** took care of the soft and precise landing of the rover on the Martian surface. It was the descent stage that held the sky crane system mentioned above.



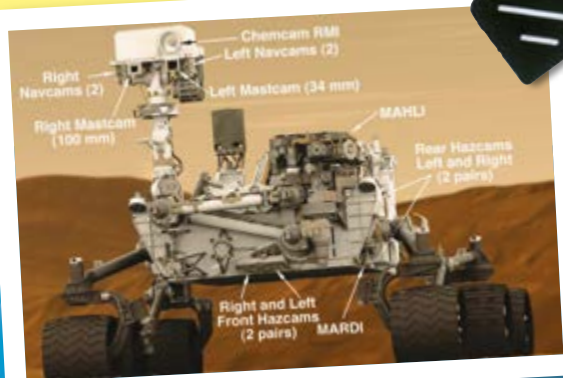
### CURIOSITY'S ENGINEERING IN DETAIL

With a mass of 900 kg and the size of a compact car, Curiosity is by far the heaviest man-made object ever to land on the Martian surface.

In contrast to earlier rover missions to Mars, Curiosity is powered with a small atomic battery rather than solar cells. That makes it more mobile and frees it from having to rely on solar radiation.

For moving across the Mars surface, Curiosity has six wheels symmetrically attached to two tubular frames. The rover is steered by the two pairs of wheels at the front and back. Since they can turn a full 90° to the left or right, the rover can rotate 360° while standing in one spot.

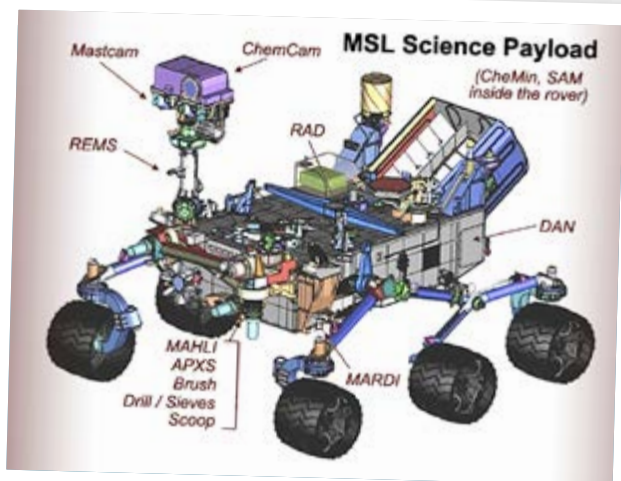
Curiosity can move at a speed of up to 4 centimeters per second. That means it can cover 100 to 300 meters a day — admittedly not a lot. But the rover isn't on Mars just to drive around. It's there to collect data. To be able to do that wherever it goes, it can handle slopes of up to 45° and obstacles of up to 75 cm in height — in all directions. So it's a virtual rock-climbing master.



### EVERYTHING IN FOCUS

The rover has a lot of scientific instruments on board for studying rocks, atmosphere, and radiation. For example, there are four "hazard avoidance cameras" (hazcams) installed on the lower portion of the rover for collecting environmental data. These cameras collectively cover a field of view of 120° and can take 3D pictures. With their help, the entire surroundings can be searched for obstacles up to four meters away.

Curiosity is also equipped with a two-meter-long robotic arm on the front. This is called a "Sample Acquisition, Processing, and Handling" system, or "SA/SPaH" for short. Its three joints make it resemble a human arm, or more precisely a system composed of a shoulder, elbow, and wrist joint. That makes it very flexible and capable of moving some of its instruments right up next to the object being studied.







## WELL EQUIPPED WITH DRILL, SHOVEL, AND BRUSH

Curiosity's arm is equipped with a drilling system, a digging shovel, a brush, and a sieve with collection containers. This equipment can even allow it to analyze deeper levels of soil and rock.

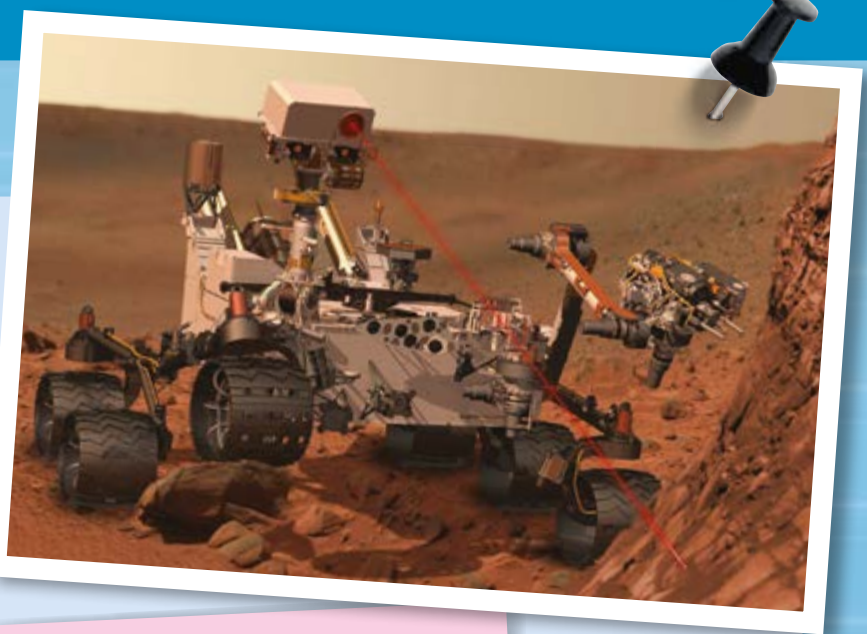
The most important part of the arm is the drill at its tip. This is capable of drilling holes in rock up to 5 cm deep. In the process, the drilling core material is pulverized and analyzed.

A particularly striking feature is the 1.1-meter mast at the front left corner of the chassis. The top part, which contains almost all the instruments, resembles a human head due to its freedom of movement. In fact, Curiosity's mast can rotate 360°.

The chemistry and camera system (ChemCam for short) consists of a laser, spectrometer, and camera. Spectrometers are used to determine the composition of light radiation. That in turn lets you figure out what elements Martian rocks are made of, since every element has its own characteristic spectra. In this process, the laser is focused on a small point and heats the material there so intensely that it starts to vaporize. Then, the optical spectrometer studies the composition of the gases and plasmas created.

For general meteorological measurements, the rover is equipped with instruments for determining wind speed and direction, UV radiation, surface temperature and pressure, and the temperature and relative humidity of the atmosphere.

For communication with ground control on Earth, Curiosity has two communication systems. One is responsible for receiving control commands and transmitting status data. The other handles the transmission of scientific data (up to 250 megabits per day), which are then analyzed by NASA scientists.



## GREETINGS FROM EARTH

As part of NASA's "Send Your Name to Mars" program, members of the public were able to immortalize themselves by entering their names onto a Mars rover microchip. 1.2 million names were scanned in, laser-etched onto two small microchips each about the size of a dime, and brought on board Curiosity. Is that cool or what?



## CURIOSITY FINDS THE BUILDING BLOCKS OF LIFE ON MARS

And was there ever life on Mars? After just a few days, Curiosity delivered further proof for the earlier presence of water on Mars (see also next section). The rover discovered some of the building blocks of life on a chip of stone. The samples showed traces of clay, sulfates, and other minerals — all elements that make life possible. So you see, Curiosity has made us smarter!



# Getting to Know Mars, One Step at a Time

For researchers, Mars was right up there with the moon as an attractive candidate for exploration. It is close to Earth and a rocky planet. It gets its red color from iron compounds in its soil. Its surface is a rocky desert with monstrous extinct volcanoes and dried seas and river beds.

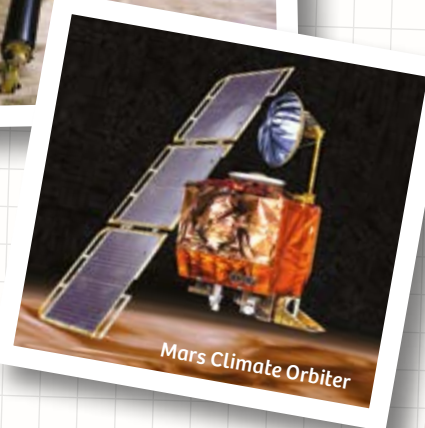
A trip to Mars on a space ship would take about a year. For centuries, researchers have wanted to find out whether humans might be able to settle there one day.

## STARTING SHOT, 1960

The history of Mars expeditions is a long one. But its starting point wasn't marked by Americans. The Russians (or Soviets, at that time) were the first to take off for Mars, the so-called red planet. On October 10, 1960, they sent a probe on its way to Mars. However, it didn't even manage to reach an orbit around Earth. NASA's first Mars mission, Mariner 3, also failed. That 1964 probe was unable to separate from its booster rocket.

Over 30 more missions were to follow — and more than half of them failed. The challenges have always been immense.

In 1965, Mariner 4 was the first probe to fly by Mars. It was equipped with a camera and took 22 photos. One important insight gained from that mission: The Martian surface is barren and desolate, more or less like a lunar landscape.



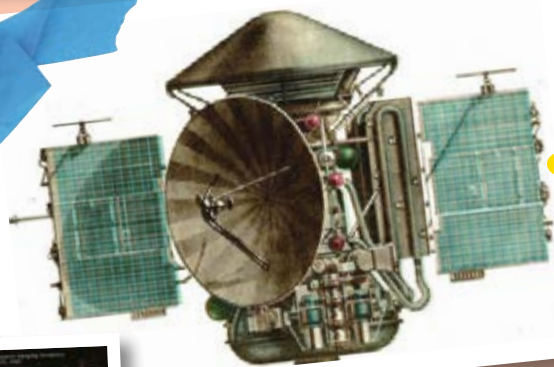
## MORE FAILURES, THEN A BREAKTHROUGH

1971 brought more failures: Mariner 8 failed right at launch. The Soviet probe Kosmos 419, which was supposed to be the first to land on Mars, only reached an orbit around Earth.

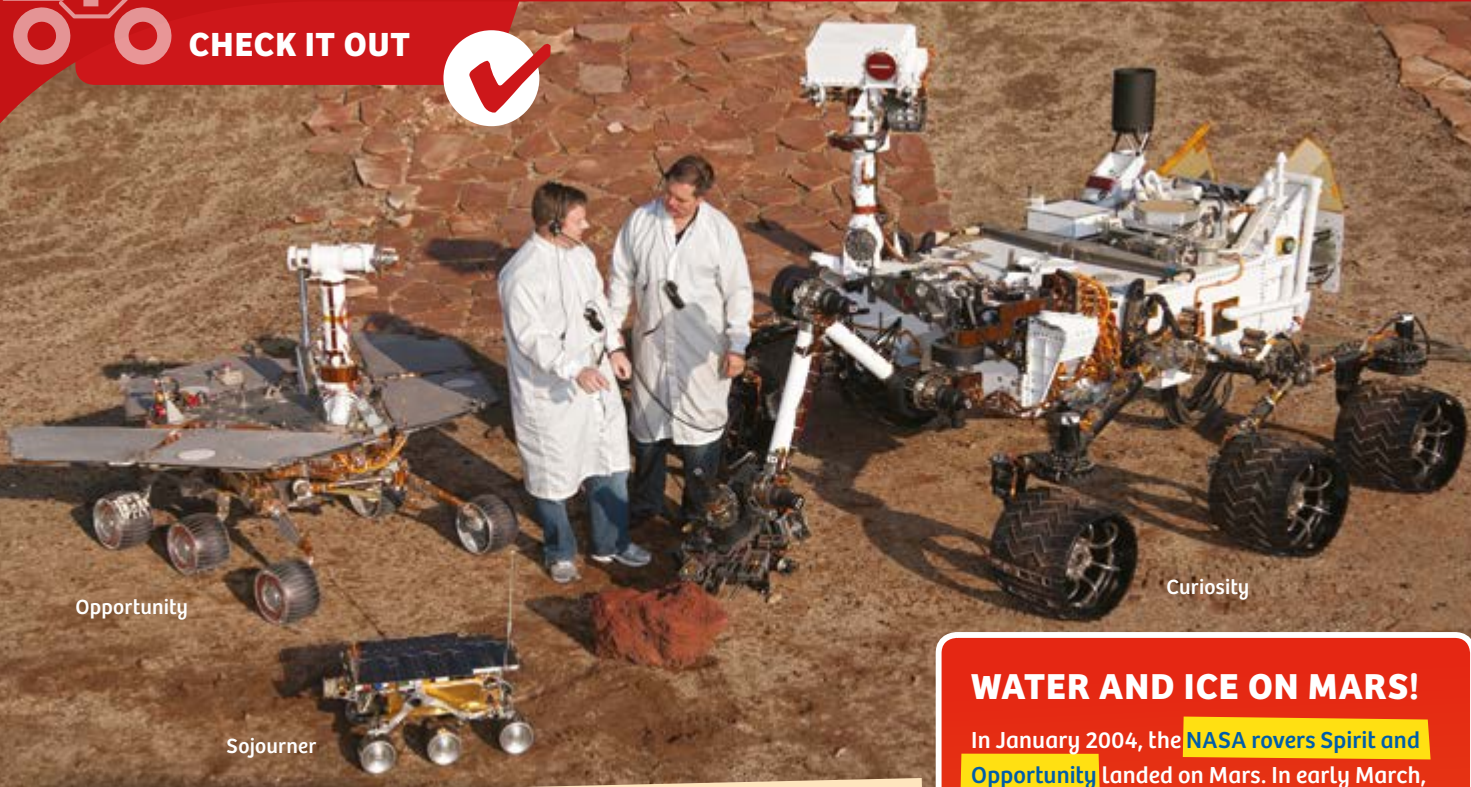
Mars 2 and Mars 3 (Soviet Union) did reach the planet, but only provided a little data. The landing module of Mars 3 was the first Earth object to land on the red planet.

The NASA probes Viking 1 and Viking 2 took off for Mars in 1975. They were the first American missions to land space vehicles on the surface of Mars.

Viking 1 accomplished this on June 20, 1976, and Viking 2 landed successfully as well. Both probes sent more than 50,000 photos and a wealth of data about the composition of the Martian surface. The hope of finding traces of life, however, was not fulfilled.







Opportunity

Sojourner

Curiosity

## EXPLORING AND MEASURING THE RED PLANET

With **Pathfinder**, NASA landed another probe on the red planet in 1997. Pathfinder and its robotic vehicle **Sojourner** transmitted 16,000 pictures to Earth. And their radar data provided evidence for the **widespread presence of water ice under the Martian polar regions**. Water is, of course, a crucial prerequisite for life.

On October 24, 2001, the NASA probe **Mars Odyssey** entered into an orbit around the red planet. It delivered data about the Mars surface, looked for evidence for the past presence of water, and used its gamma spectrometer to measure the composition of the surface and its minerals.

The 2003 European mission **Mars Express** was also a success. The probe created a three-dimensional map of the Martian surface with unprecedented resolution. Its **Beagle 2** lander, however, remains lost. Good and bad luck often go together on Mars missions.

## WHAT NOW?

Most of the probes are no longer in operation. The Curiosity rover, though, which you know about from the first chapter, is still actively delivering data. Over all these years, the numerous Mars missions carried over 9 tons of material to that planet. But so far, nothing has been carried from Mars back to Earth. Just think of how exciting it would be to study some Martian rocks here in our laboratories!

A joint American-European project has set itself precisely that task. **Mars Sample Return (MSR)** is in the planning stages with NASA and ESA, the European counterpart to NASA. **The plan is to bring the very first rock samples from Mars to Earth.** The mission is currently in an early phase of development, with liftoff expected as soon as 2022. You never know, you might be part of the research team when the time comes, if you do your homework!

## WATER AND ICE ON MARS!

In January 2004, the **NASA rovers Spirit and Opportunity** landed on Mars. In early March, they delivered the sensational news: **There was liquid water on Mars.** Opportunity found sulfur compounds that can only form in liquid water. The two rovers transmitted several hundred thousand photos to Earth.

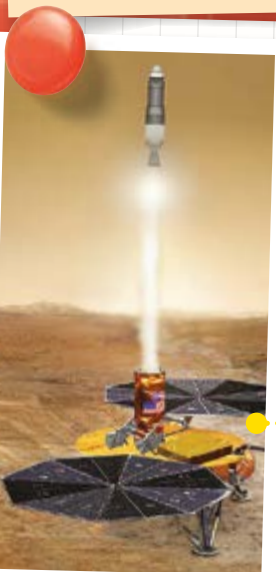
In May 2008, the **NASA probe Phoenix** landed in the arctic latitudes of the northern Martian hemisphere. Its gripper arm of over two meters in length allows it to look for ice under the surface. Its very first excavation job was a success: Just a few centimeters under the Martian dust, Phoenix found conclusive evidence of water ice.



## THE ULTIMATE QUESTION

Is or was there ever life on Mars?

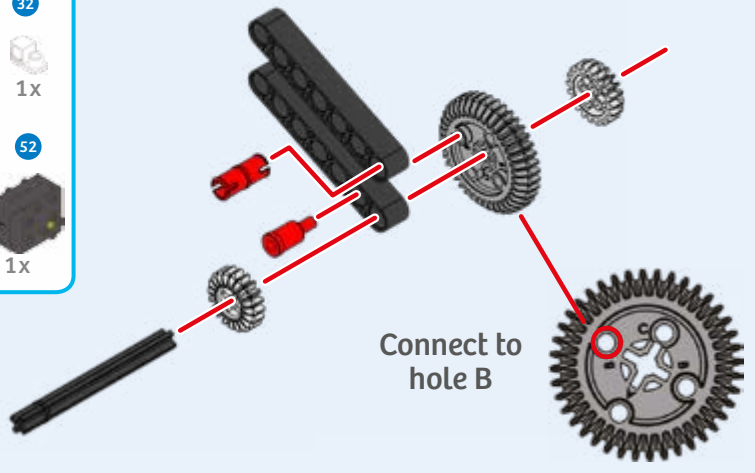
The various Mars mission experiments provided no clear evidence about the existence of organic life on Mars. All of the biological experiments, however, observed changes that could be caused by organic life. Still, who knows?



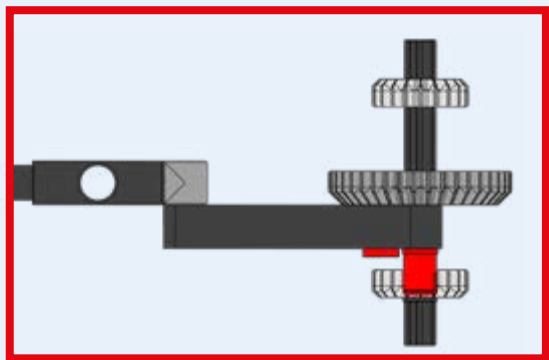
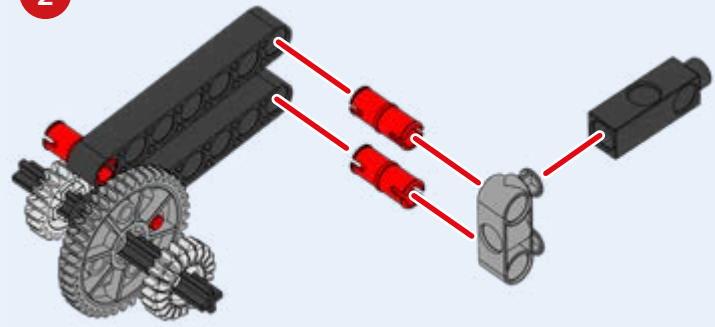
SPACE SHUTTLE

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| 22 | 23 | 25 | 26 | 28  | 30 | 31 | 32 |    |    |    |
| 4x | 2x | 1x | 4x | 3x  | 1x | 2x | 1x |    |    |    |
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| 3x | 1x | 3x | 4x | 38x | 3x | 1x | 4x | 1x | 1x | 1x |

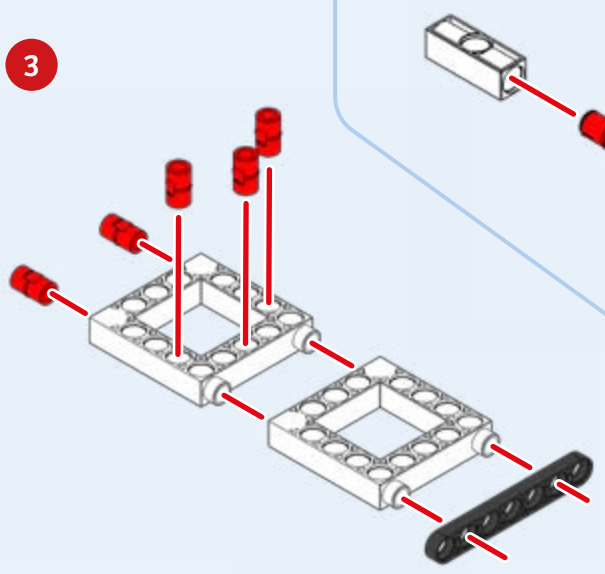
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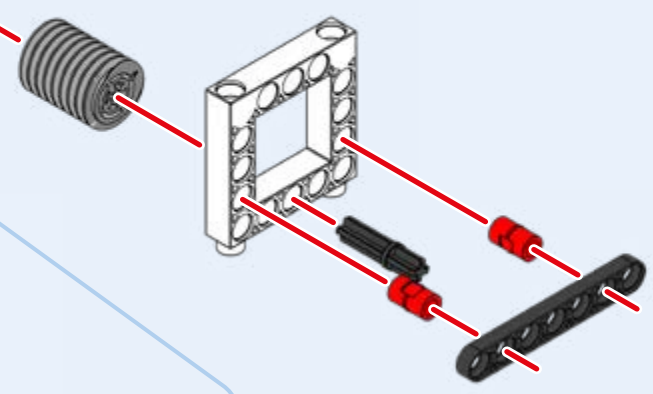


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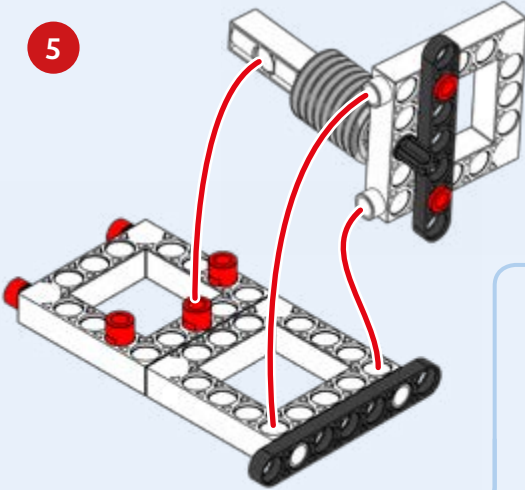
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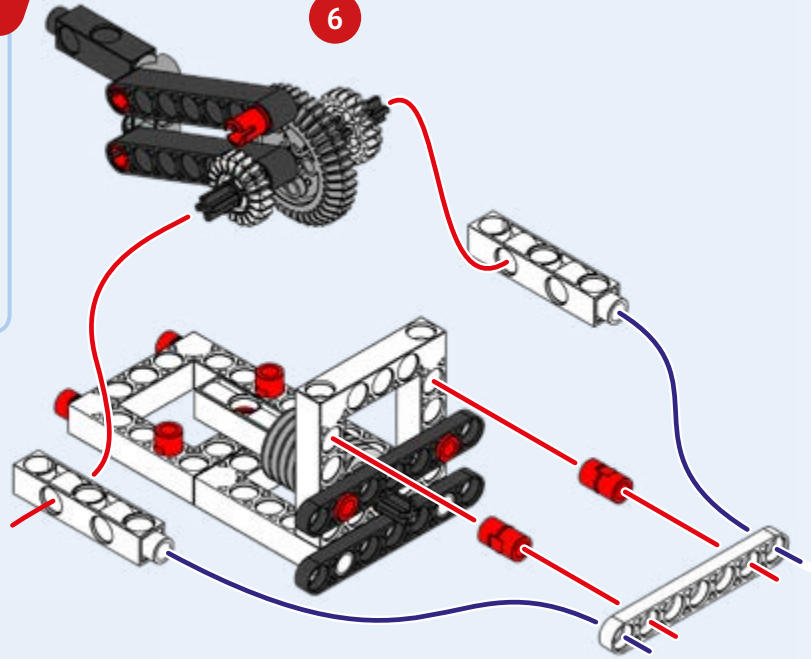




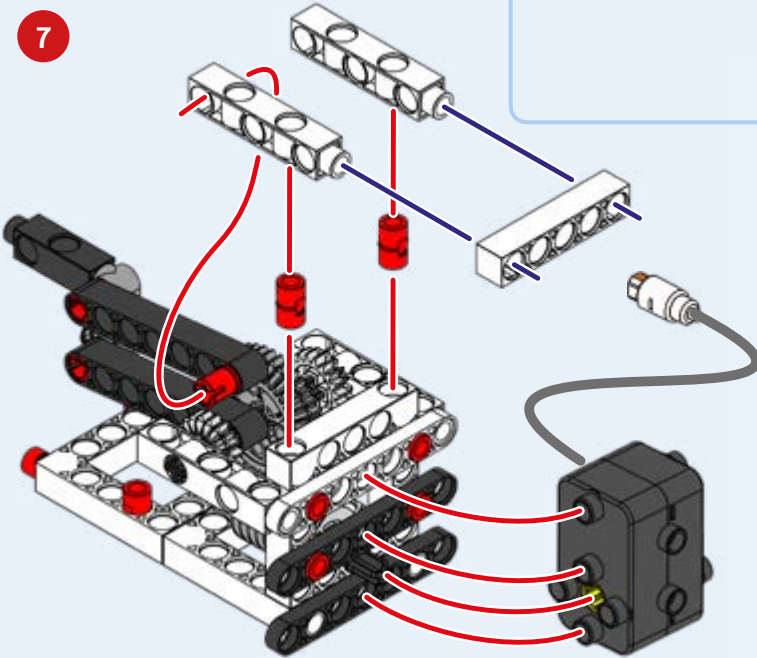
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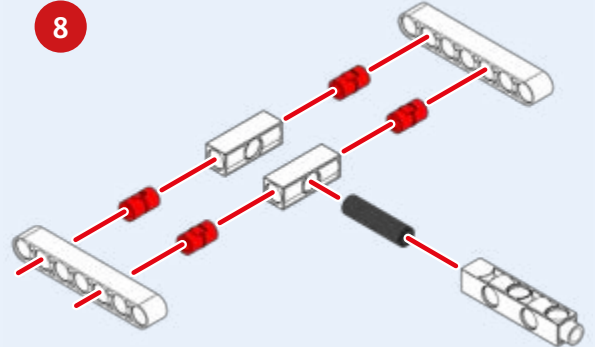
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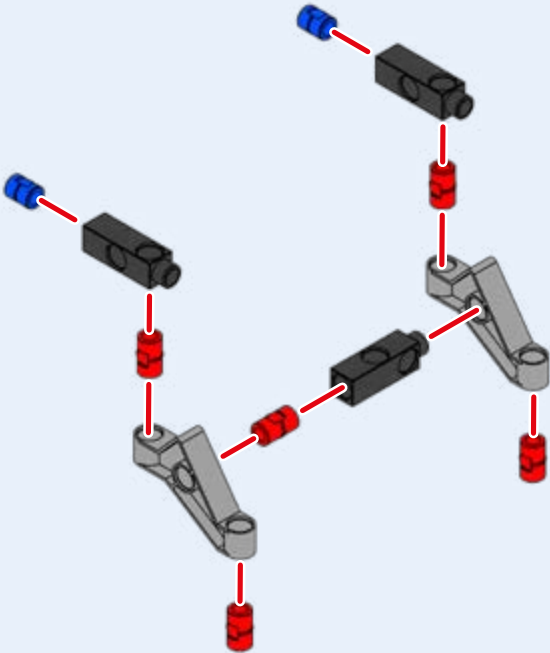
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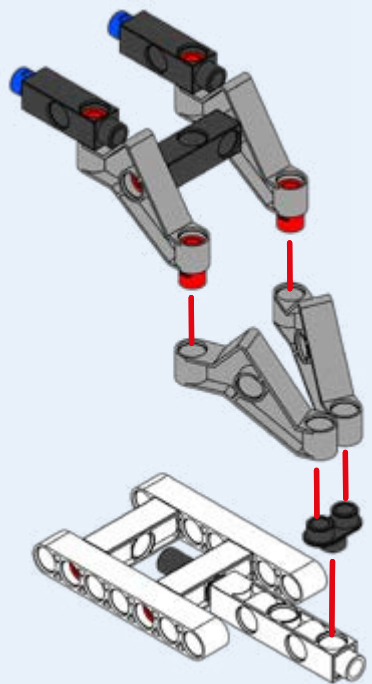
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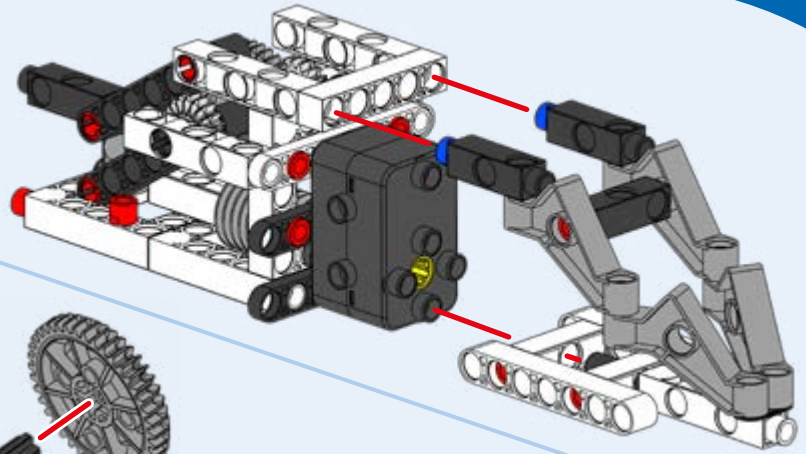
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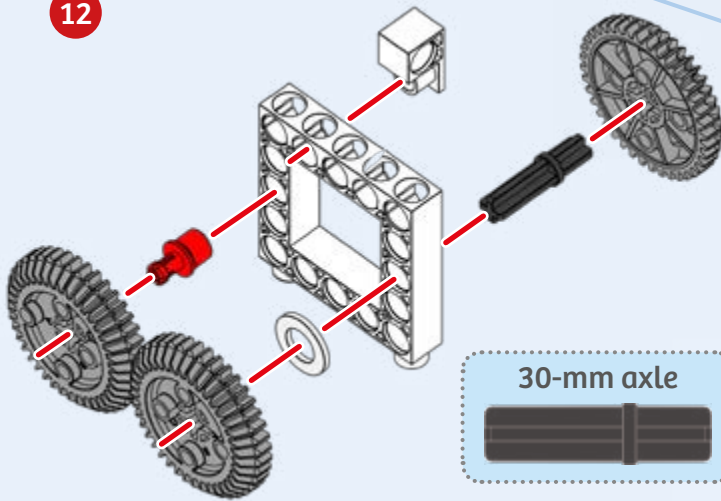
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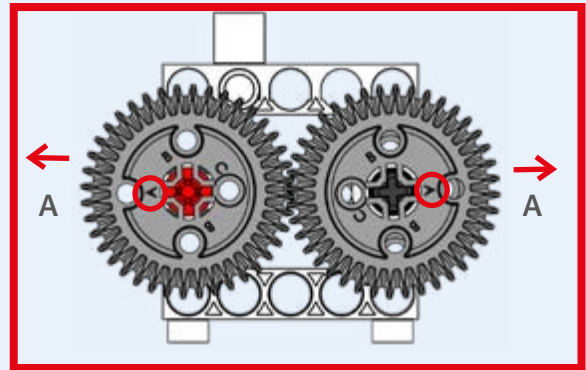
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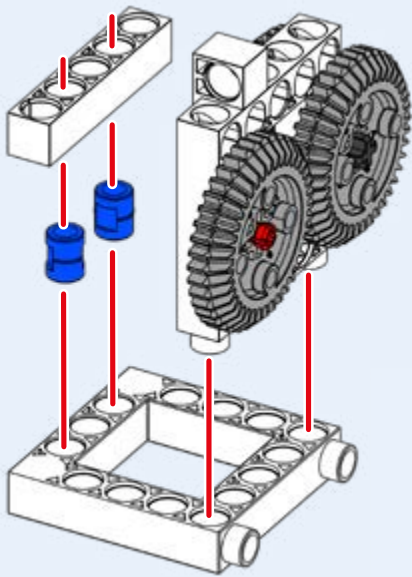
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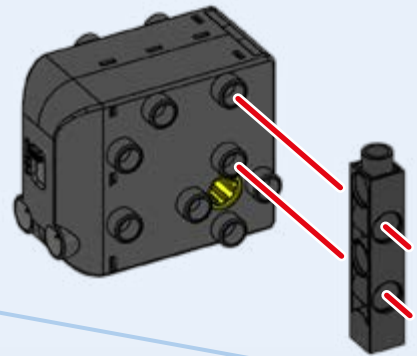
30-mm axle



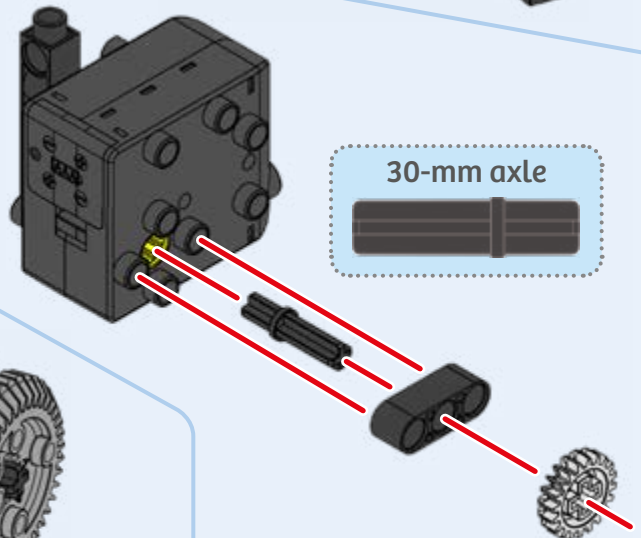
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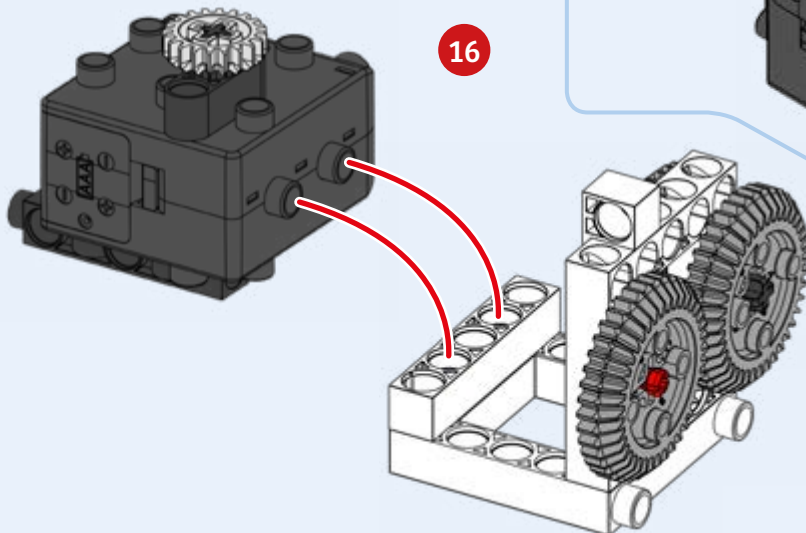


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30-mm axle

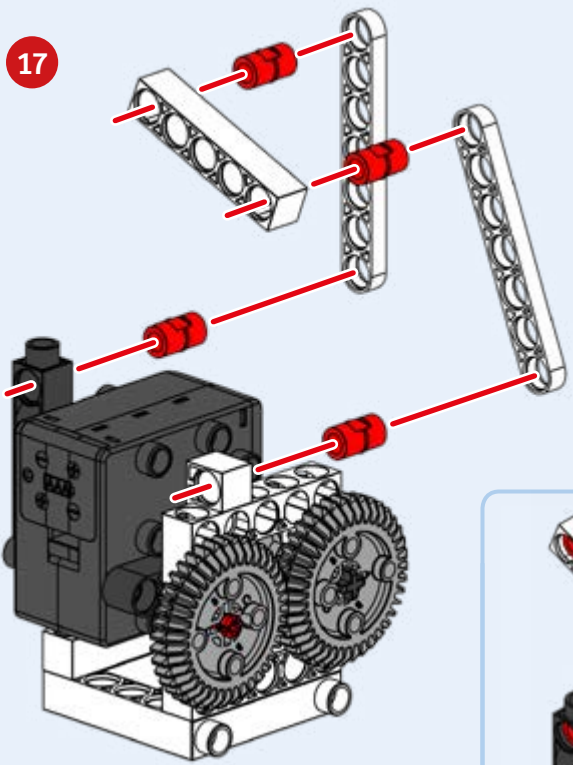
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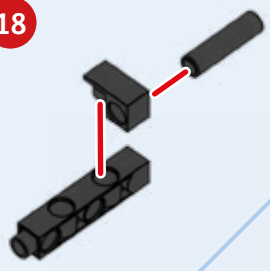




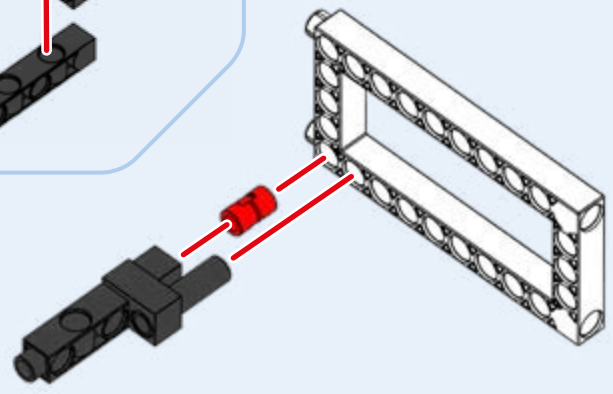
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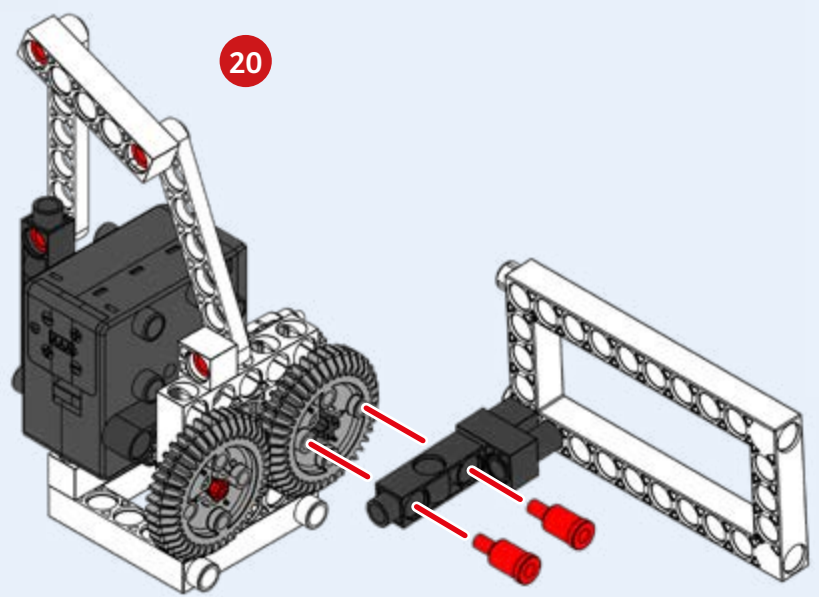
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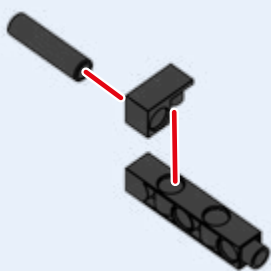
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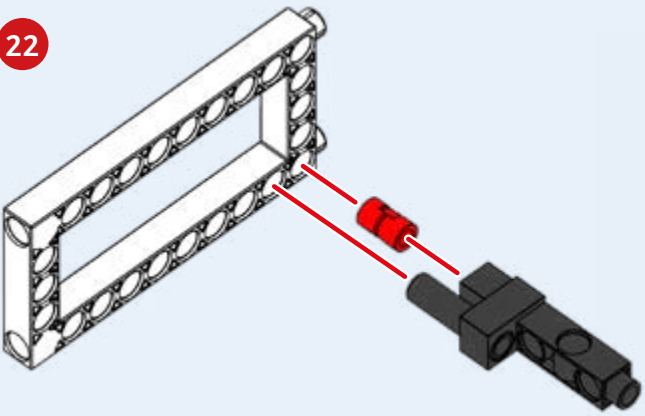
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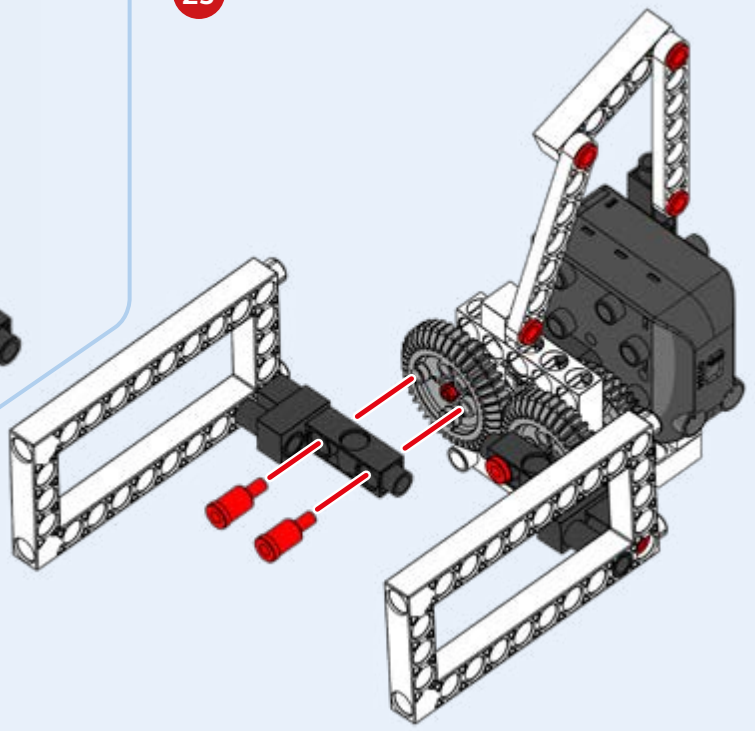
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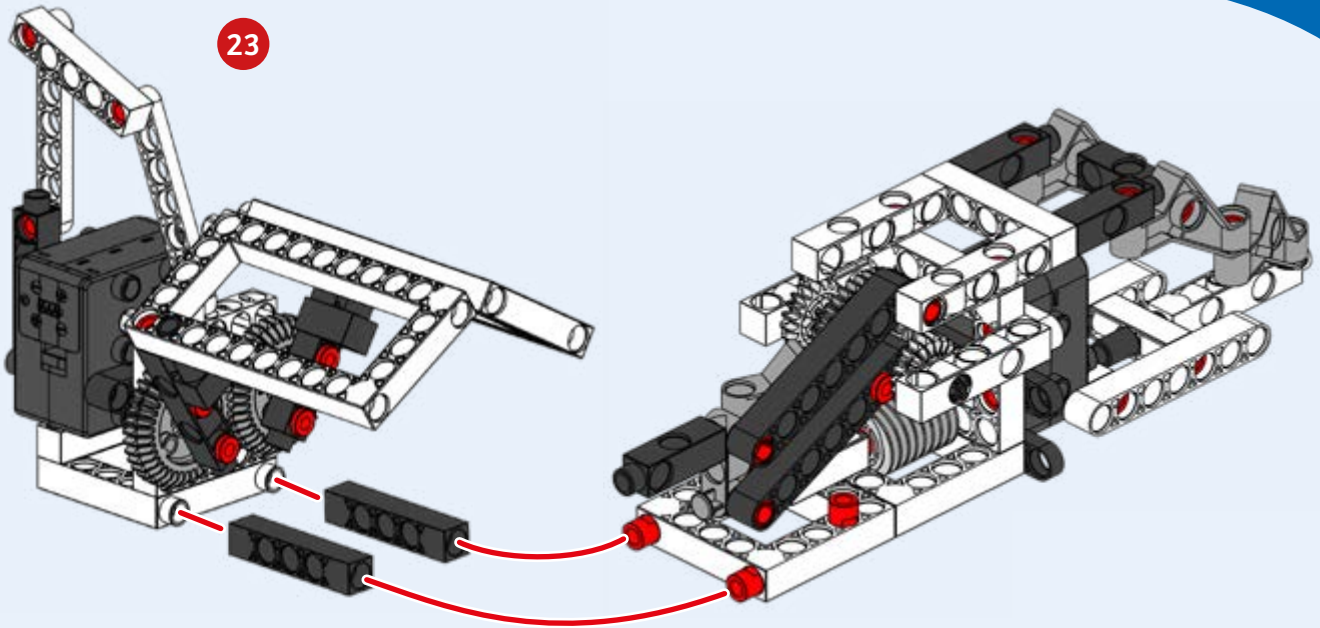
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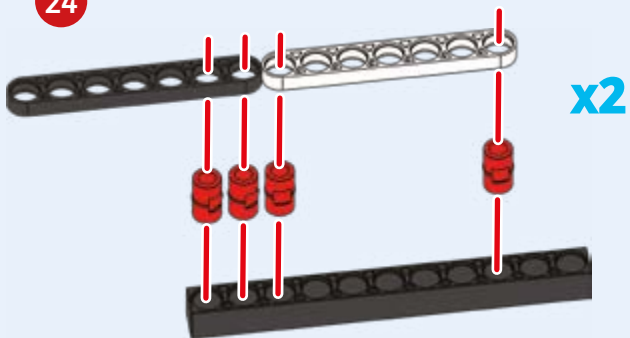
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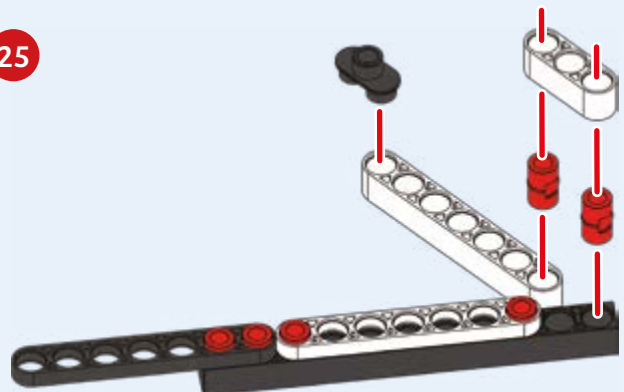
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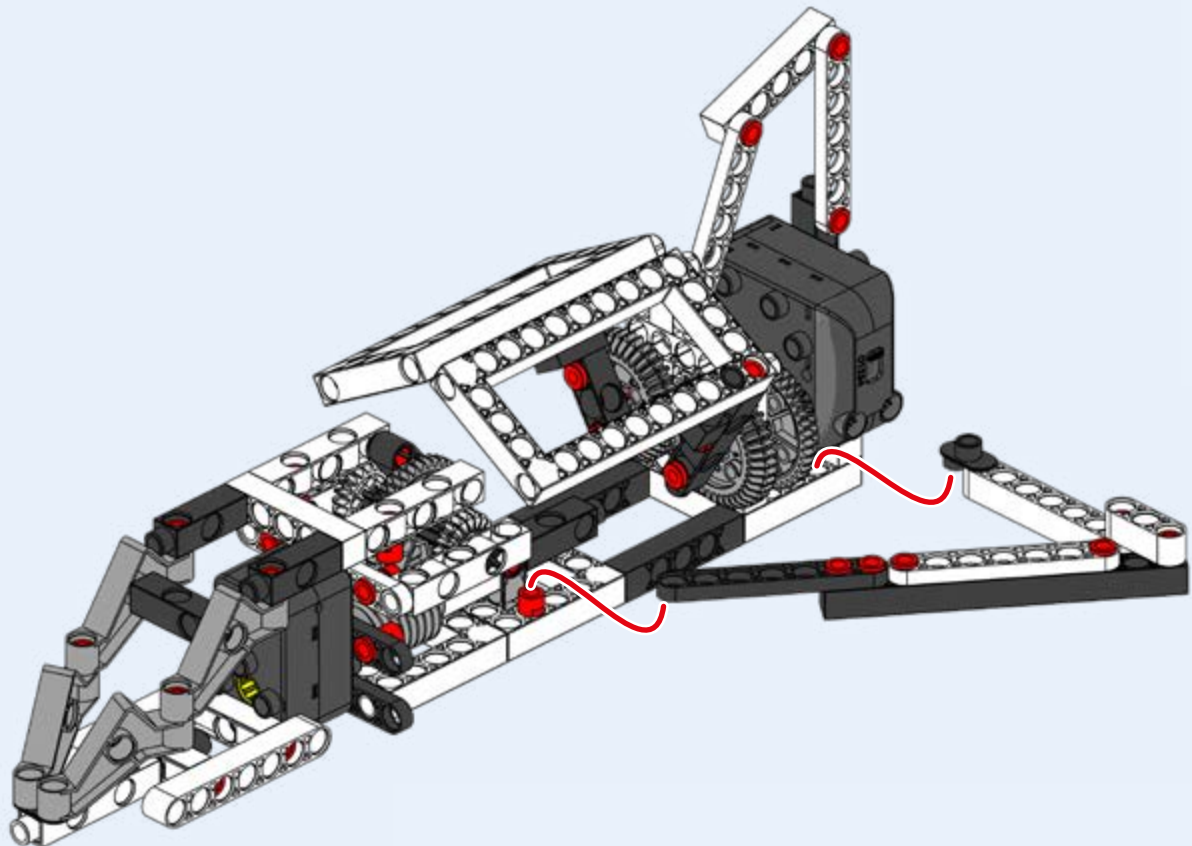
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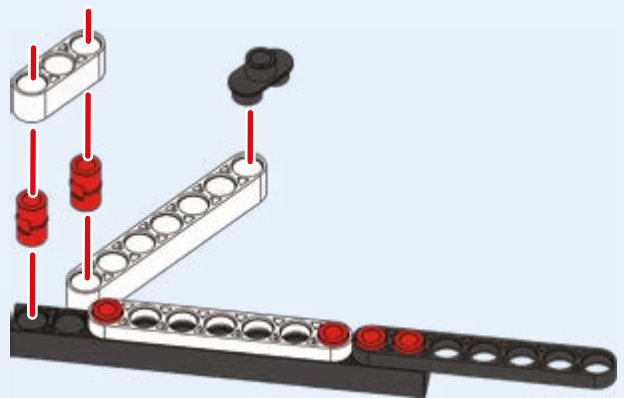
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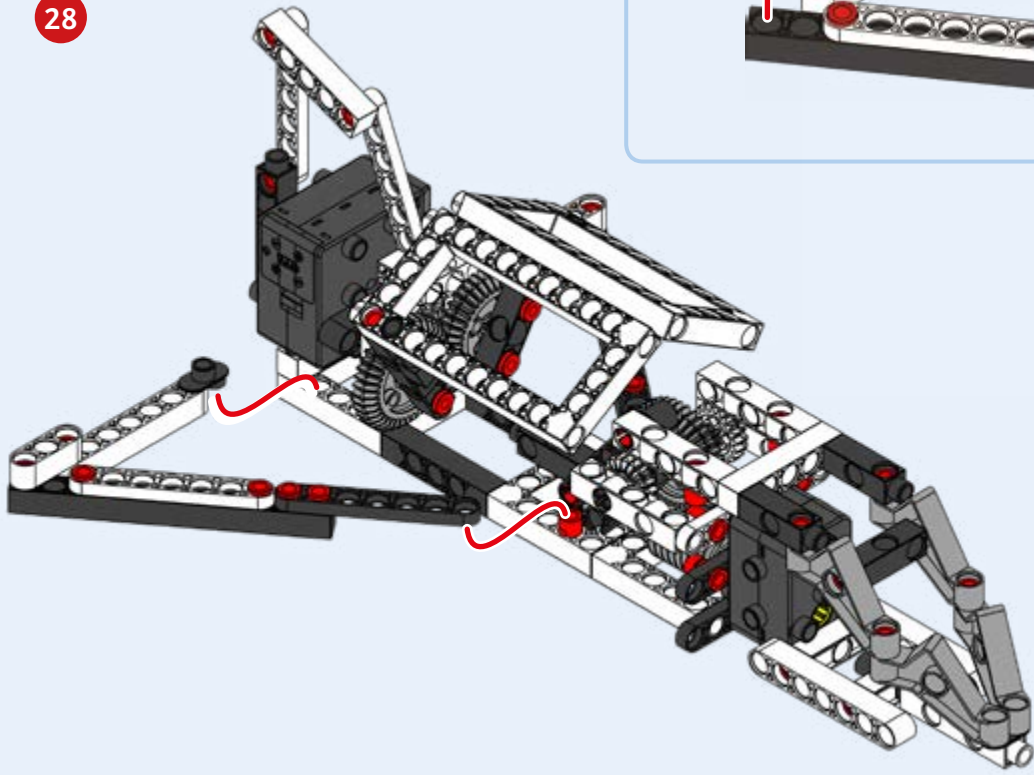




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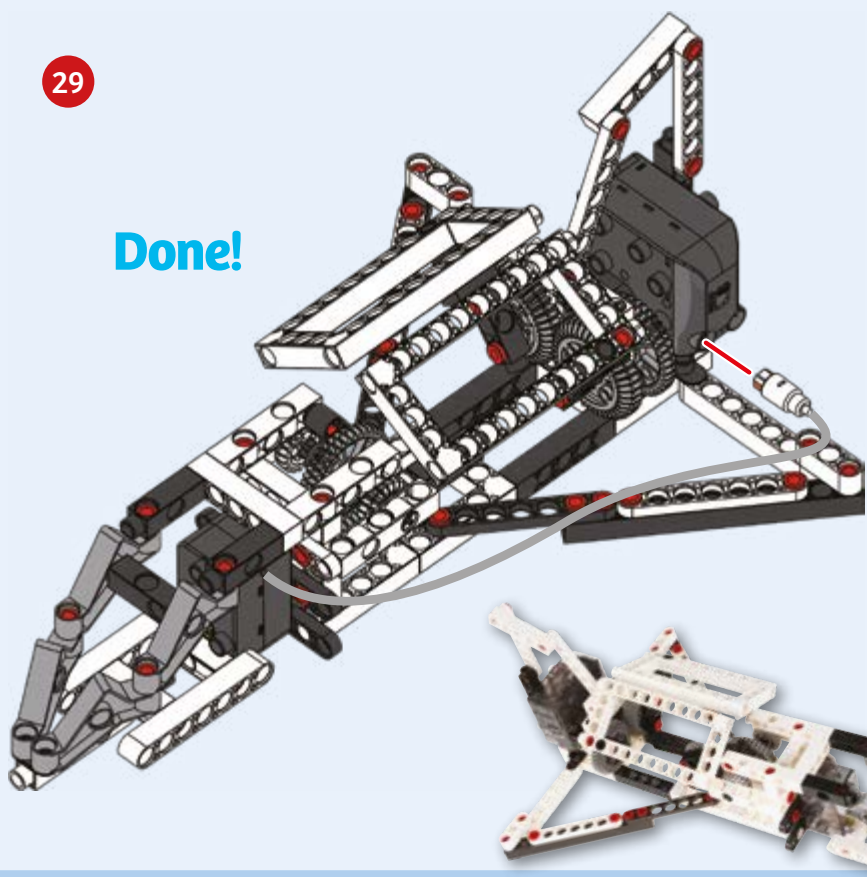


28



29

Done!



EXPERIMENT 2

Cargo mission

HERE'S HOW

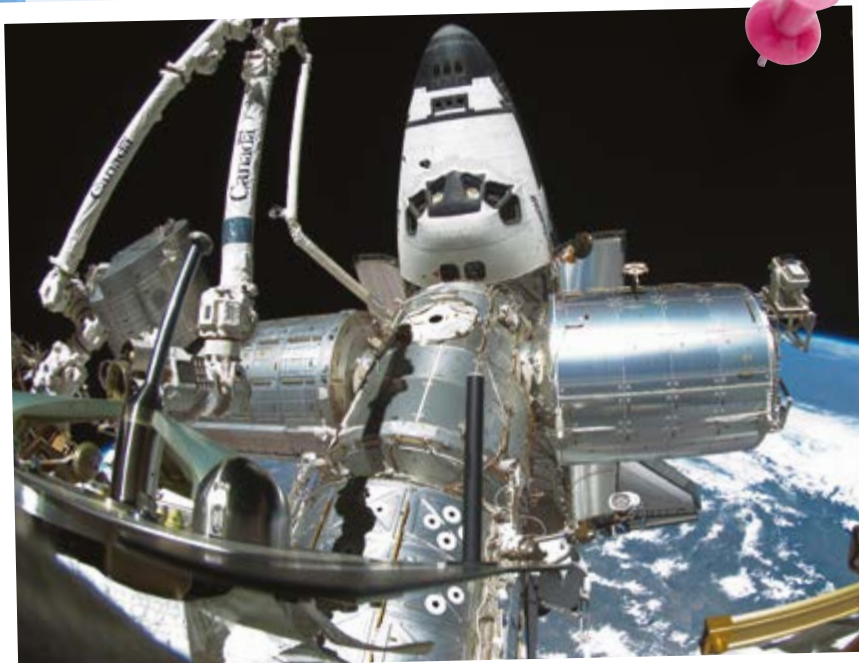
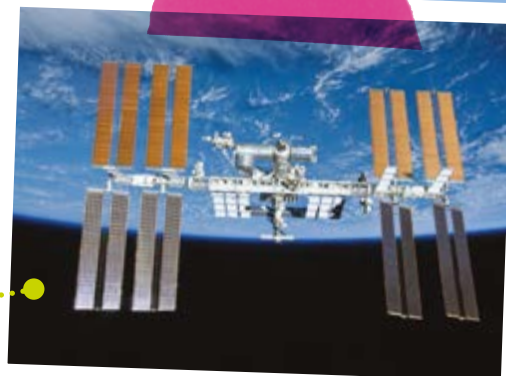
What can your space shuttle transport to the International Space Station? Turn on your model and see if you can remotely control the space shuttle's cargo bay doors to open and the inner mechanical arm to lift out of the cargo bay. Can you get the arm to lift a small object (e.g., a small toy or coin) out of the cargo bay? Can you close the cargo bay doors after you stow the mechanical arm?

CHECK IT OUT



## A Cargo Truck for Space

Its loading bay gave the Space Shuttle a lot of flexibility. It was the only carrier capable of taking a cargo of up to 24.5 tons from Earth to space, such as to the **International Space Station**. The ISS is a manned space station operated and equipped by several countries working together.



### OFF INTO SPACE — AND BACK AGAIN

Among the shuttle's greatest successes was the servicing of space probes and the Hubble Space Telescope, as well as many flights with built-in laboratories.

In addition, the shuttle was able to bring satellites from space back to Earth. This first happened during the STS-51-A mission, when two satellites had to be re-captured.

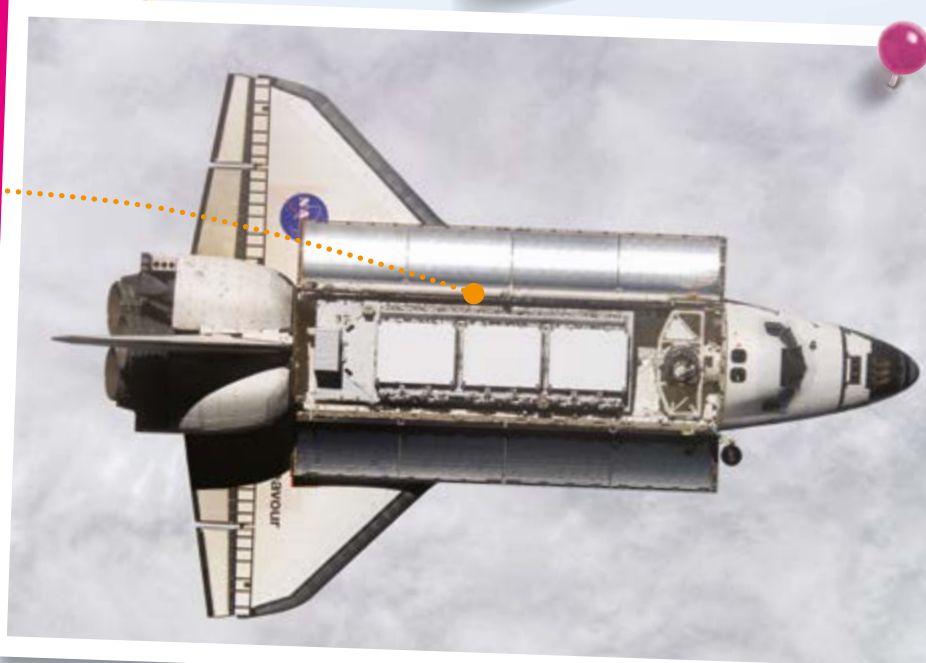
Other missions, such as STS-7, saw research platforms carried in the cargo bay and then released into space for several hours during the mission. Then, they were captured with the robotic arm again (see next chapter).

### ROOM FOR MORE THAN ONE SCHOOL BUS

The cargo bay was located in the shuttle's central portion. It had two large gates that could be swiveled upward in order to expose the bay to open space.

The bay was 18.38 meters long and had a diameter of 4.57 meters.

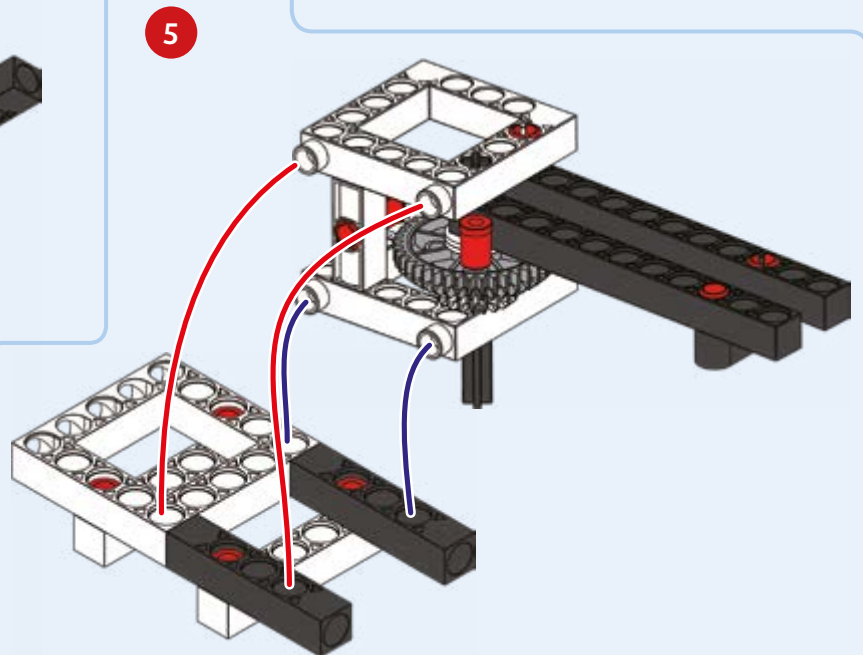
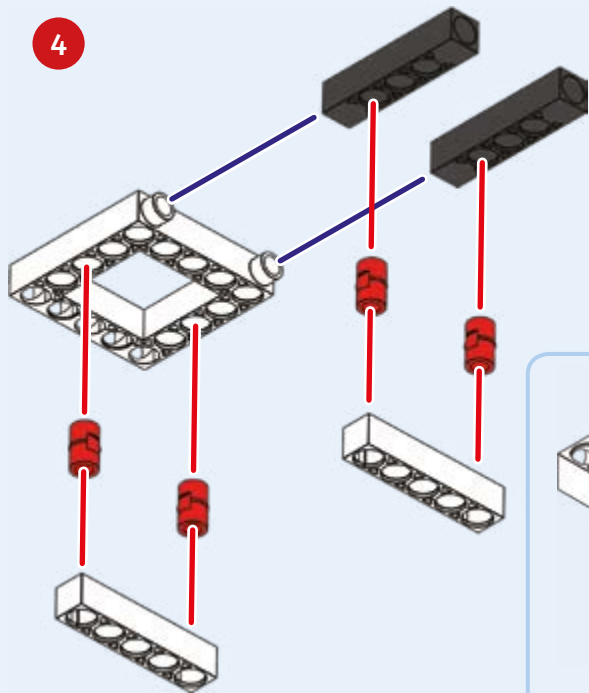
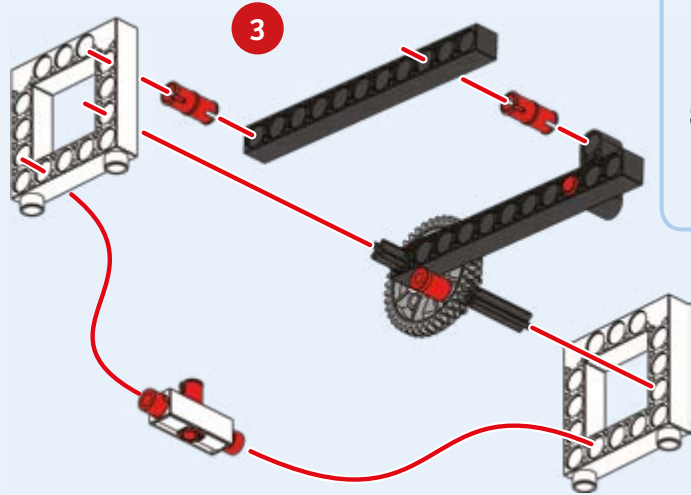
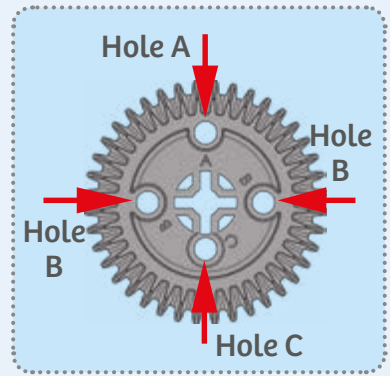
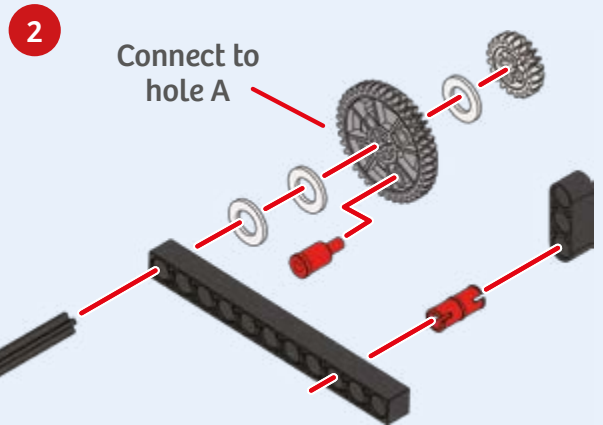
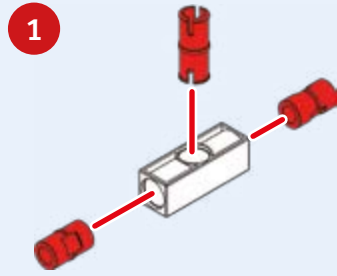
That could easily hold a school bus. Or how many times would your car fit into it?



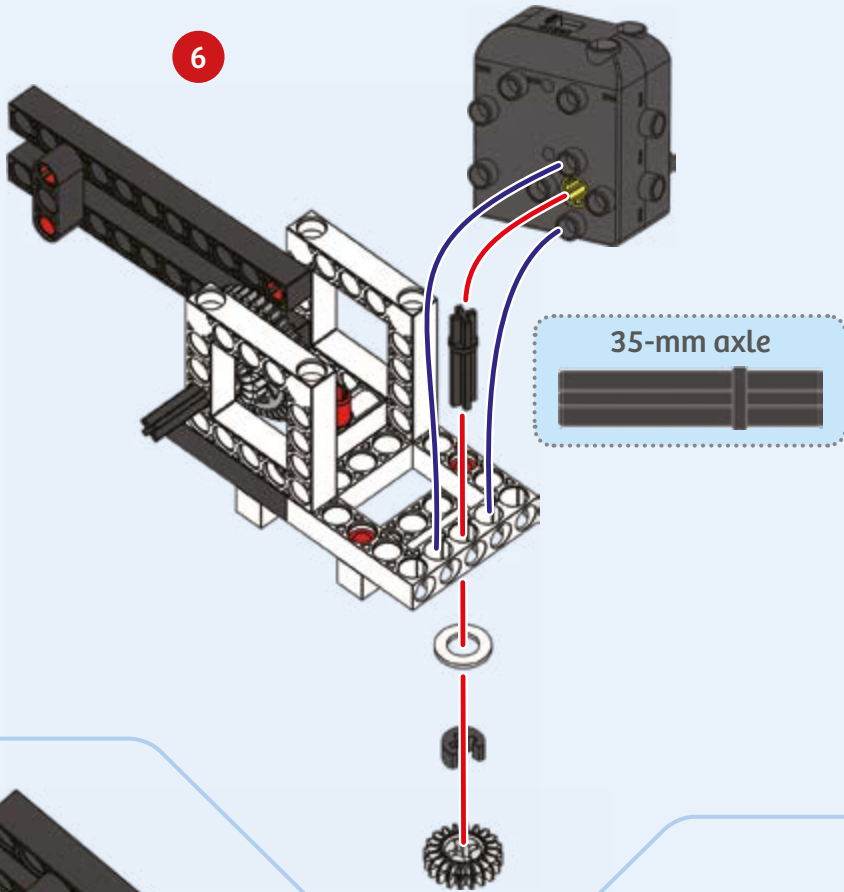


# SHUTTLE ARM

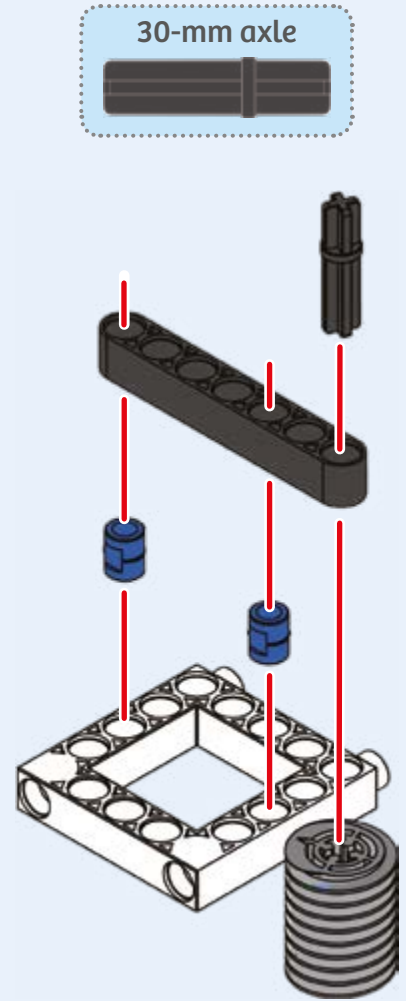
- |    |    |    |    |     |    |    |    |    |    |    |
|----|----|----|----|-----|----|----|----|----|----|----|
| 1  | 2  | 3  | 4  | 6   | 7  | 8  | 9  | 10 | 11 |    |
| 9x | 1x | 2x | 2x | 2x  | 1x | 3x | 2x | 1x | 2x |    |
| 12 | 13 | 14 | 16 | 17  | 19 | 21 | 22 |    |    |    |
| 2x | 2x | 1x | 1x | 3x  | 2x | 2x | 4x |    |    |    |
| 25 | 26 | 28 | 29 | 30  | 32 | 34 | 36 | 37 |    |    |
| 1x | 4x | 1x | 4x | 1x  | 1x | 3x | 6x | 1x |    |    |
| 38 | 42 | 43 | 44 | 45  | 46 | 47 | 49 | 50 | 51 | 52 |
| 1x | 6x | 2x | 6x | 11x | 4x | 4x | 2x | 2x | 1x | 1x |



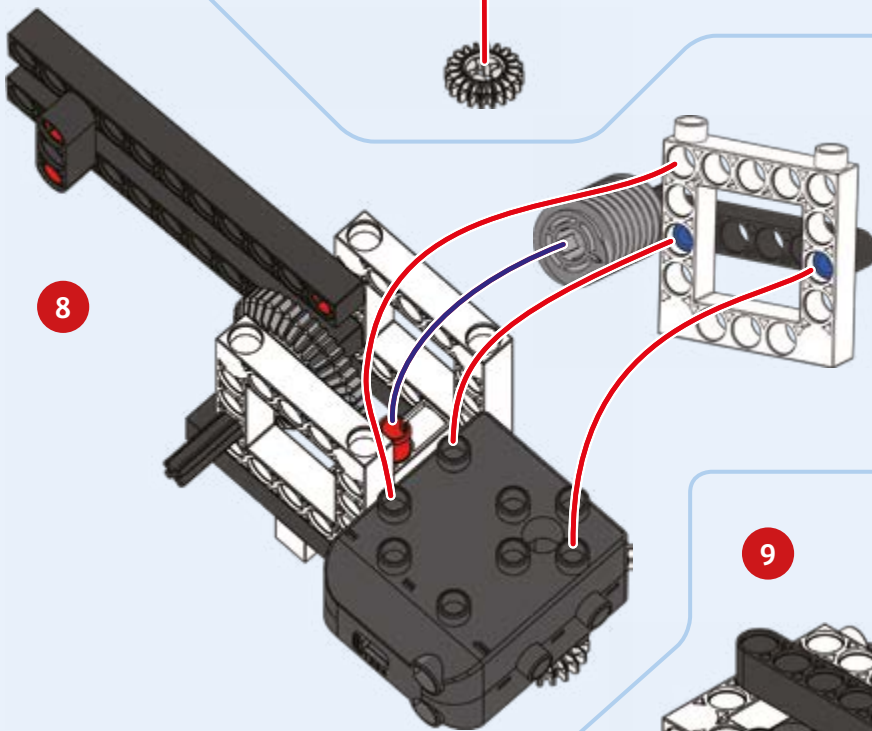
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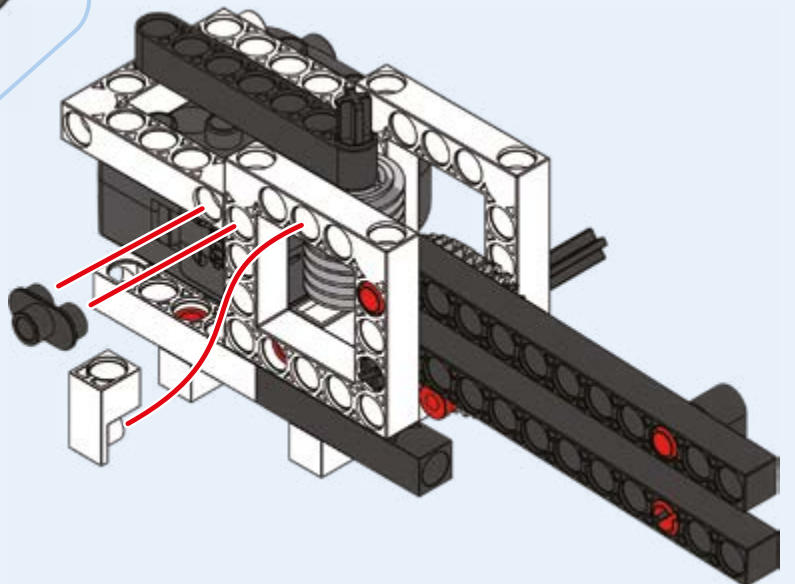
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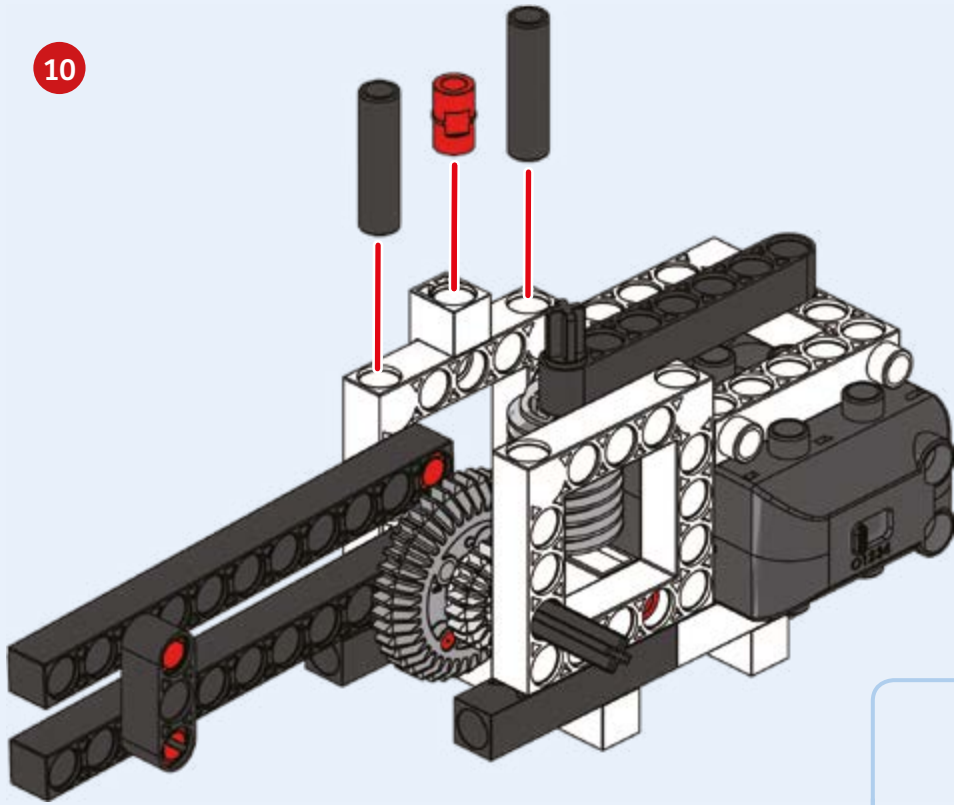
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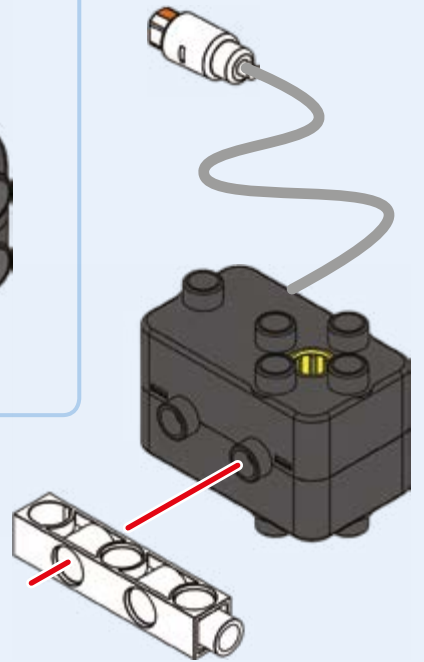


SHUTTLE ARM

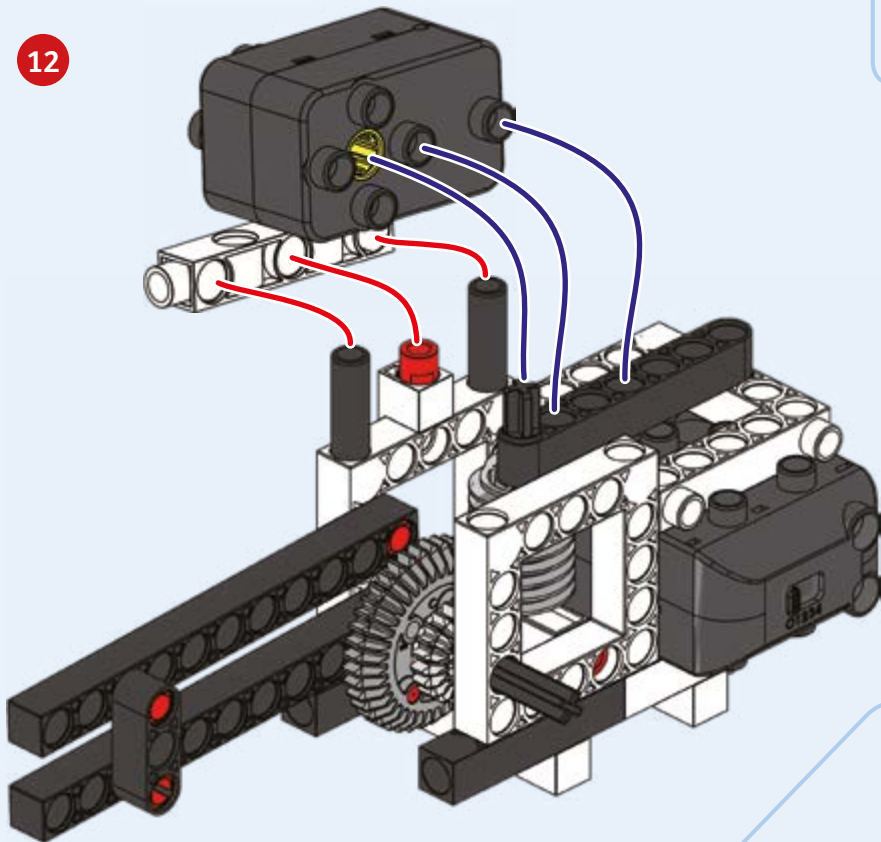
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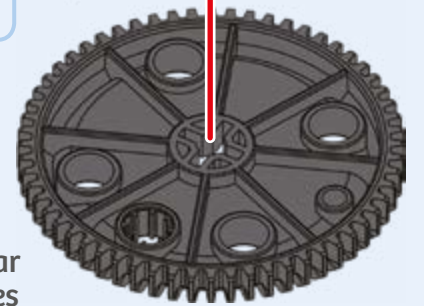
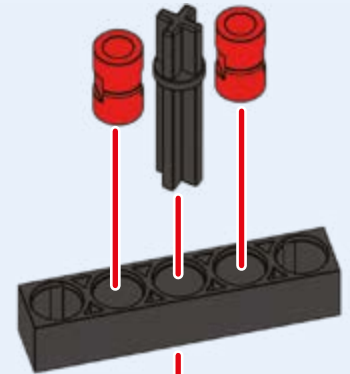


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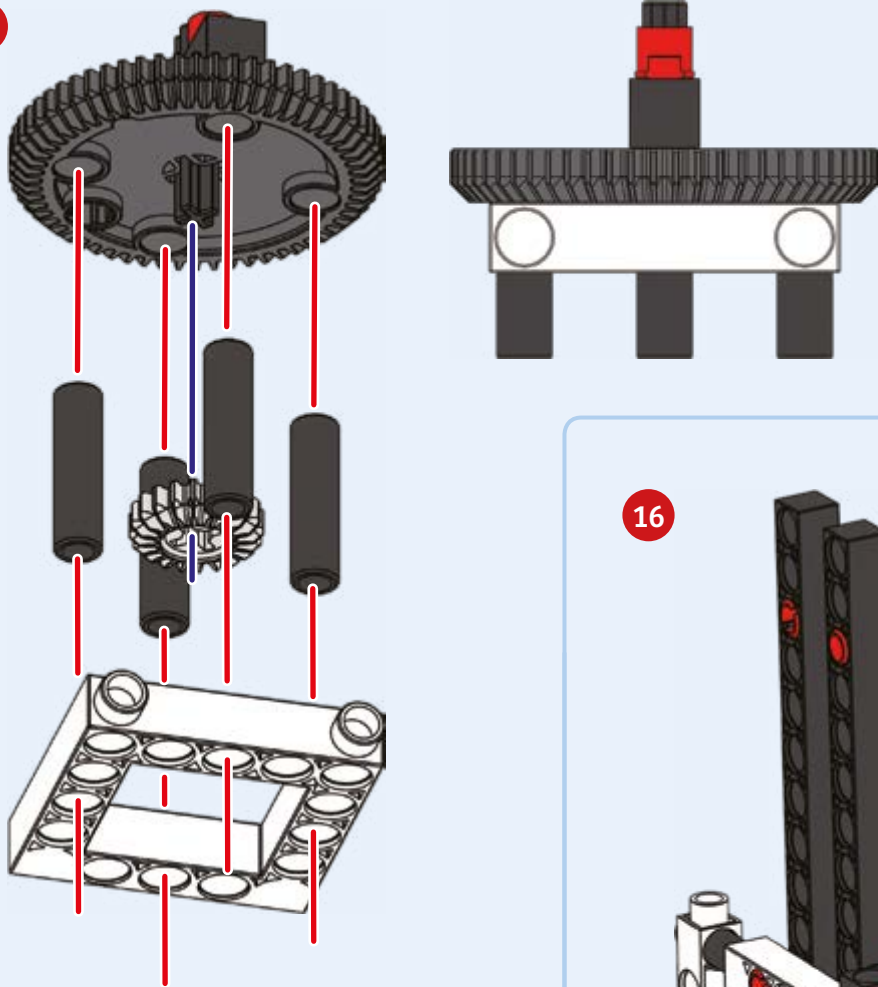
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35-mm axle

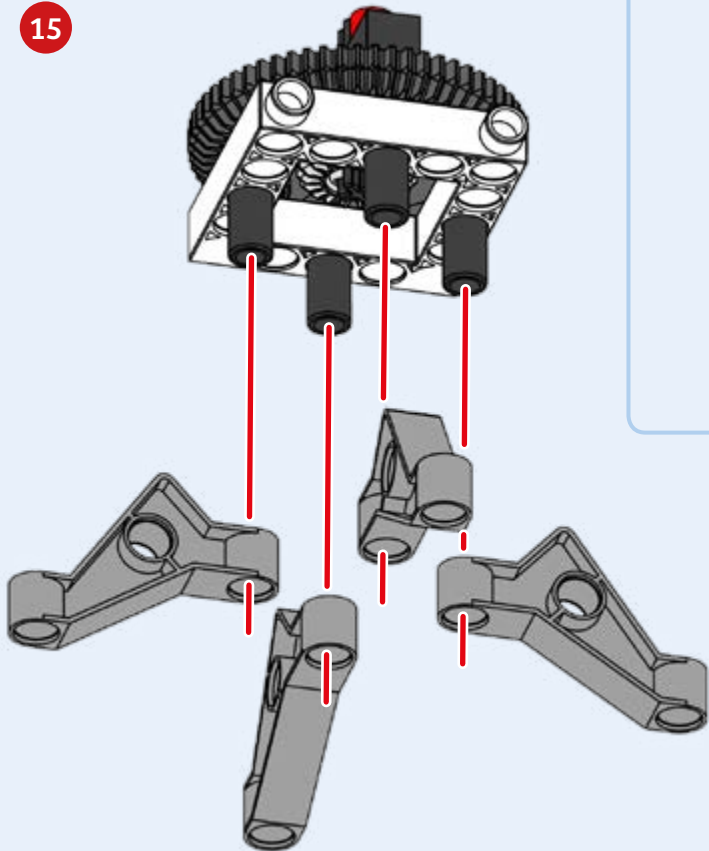


Large gear with holes

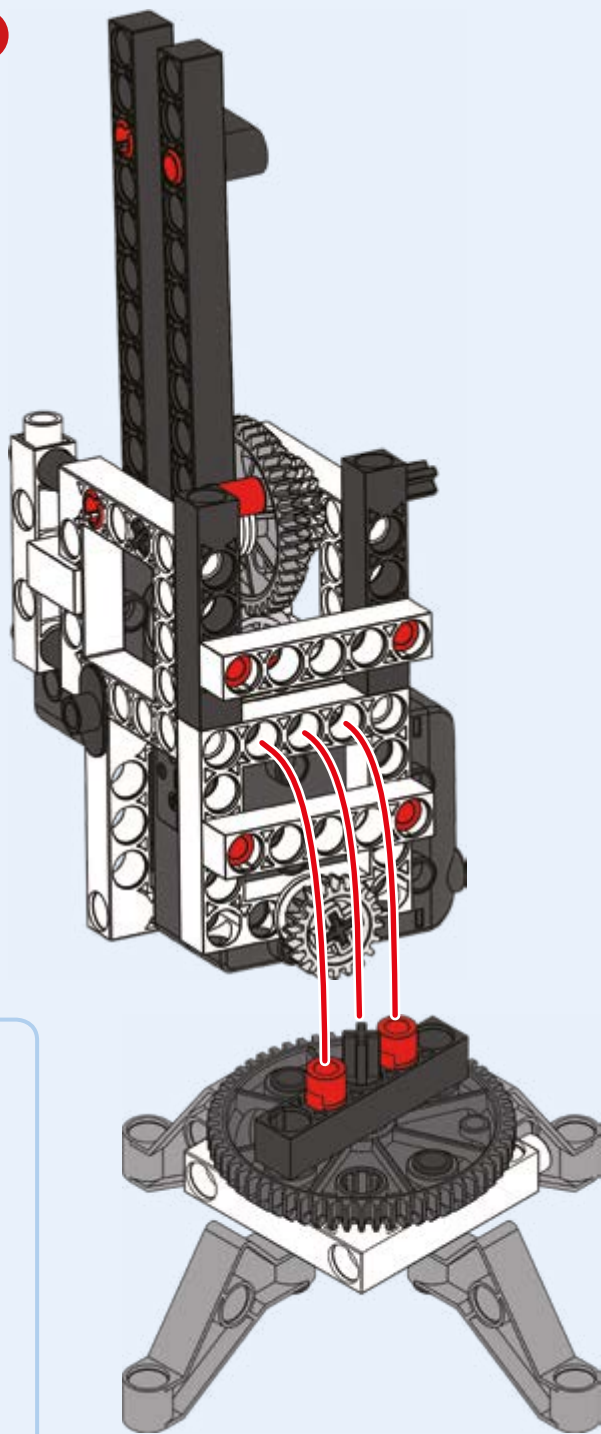
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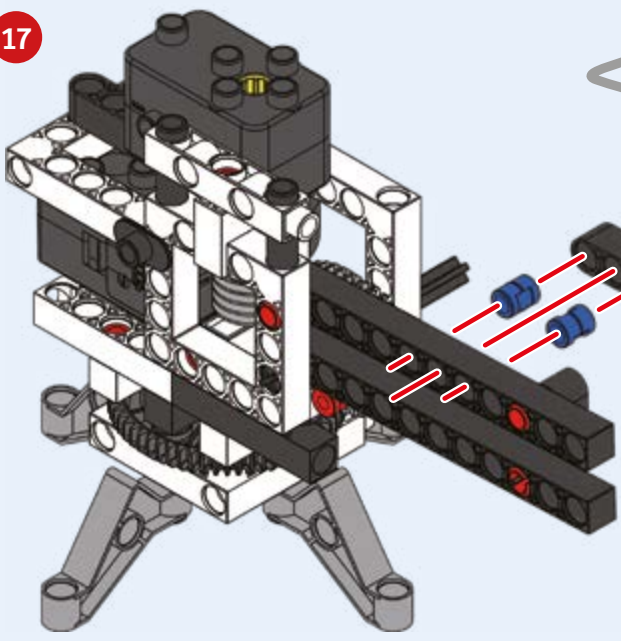
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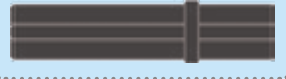


SHUTTLE ARM

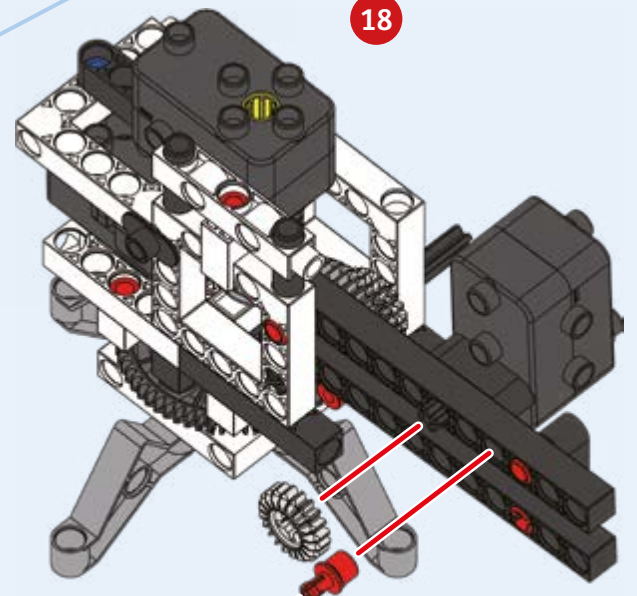
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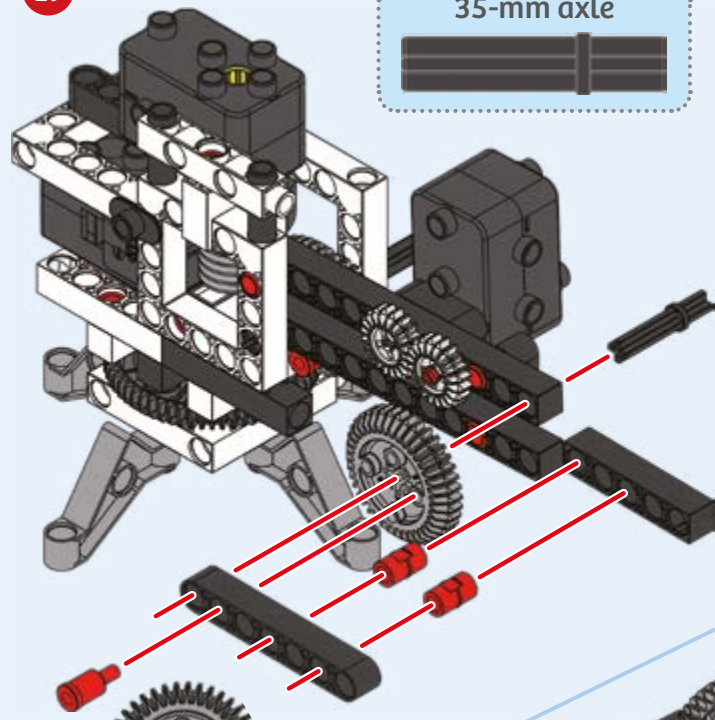
35-mm axle



18



19

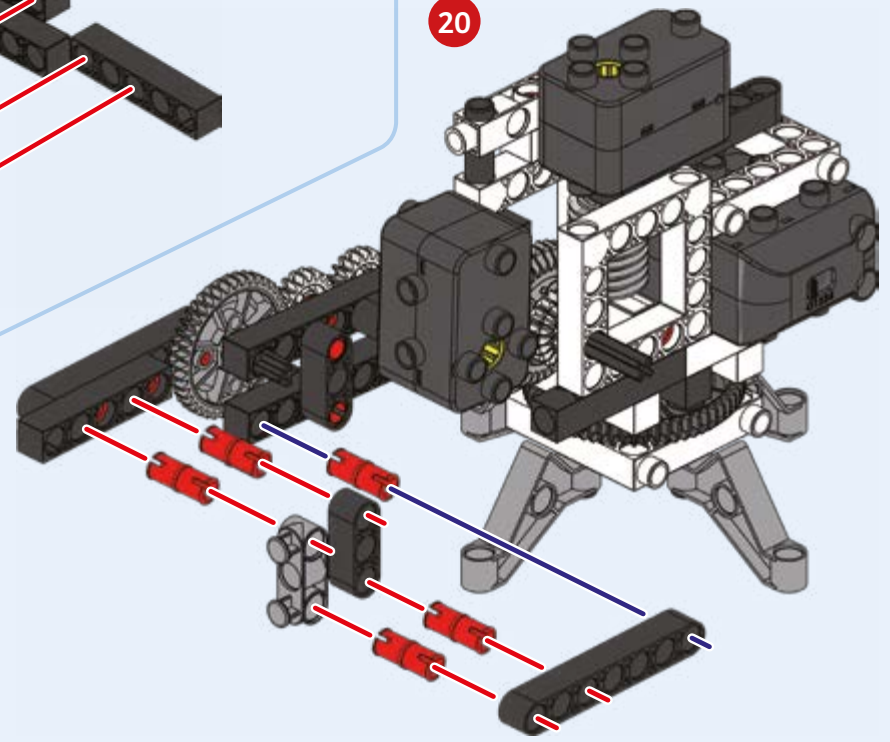


35-mm axle

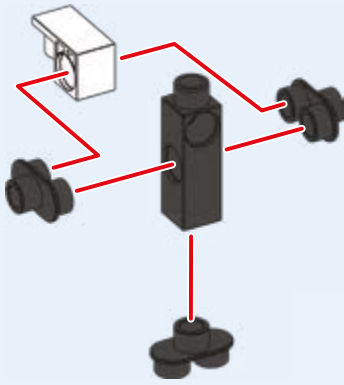


Connect to hole B

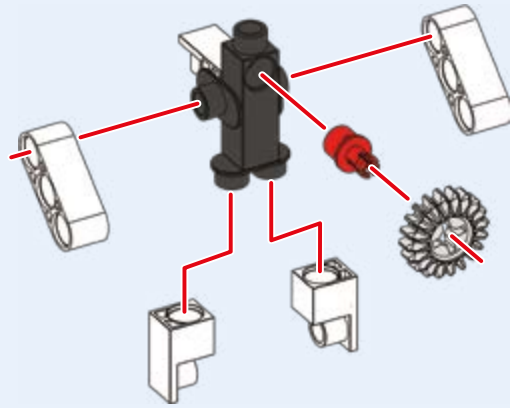
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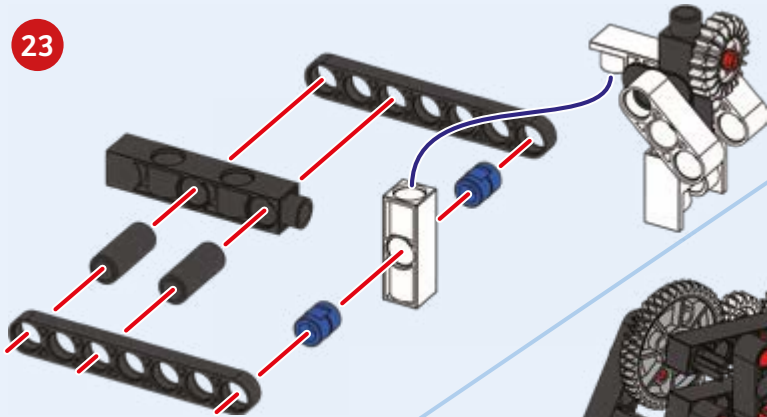
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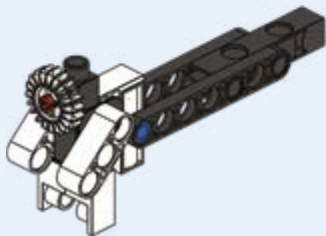
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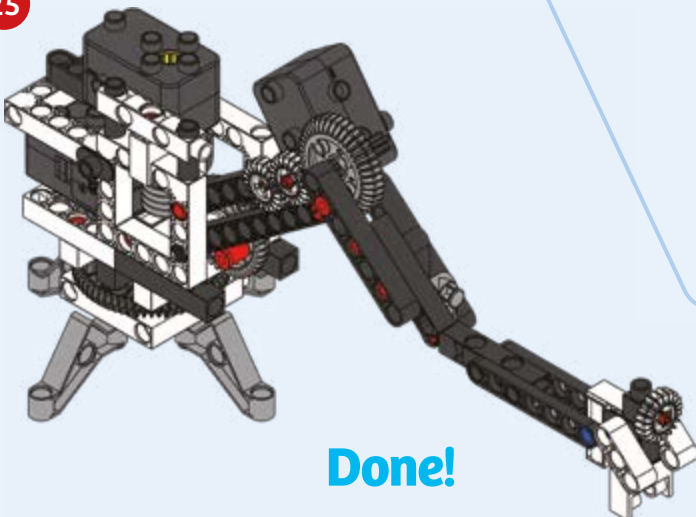
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24



25



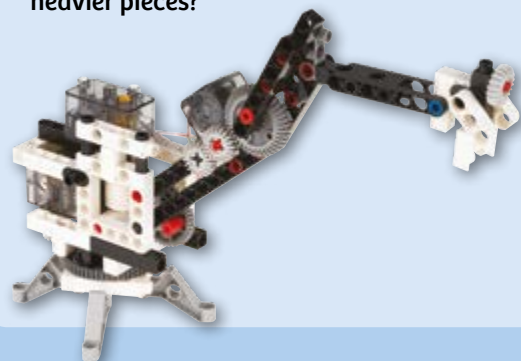
Done!

## EXPERIMENT 3

## Reach for the stars

## HERE'S HOW

Turn your model on and test its range of motion. How far to the left and right can it turn? Can it turn all the way around? Can it reach down to the horizontal plane (to the tabletop)? How high up can it reach? Also, try affixing some heavier building pieces to the end of the arm: Can it lift heavier pieces?





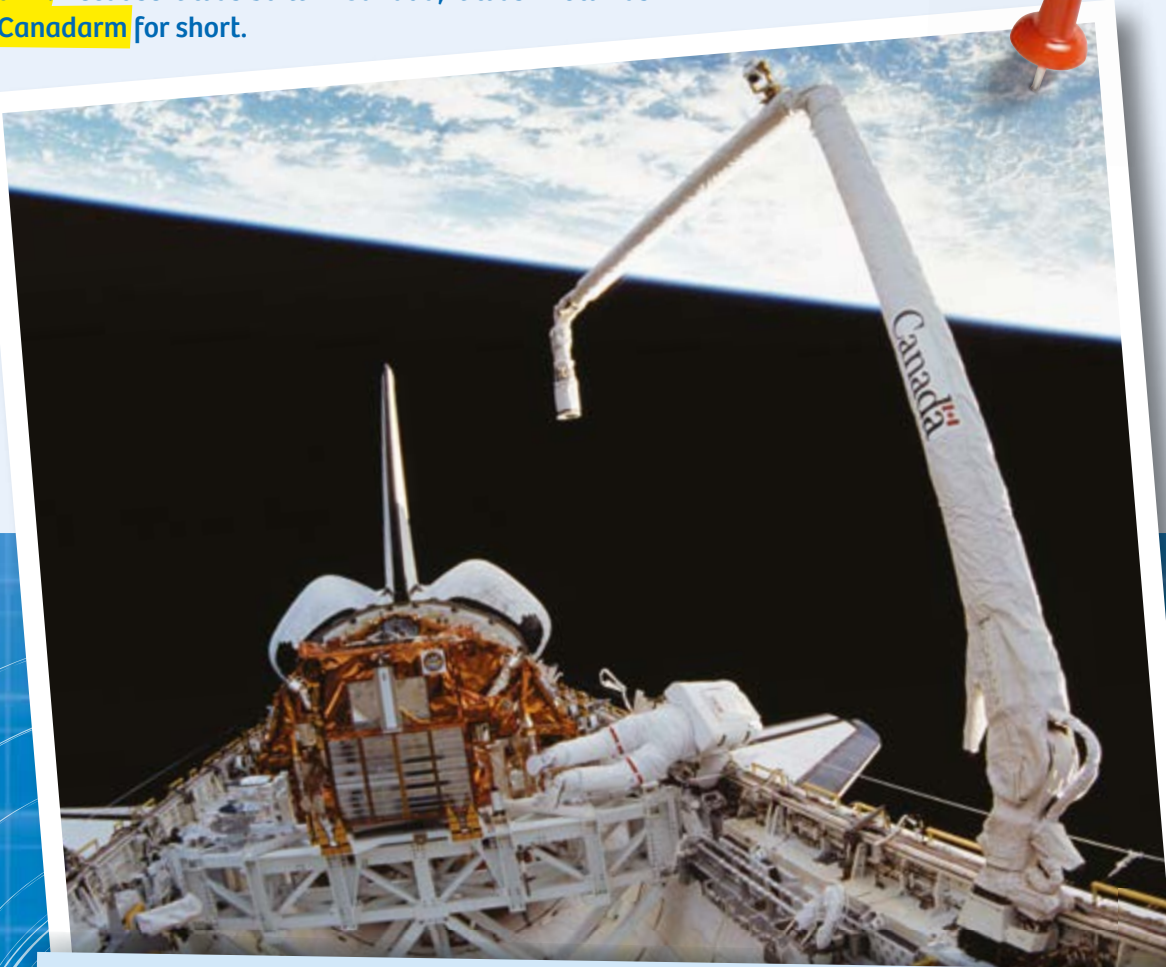


## Robotics Comes in Handy

The Space Shuttle was a reusable spaceplane developed by NASA. It is sometimes also referred to as an orbiter.

It functioned as both a space taxi and a space transporter. For example, it carried both astronauts and materials to the International Space Station (ISS), which orbits the Earth at a height of around 400 km.

In order to pull “luggage” such as satellites or ISS modules in and out of its cargo bay, it was equipped with a **robotic arm**. Because it was built in Canada, it was known as **Canadarm** for short.



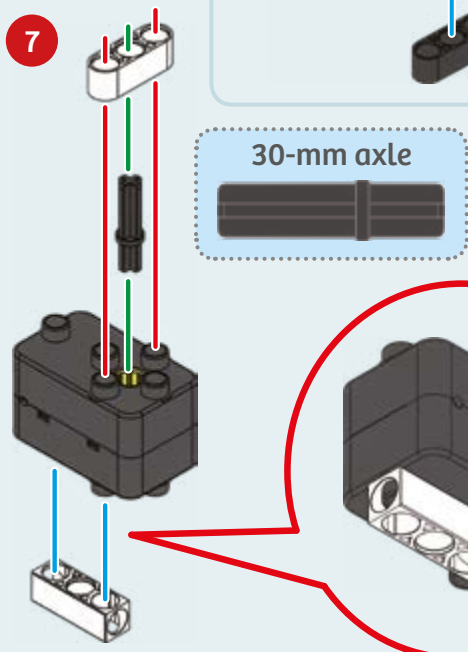
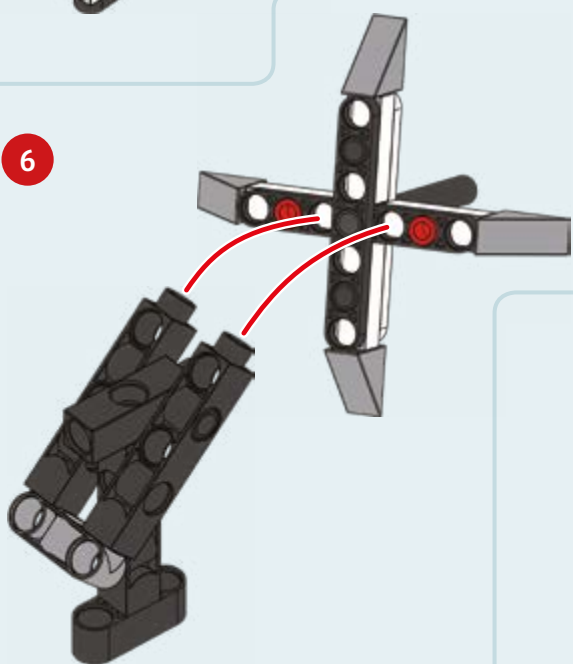
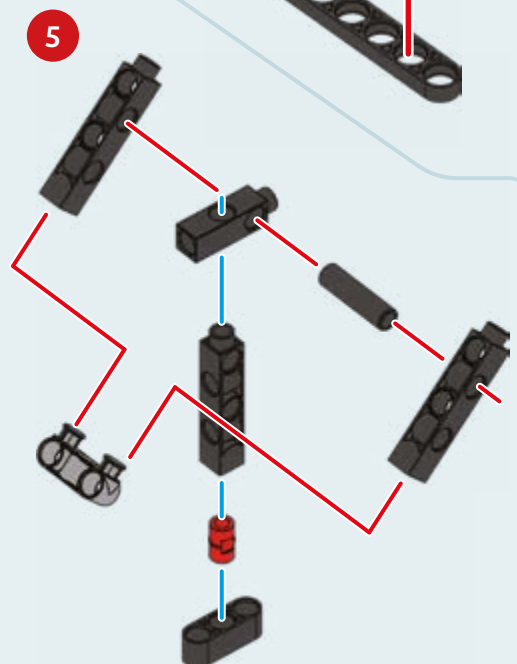
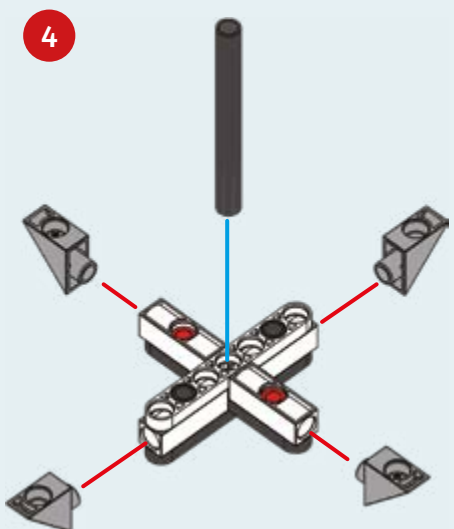
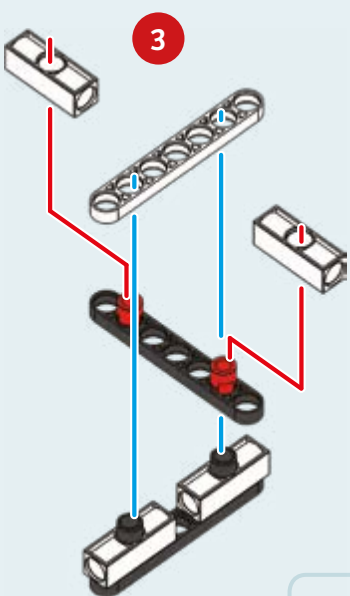
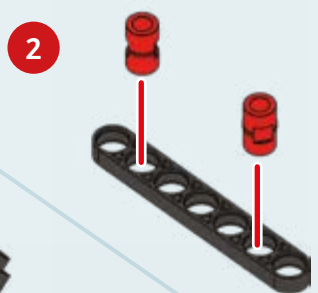
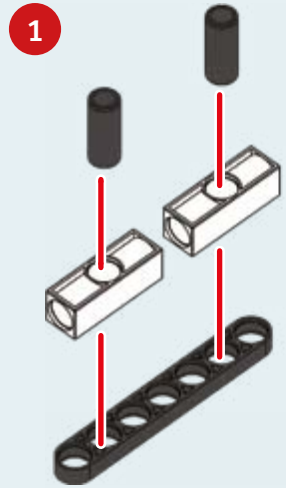
### A GIANT ARM WITH A REACH OF OVER 15 METERS

The arm was 15.33 meters long and had a diameter of over 38 centimeters. It was attached to the port side (that is, the left) of the loading bay. The Canadarm was modeled after our own arms. It had an upper and a lower portion and, of course, a hand. Thanks to its gripping mechanism, it was able to move cargo and even capture satellites so that astronauts could repair them.

The controls were handled by an astronaut who stayed on the shuttle's flight deck. Using images supplied by several cameras, the astronaut was able to steer the arm with precision. The arm was unbelievably strong, and could grab and move objects weighing up to 29 tons!

**LUNAR ROVER**

1	3	4	5	6	7	8	9	10	11	13	14		
5x	1x	2x	2x	9x	3x	4x	2x	1x	4x	1x	3x		
15	16	17	18	19	20	21	23	24	25	26	27		
1x	3x	2x	1x	4x	4x	2x	2x	2x	1x	4x	1x		
28	29	30	31	33	34	35	36	37	39	40	41		
3x	2x	2x	2x	2x	2x	4x	2x	1x	4x	2x	2x		
42	43	44	45	46	47	49	50	51	52	53	54	55	56
5x	2x	8x	21x	4x	2x	2x	2x	1x	1x	1x	1x	1x	1x

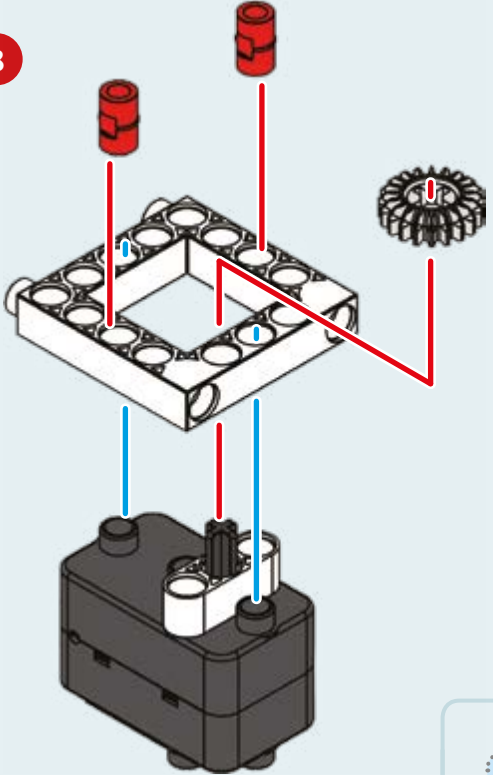




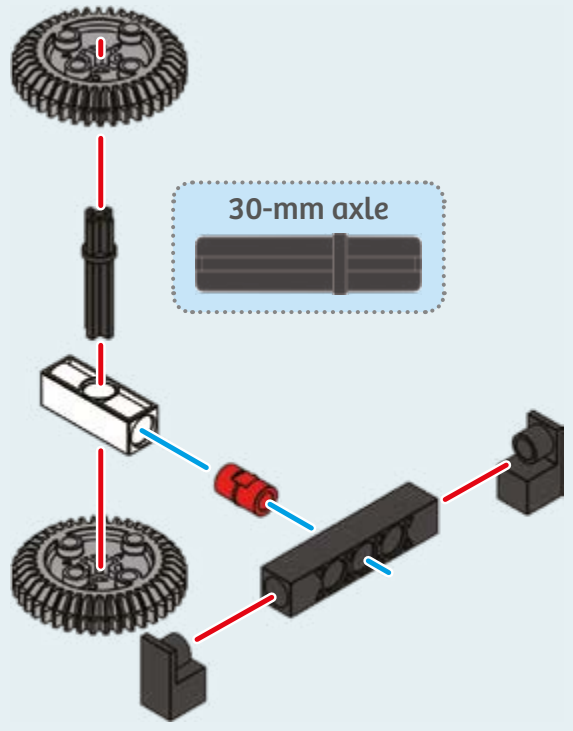


# LUNAR ROVER

8

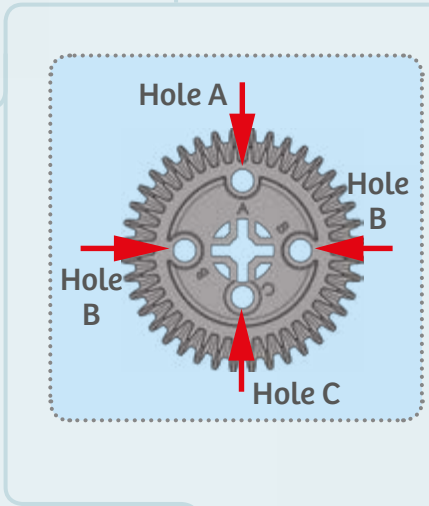
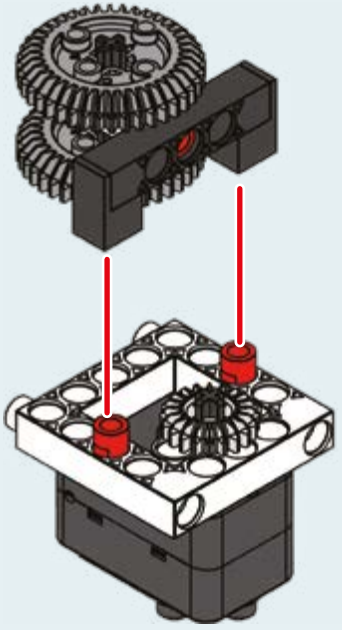


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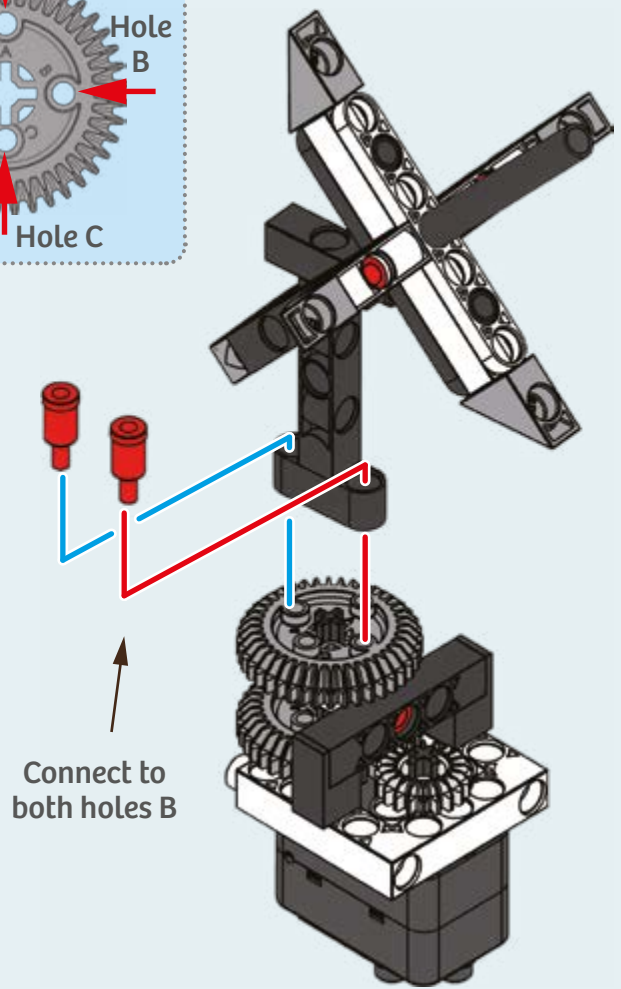


30-mm axle

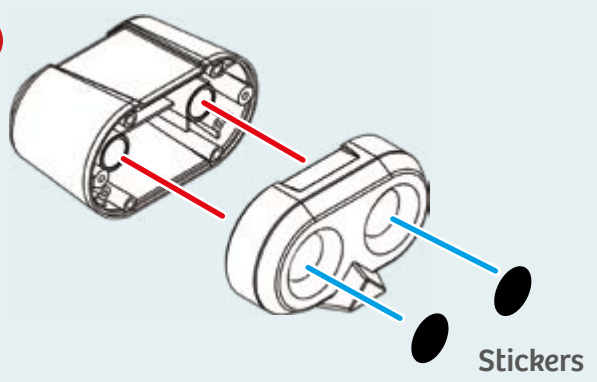
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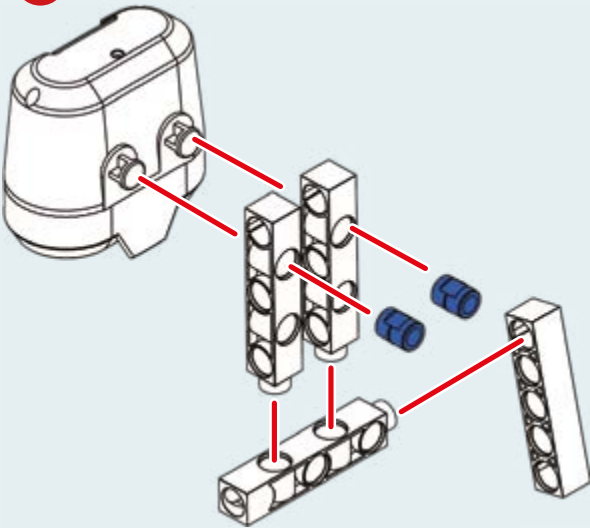
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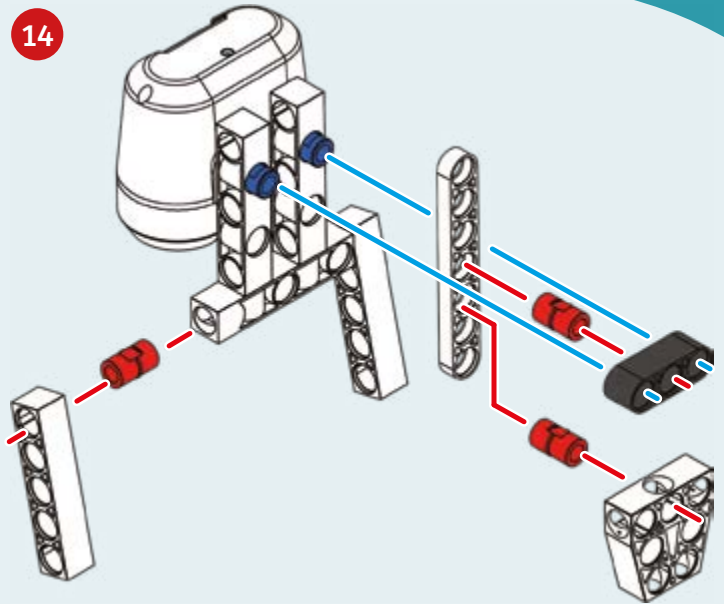
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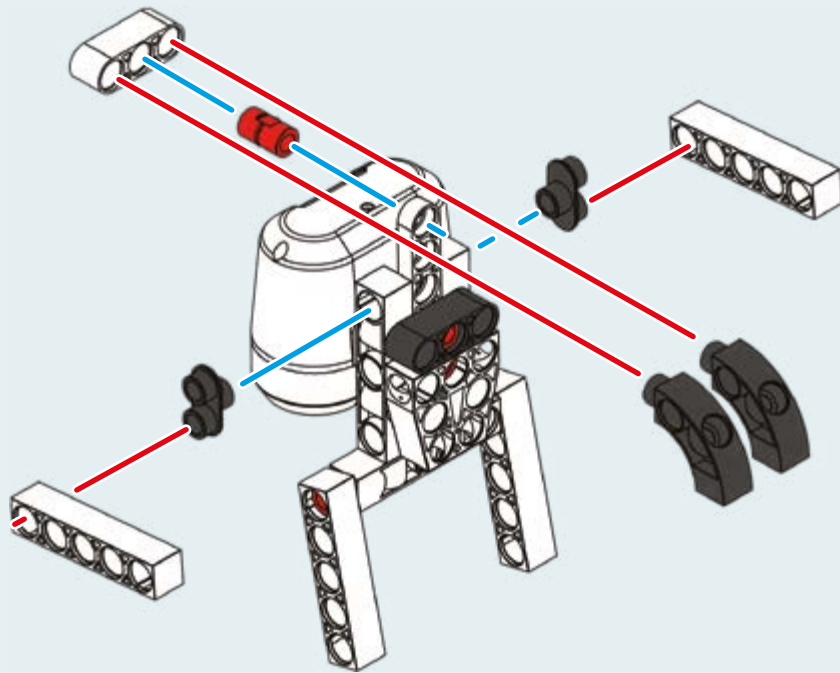
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14

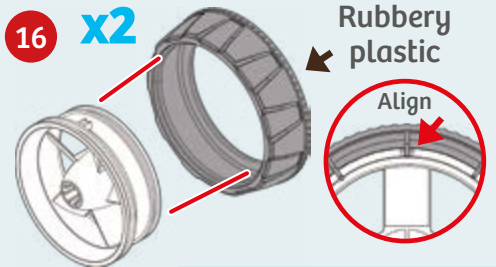


15



16

x2



Rubbery plastic

Align

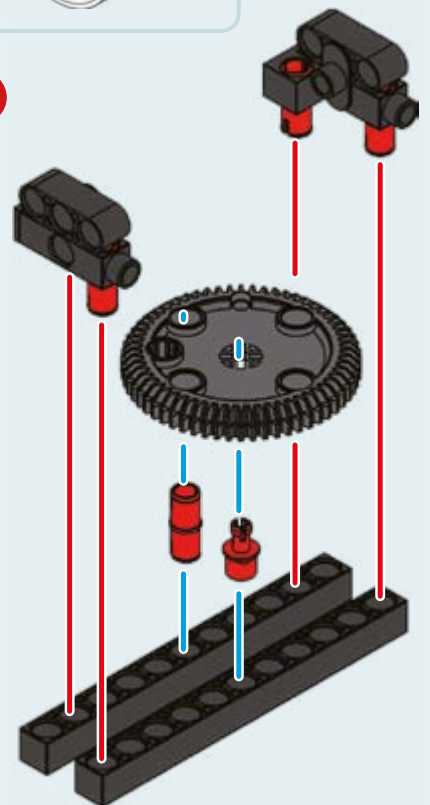
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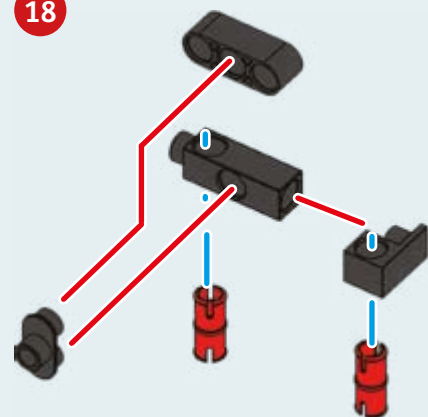
x2

Hard plastic

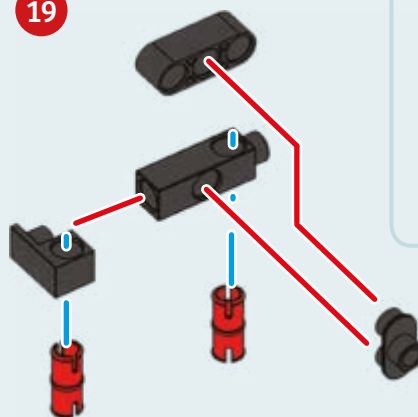
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18



19







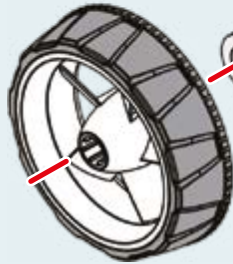
# LUNAR ROVER

21

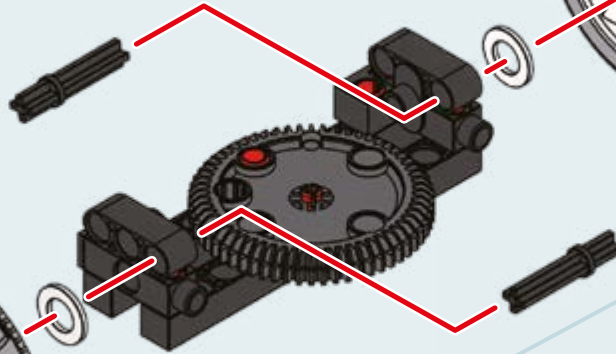
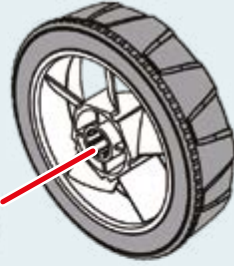
35-mm axles



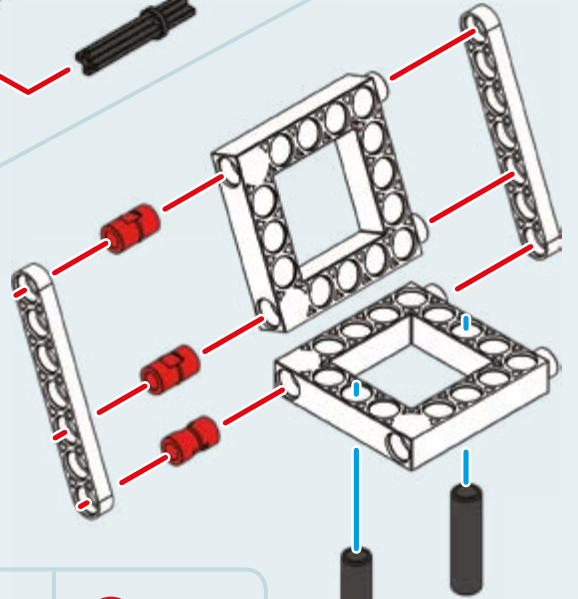
Rubbery plastic



Rubbery plastic

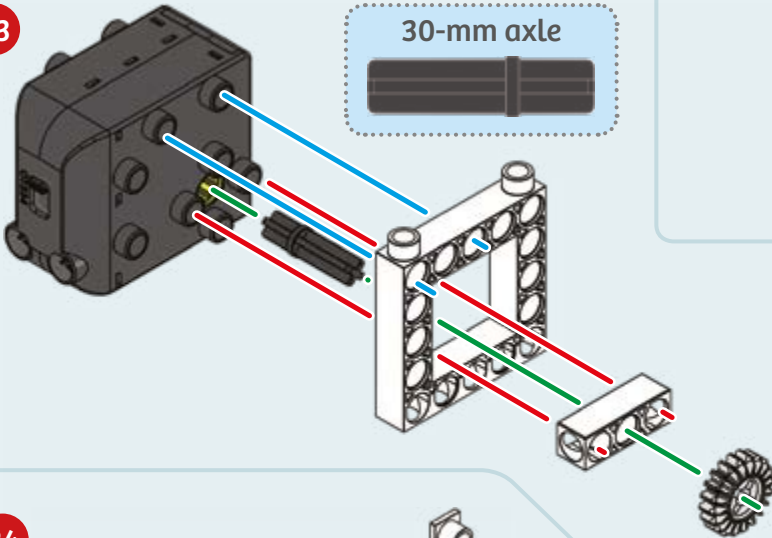


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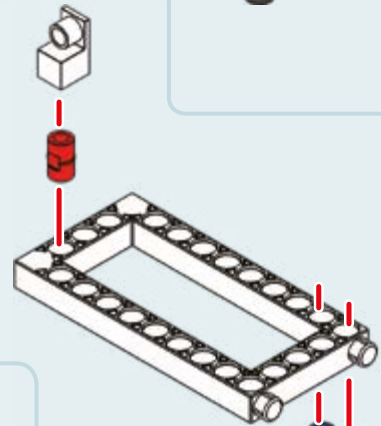


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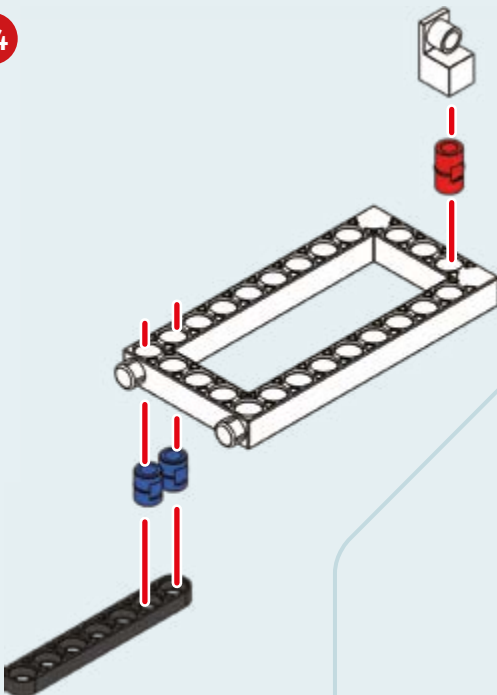
30-mm axle



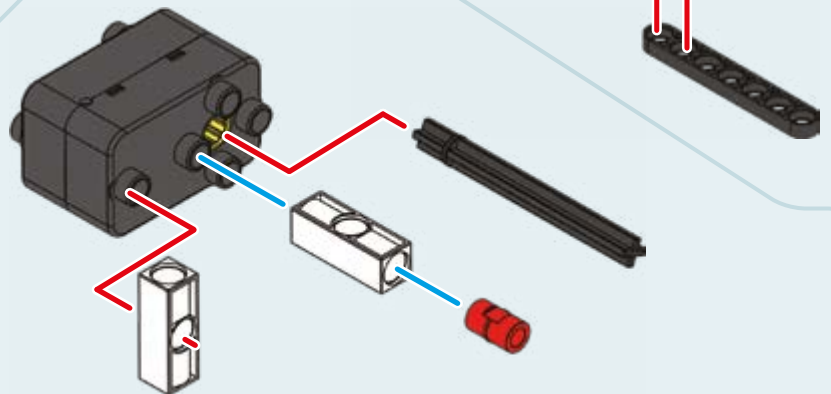
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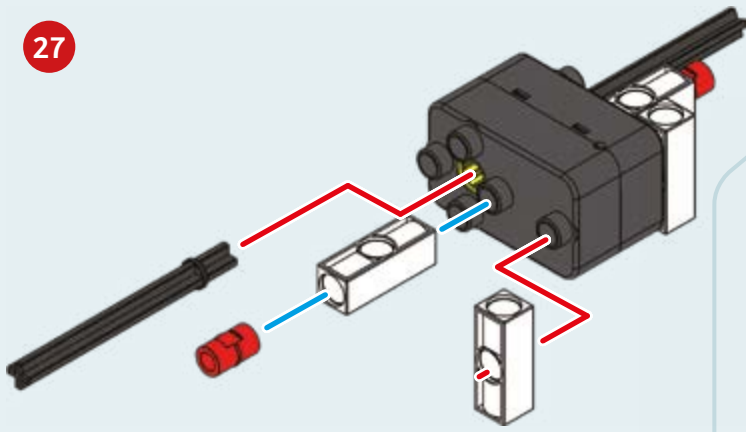
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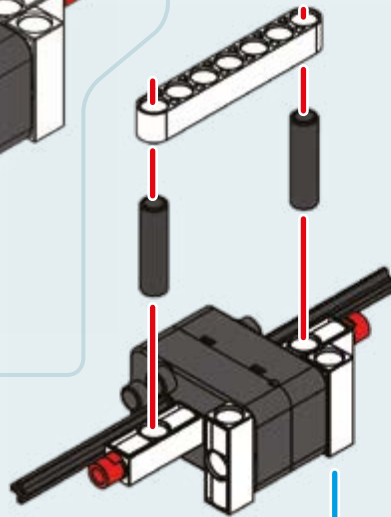
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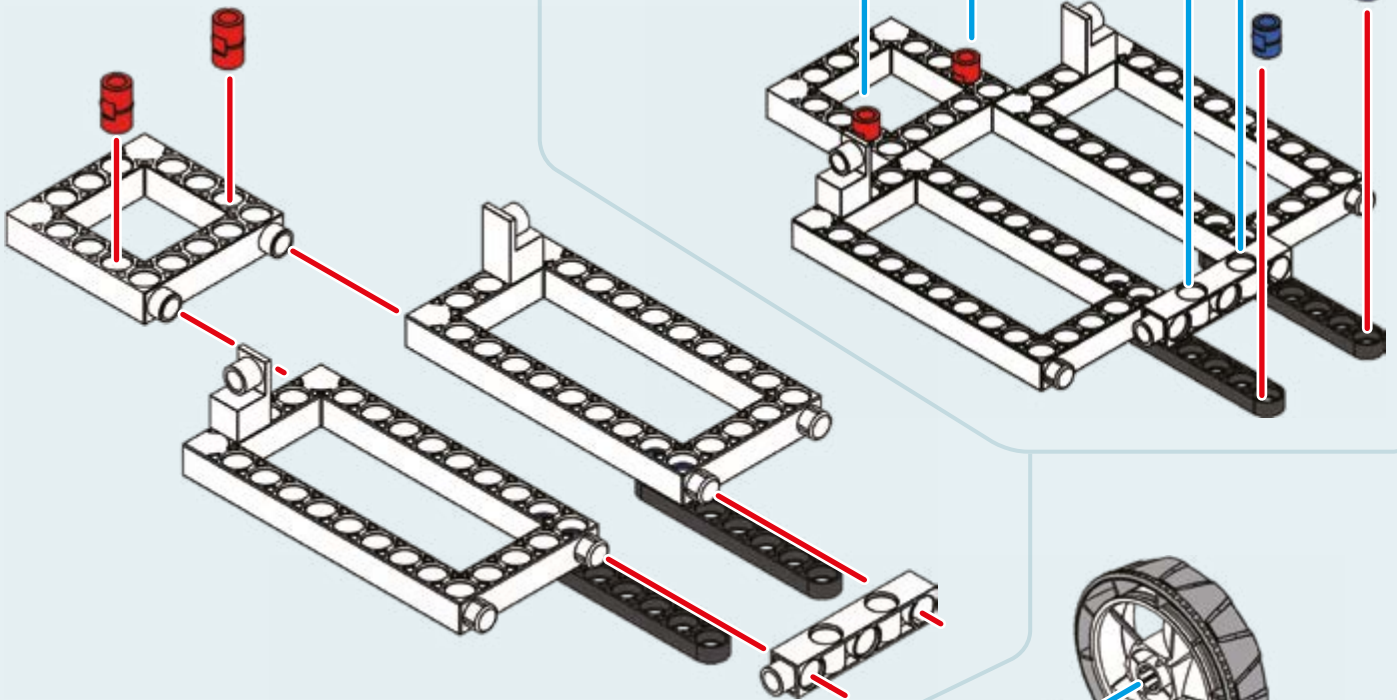
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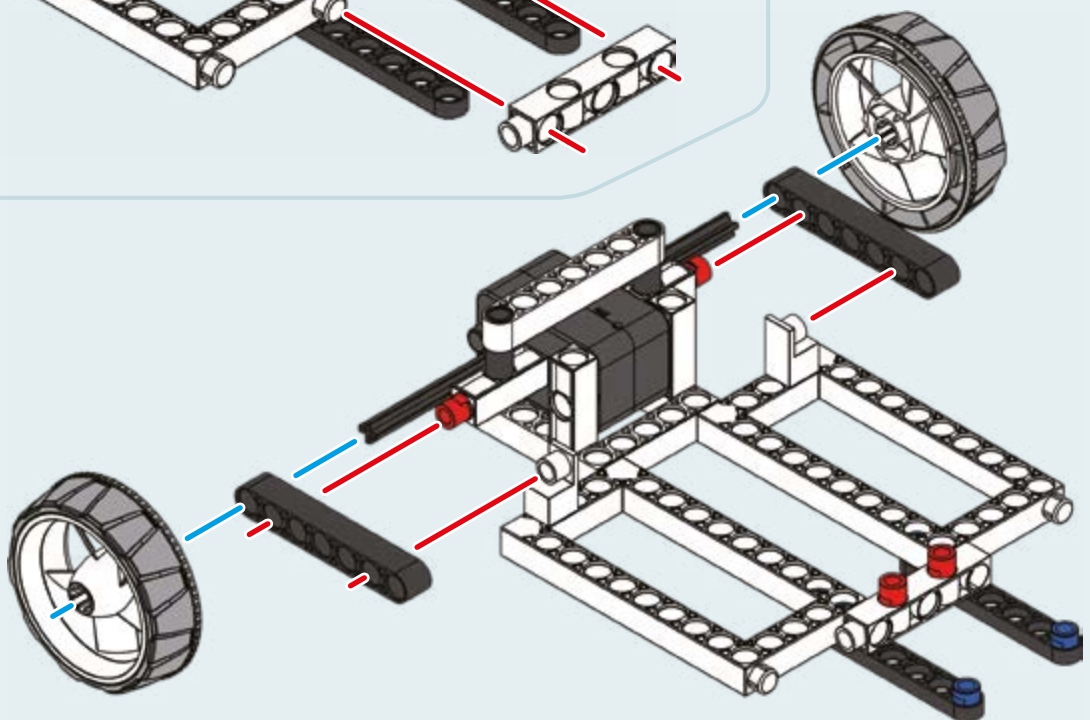
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28



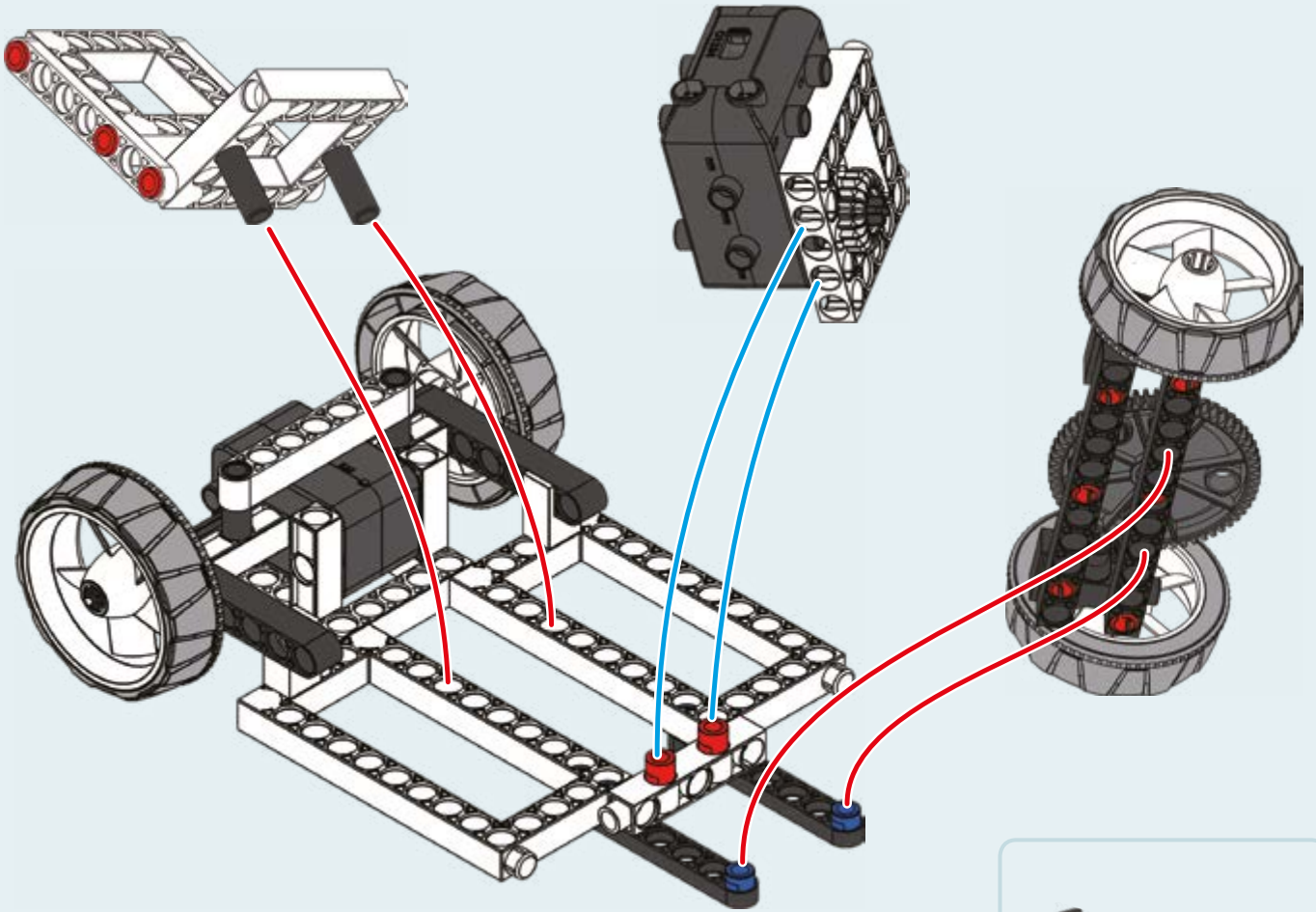
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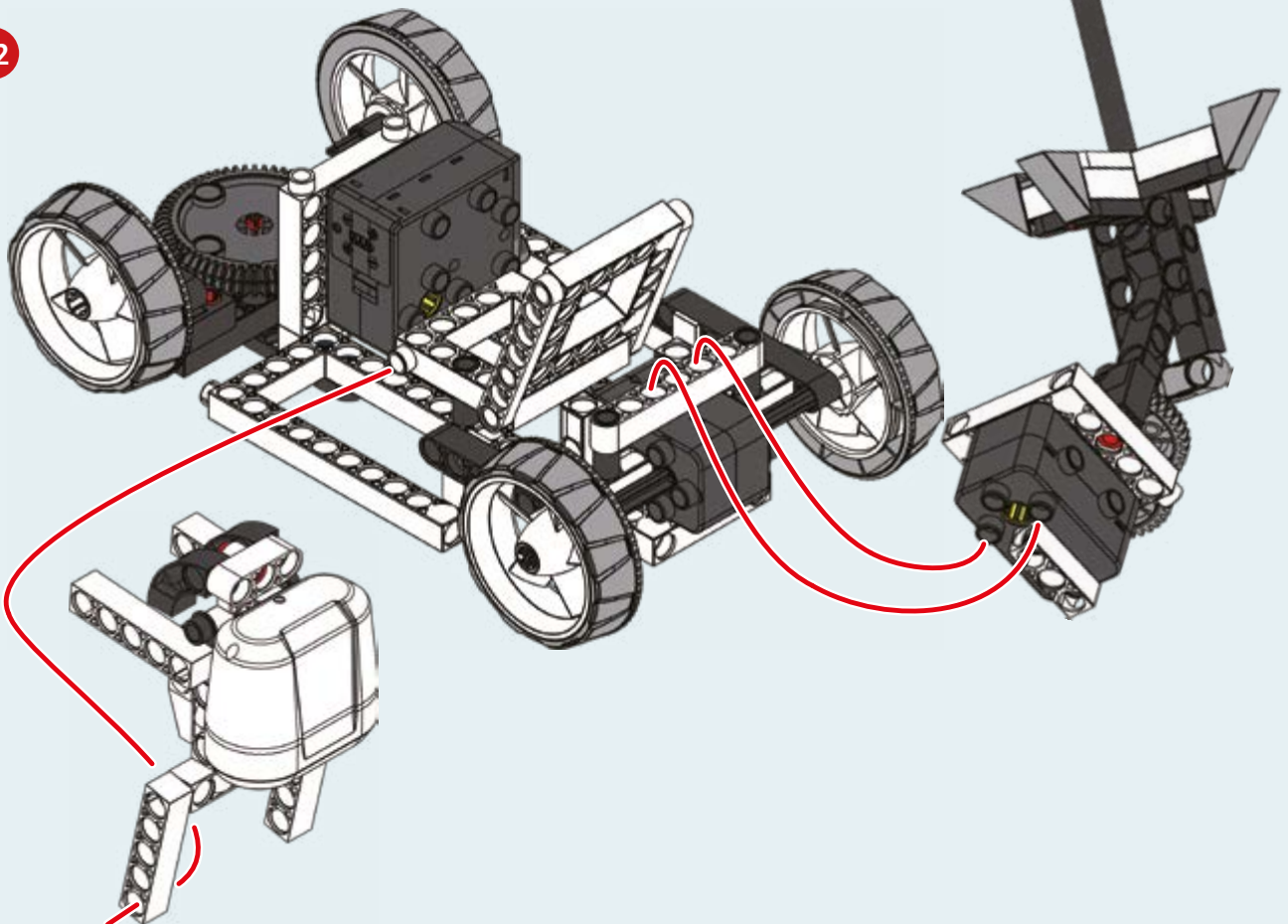




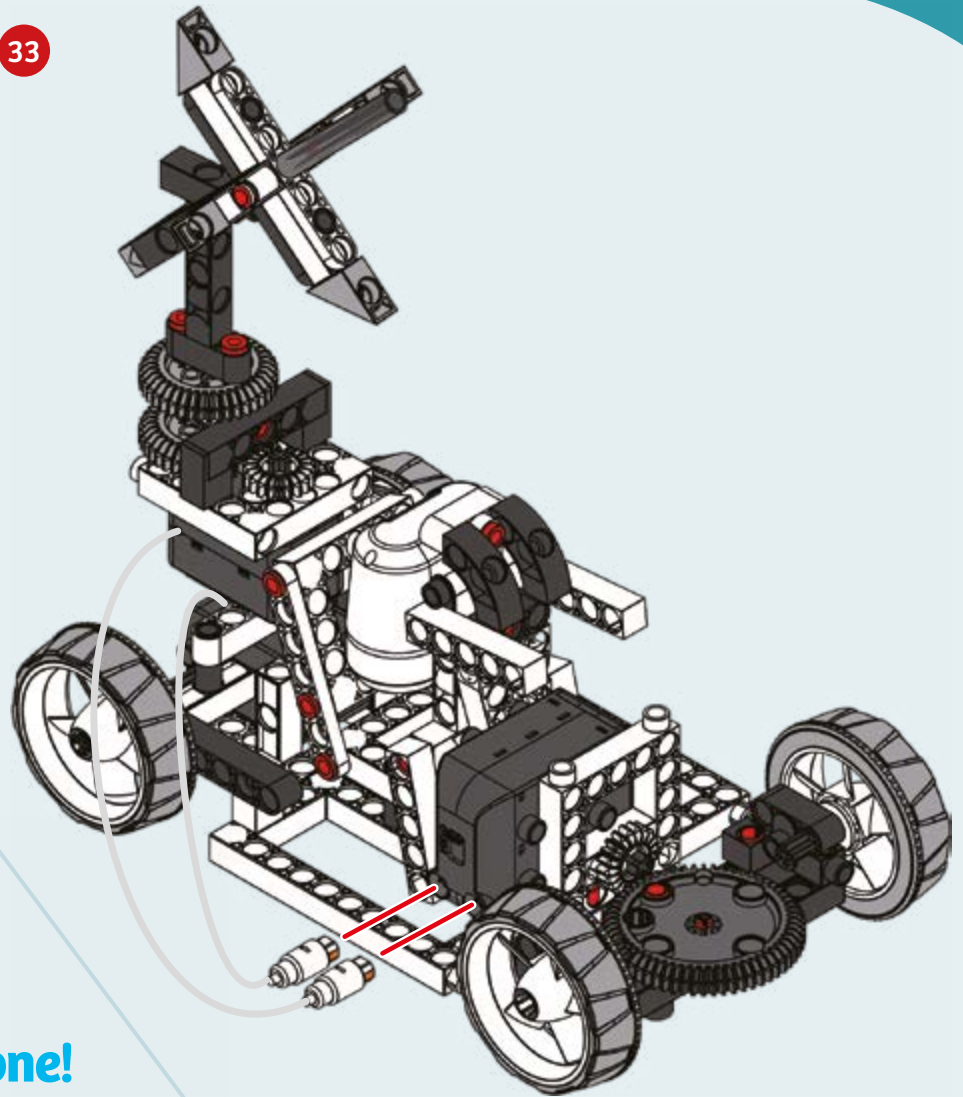
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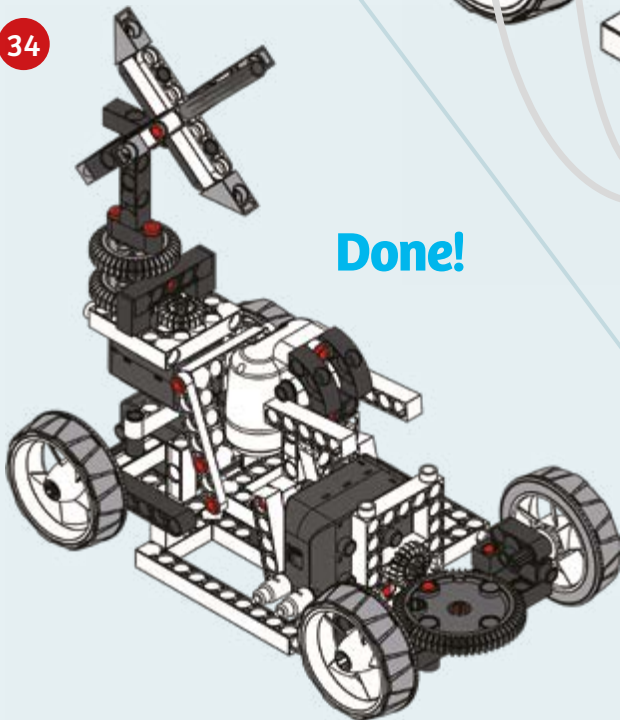
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33



34



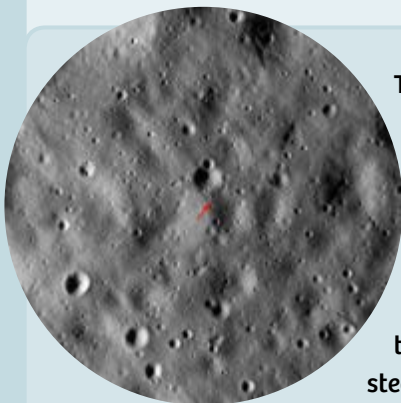
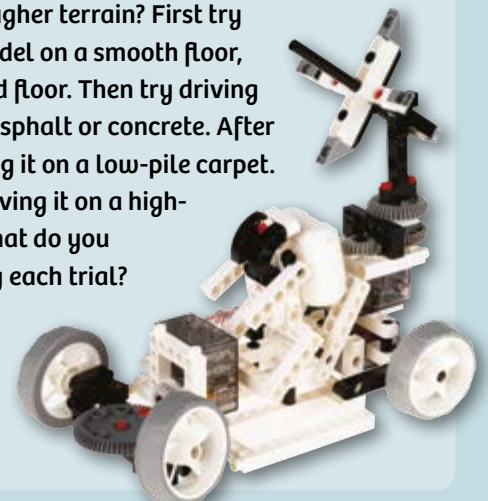
Done!

## EXPERIMENT 4

## That's one small step ...

## HERE'S HOW

Many areas on the moon's surface are very flat, so your lunar rover model was designed to travel on smooth, flat surfaces. But can it drive over bumpier or rougher terrain? First try driving the model on a smooth floor, such as a wood floor. Then try driving it on rougher asphalt or concrete. After that, try driving it on a low-pile carpet. Finally, try driving it on a high-pile carpet. What do you observe during each trial?



The highest point on the moon is 10,786 meters above the mean radius (the "baseline" surface level). By comparison, Mount Everest is 8,848 meters above sea level on Earth. But the difference is that the slope up to the top of Everest is much steeper than the slope up to the top of the moon's highest point.





CHECK IT OUT



## Trips to the Moon

The Lunar Roving Vehicle (LRV) was a car that was built especially for the NASA Apollo Moon missions. One of these four-wheeled electric vehicles was assigned to each of the last three Apollo missions 15, 16 and 17.

The job of this moon car was to help the astronauts cover greater distances on the moon and to carry rock samples.



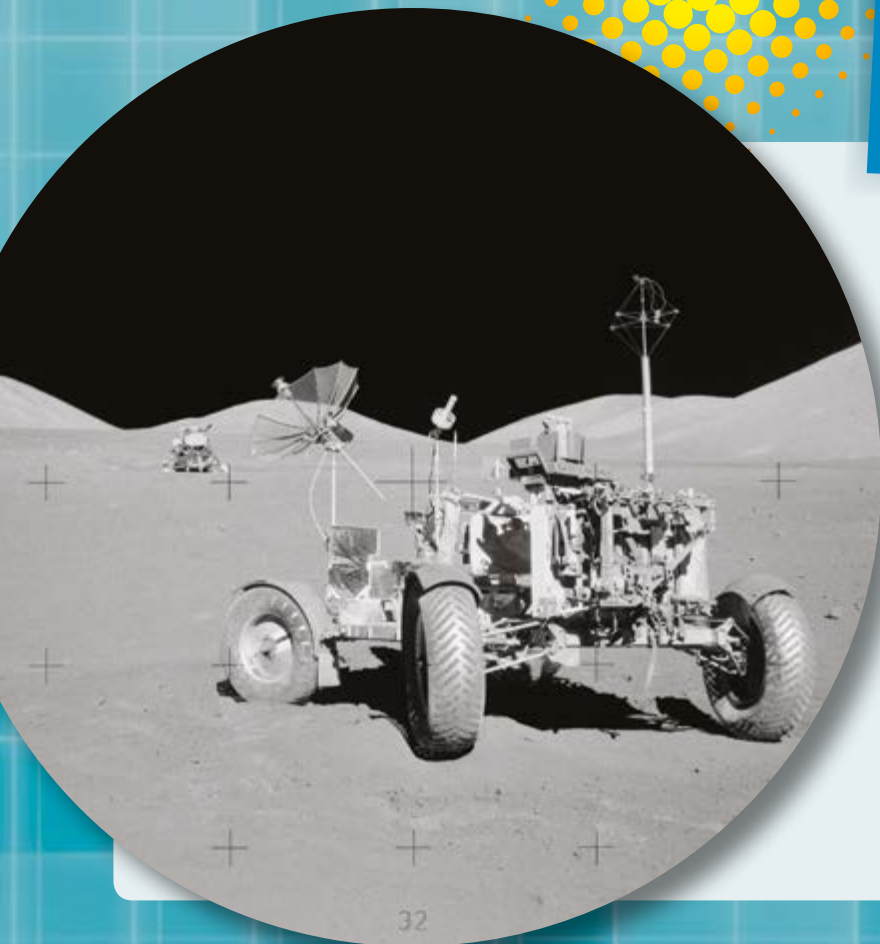
### LIGHT, COMPACT, AND KIND OF SLOW

The LRV was 3.1 meters long and weighed barely 210 kg. It had a foldable chassis, giving it a pack size of 0.90 m × 1.50 m × 1.70 m for transportation on the lunar module. That's about one third the size of a Smart Fortwo — which is about the tiniest car you can get.

### BREAKDOWN SERVICE ON THE MOON

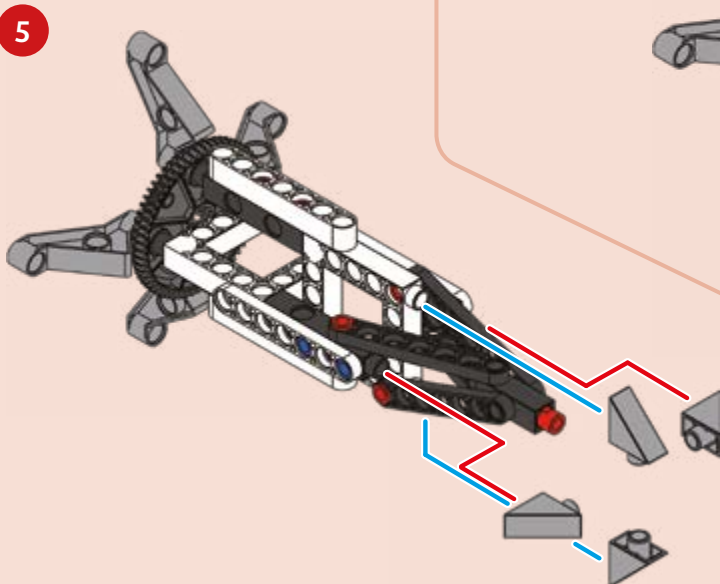
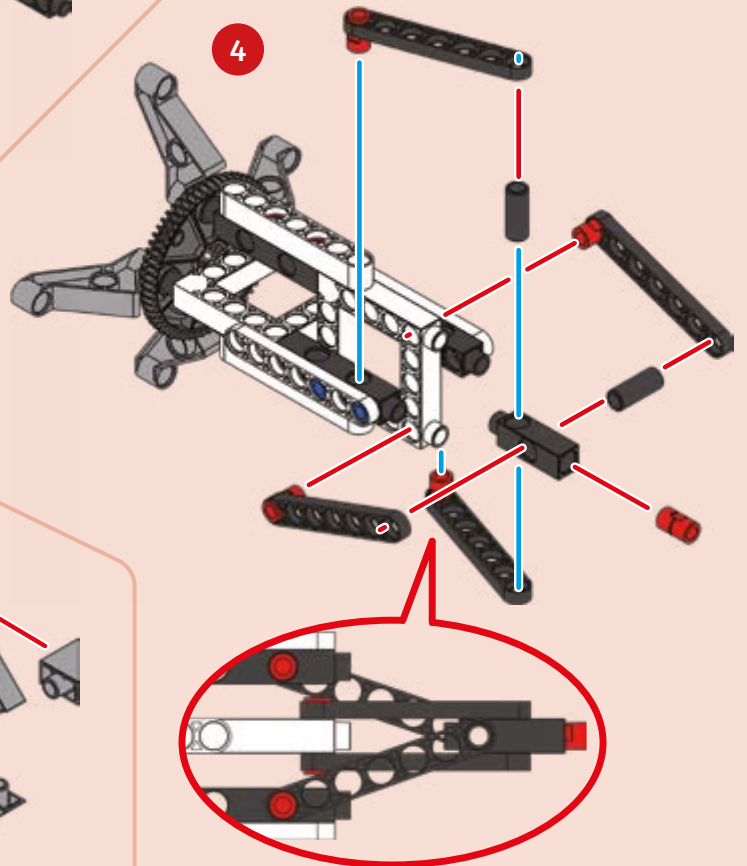
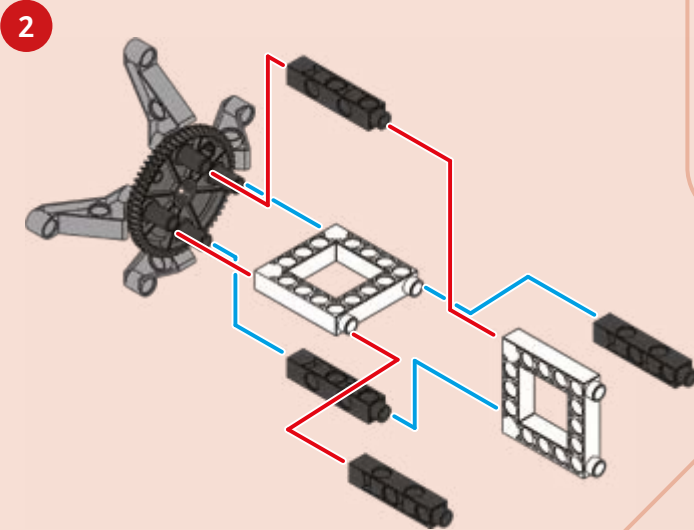
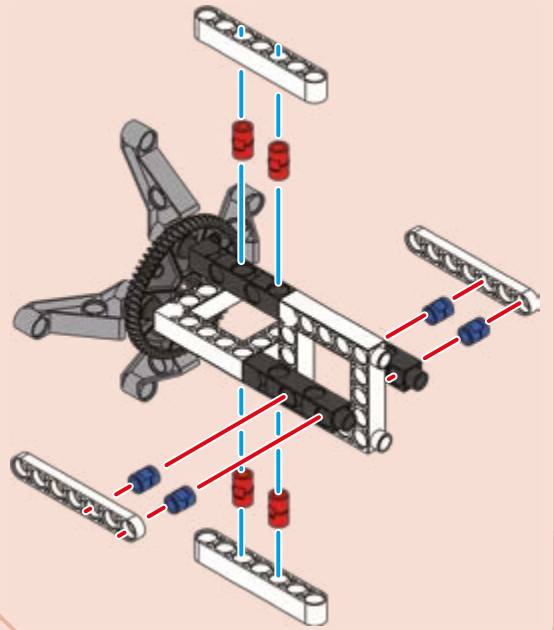
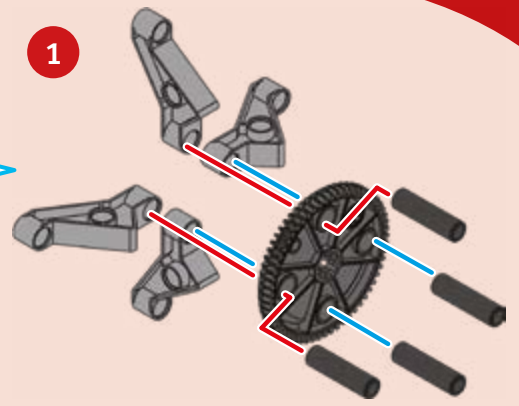
For power, it carried two non-rechargeable 36-volt silver oxide-zinc batteries, which gave it a top speed of 13 km/h and a maximum range of 92 km.

On the second day of the Apollo 17 mission, a fender was torn off the LRV's right rear wheel and had to be repaired. The only materials available were whatever was on board the lunar module — tape, maps, clamps, and the like. But they were enough to fix the problem. To this day, that was the only car repair job performed off the planet Earth!



ROCKET LAUNCH CAR

1	4	6	7	8	9	11	12	13	14	
7x	2x	2x	3x	2x	2x	2x	2x	3x	1x	
16	17	18	19	20	21	22	23	26		
4x	4x	6x	4x	3x	2x	4x	2x	4x		
28	29	30	31	32	34	35	36	37	38	39
7x	2x	2x	2x	1x	2x	4x	4x	1x	1x	6x
40	41	42	43	44	45	46	49	50	51	52
4x	2x	6x	2x	6x	30x	6x	3x	2x	1x	1x



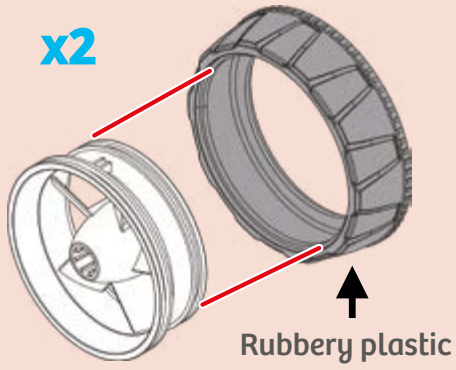




ROCKET LAUNCH CAR

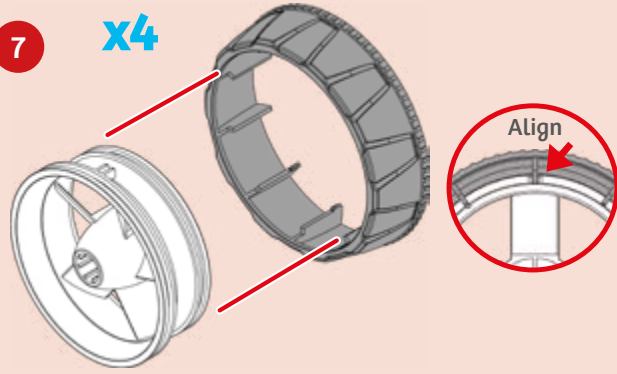
6

x2



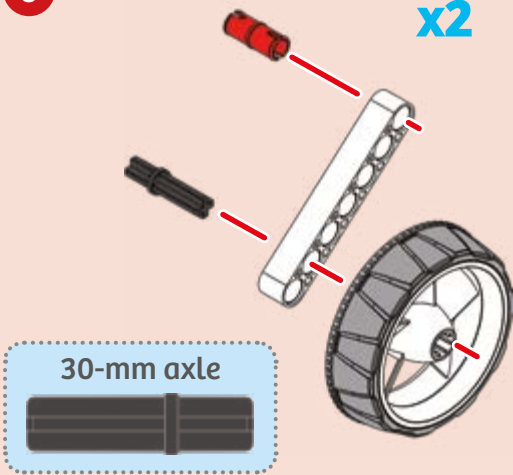
7

x4

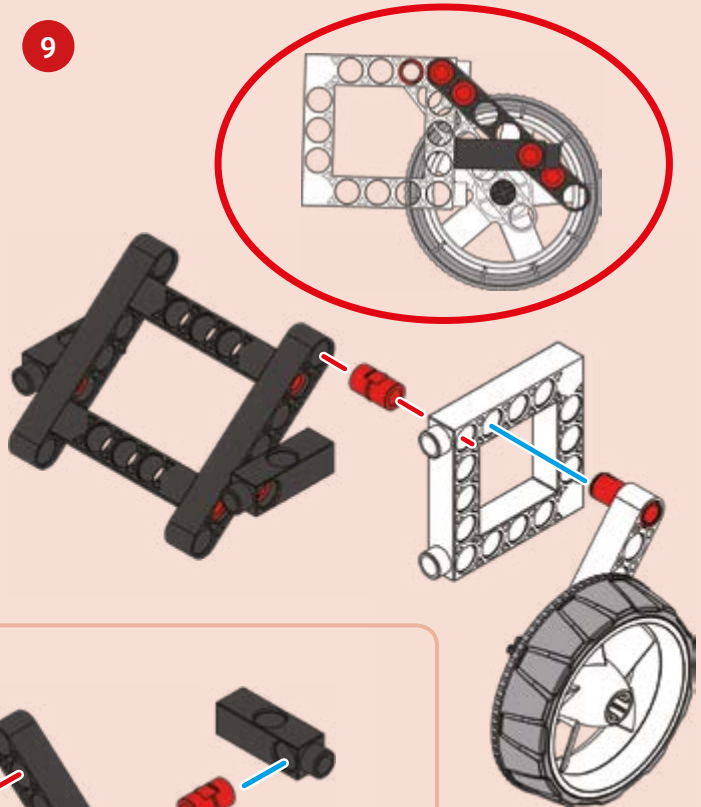


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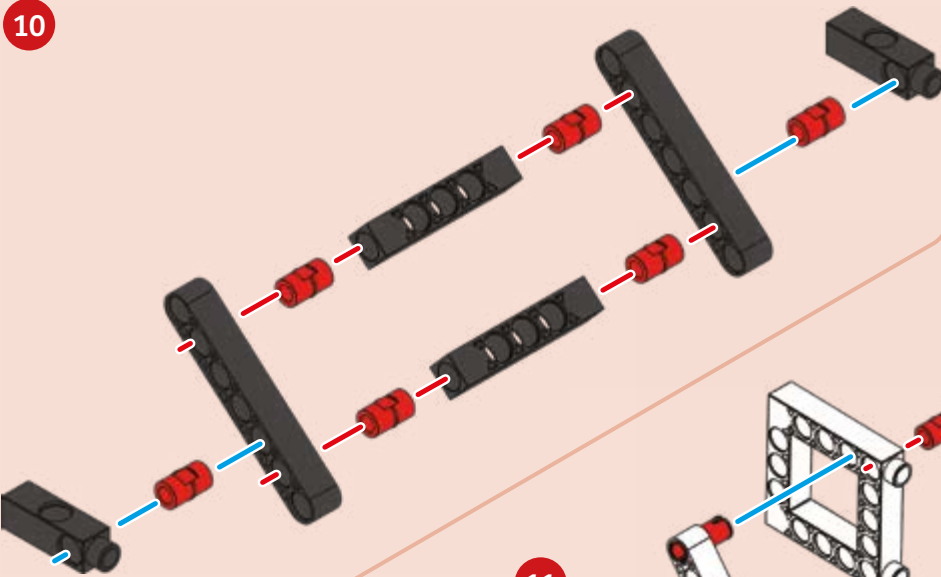
x2



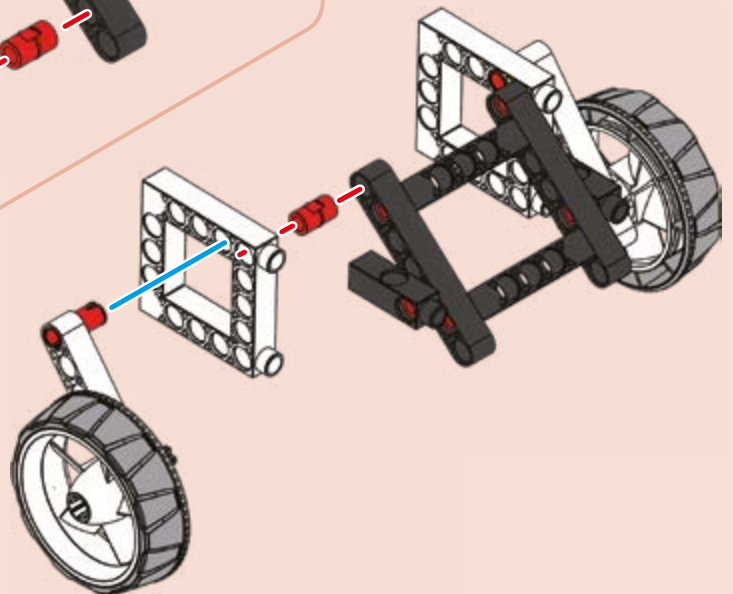
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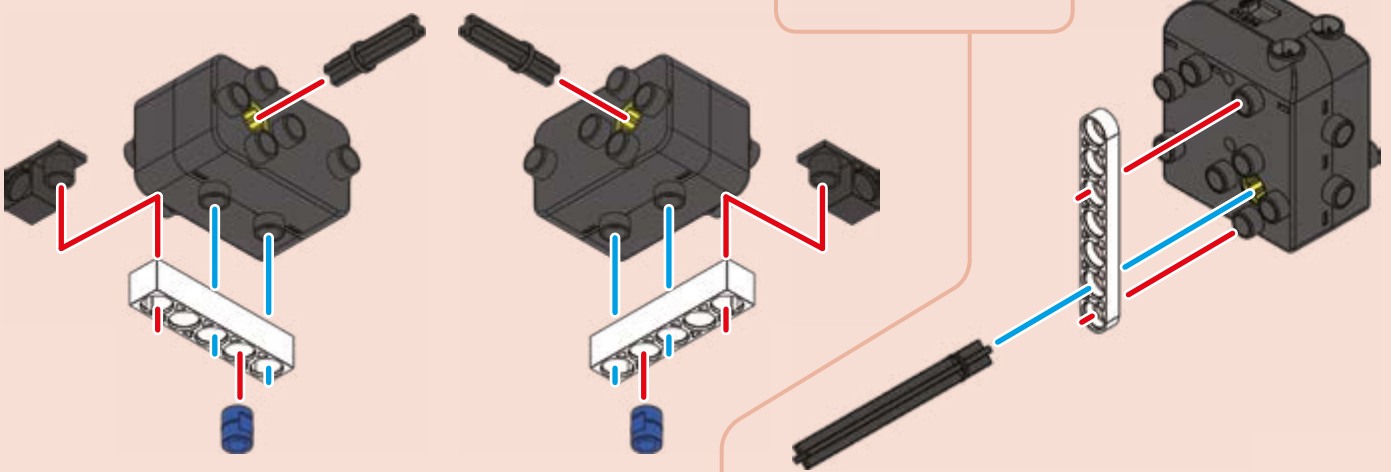
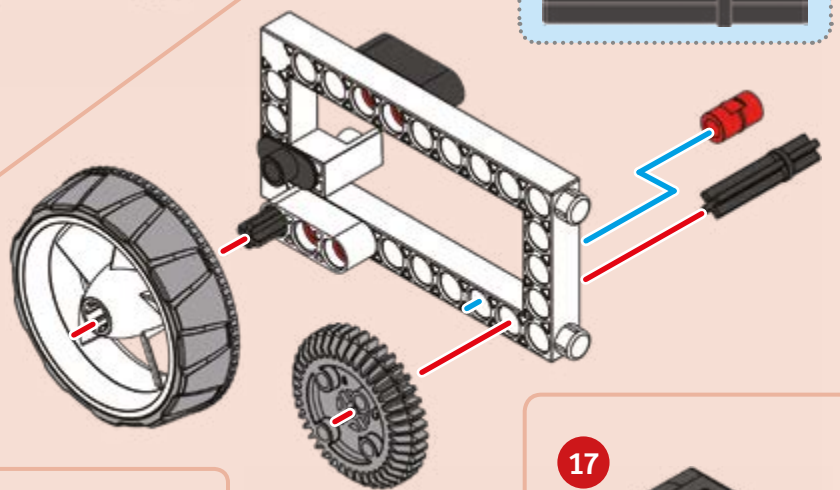
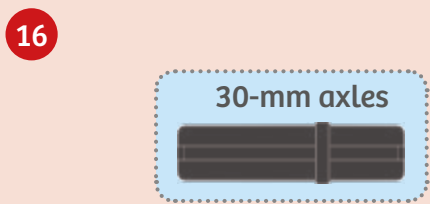
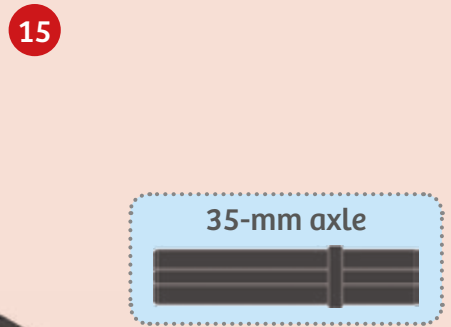
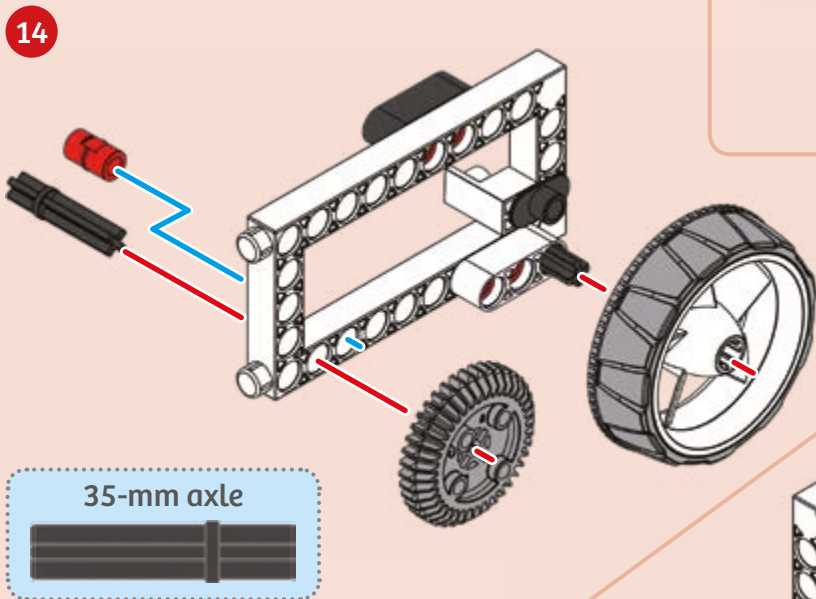
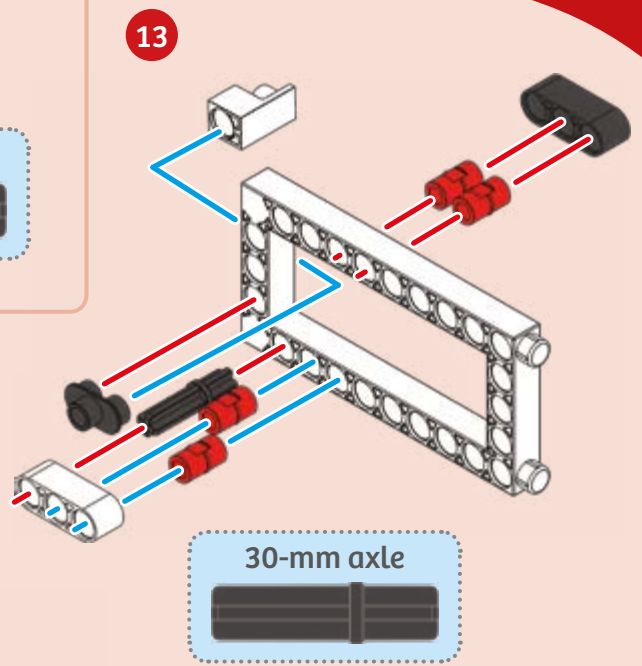
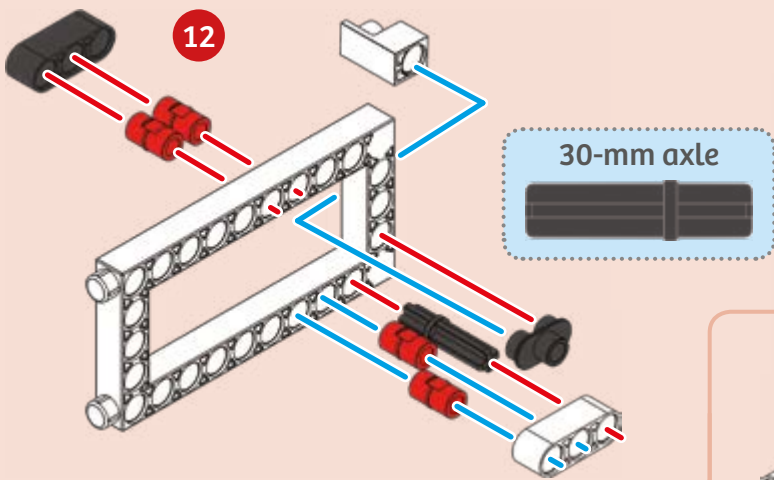


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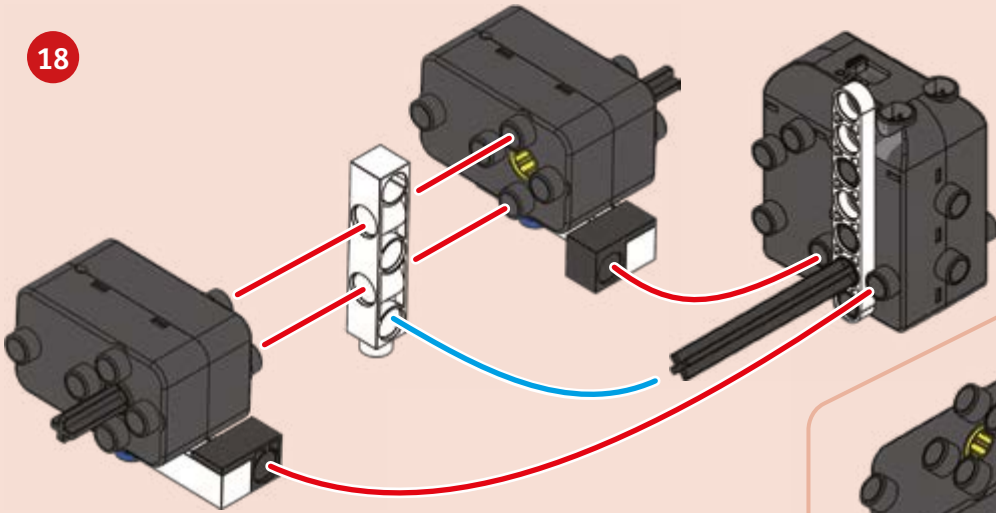




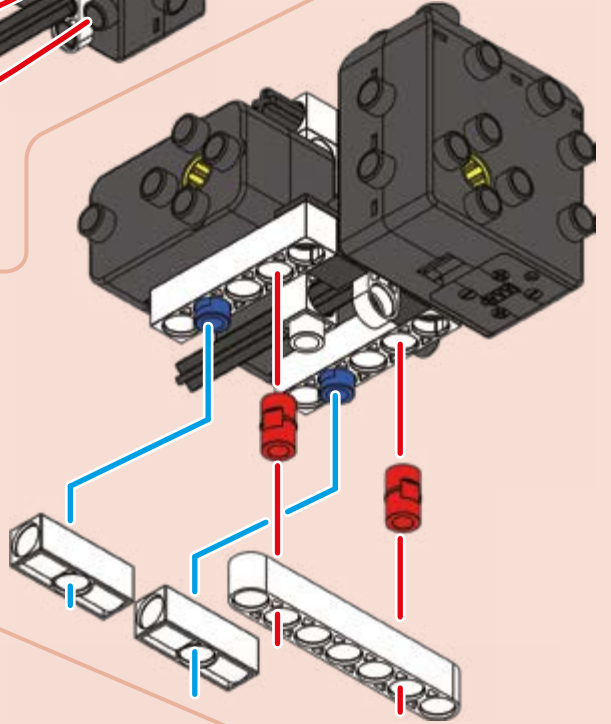




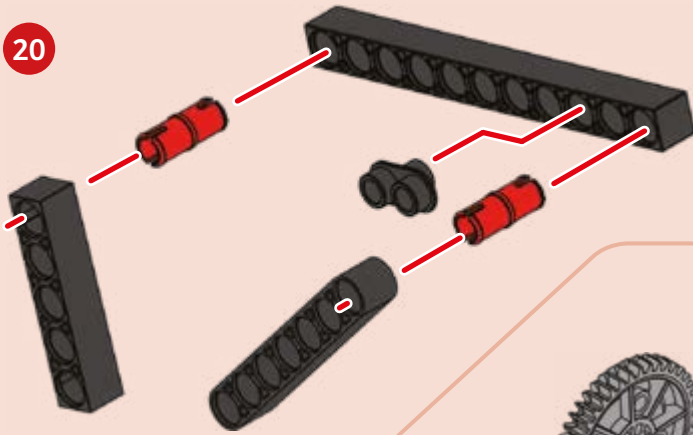
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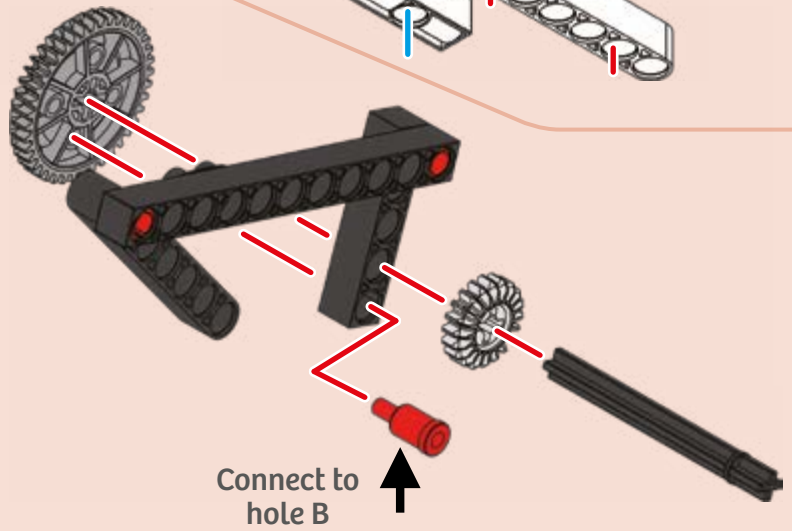
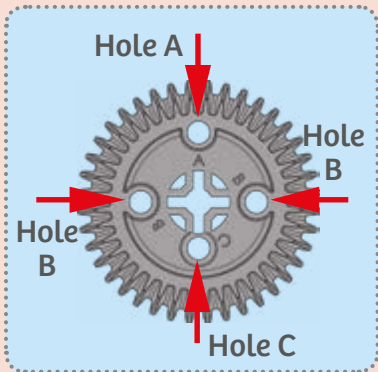
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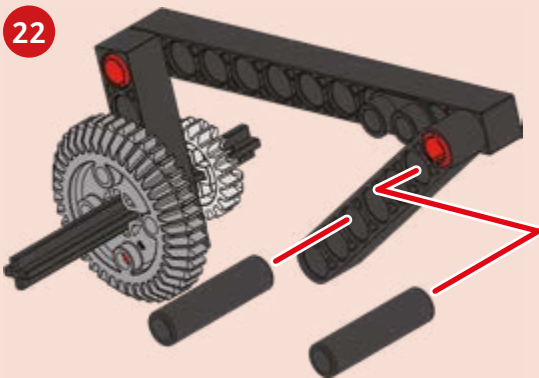
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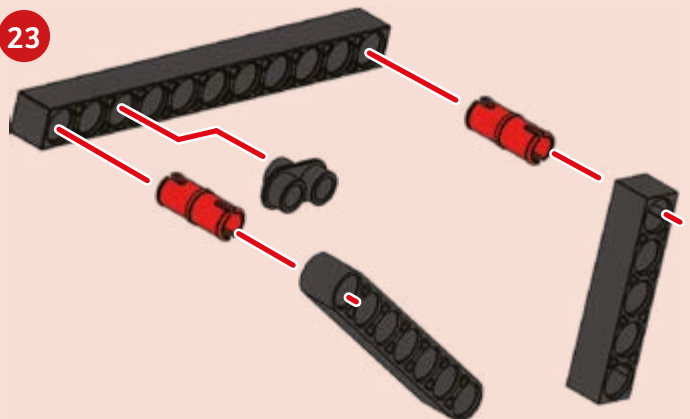
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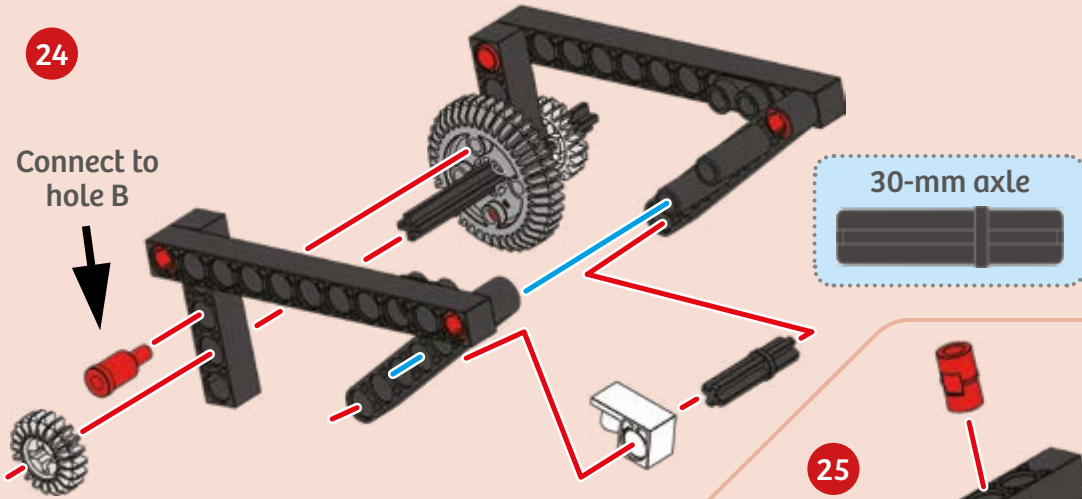
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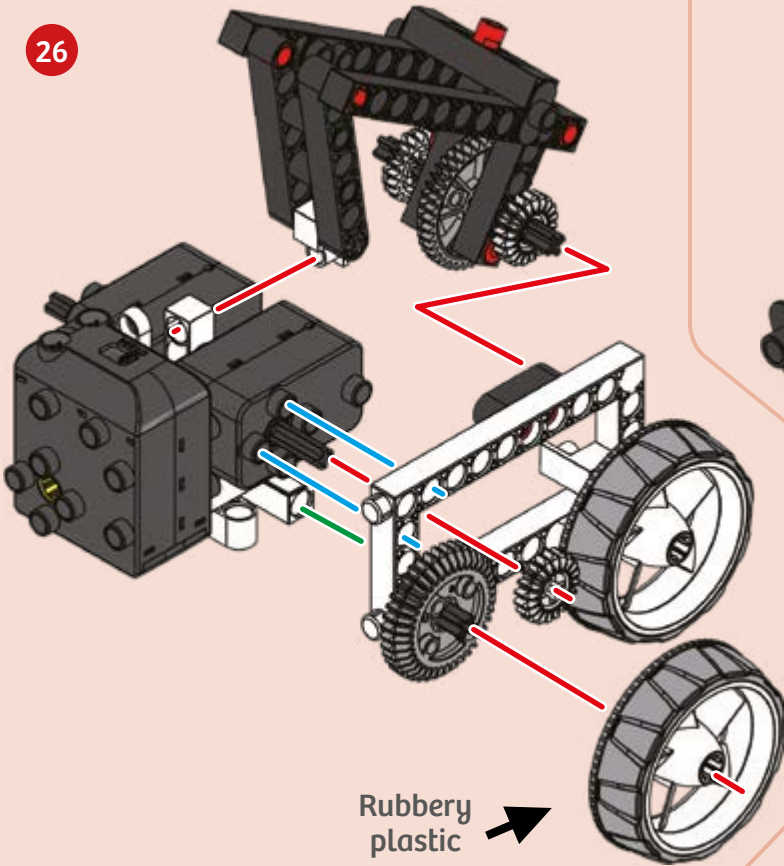
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Connect to hole B

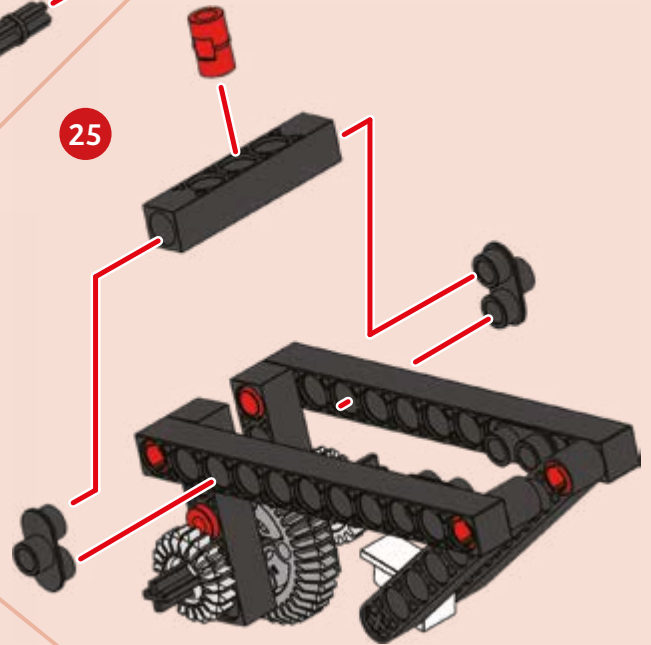
30-mm axle



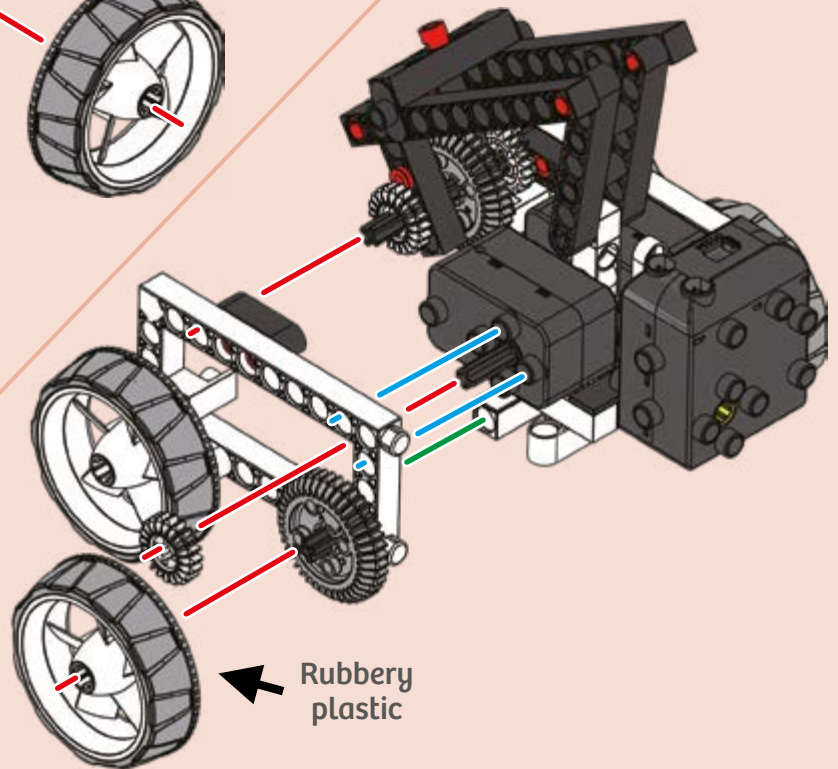
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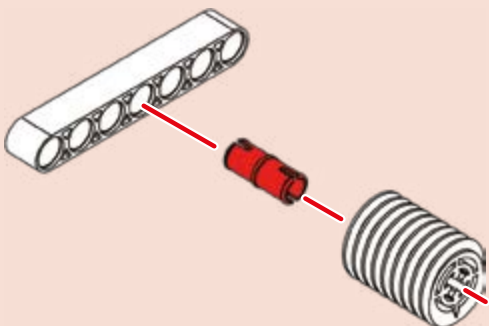
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27



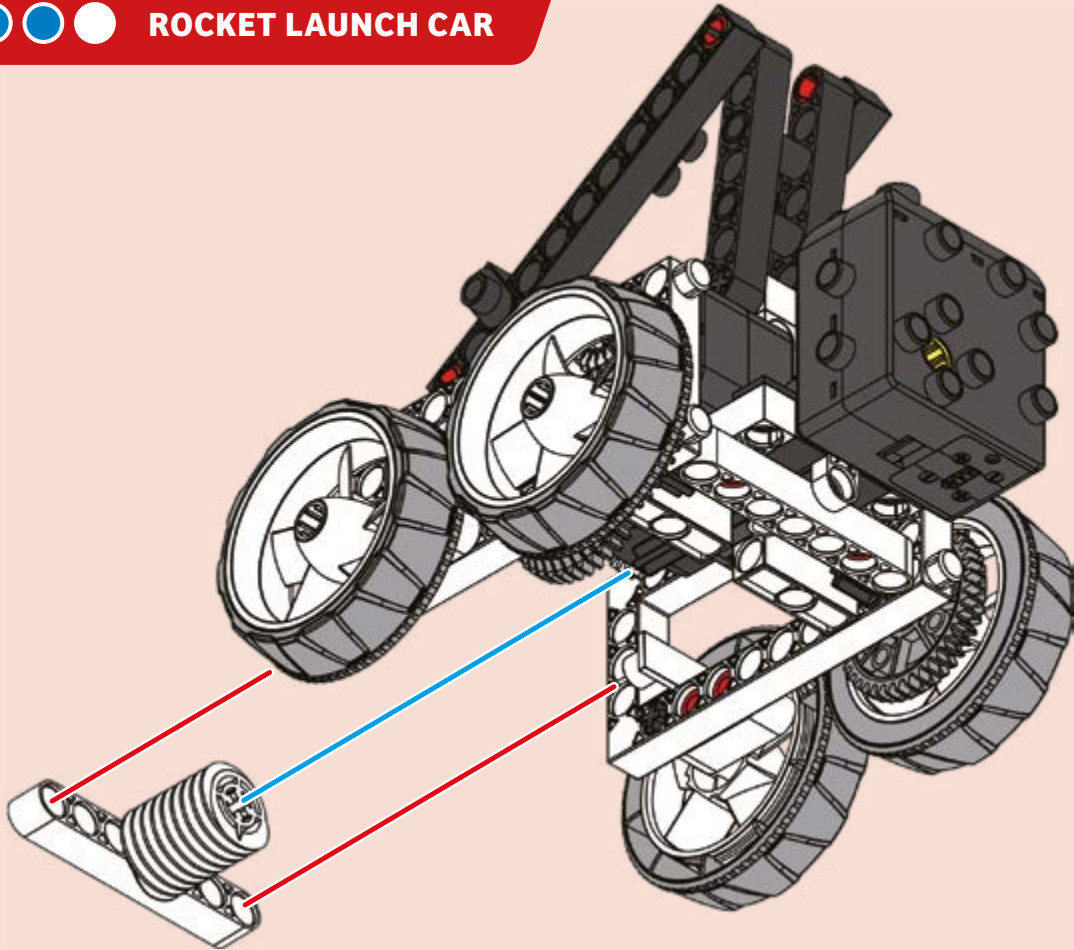
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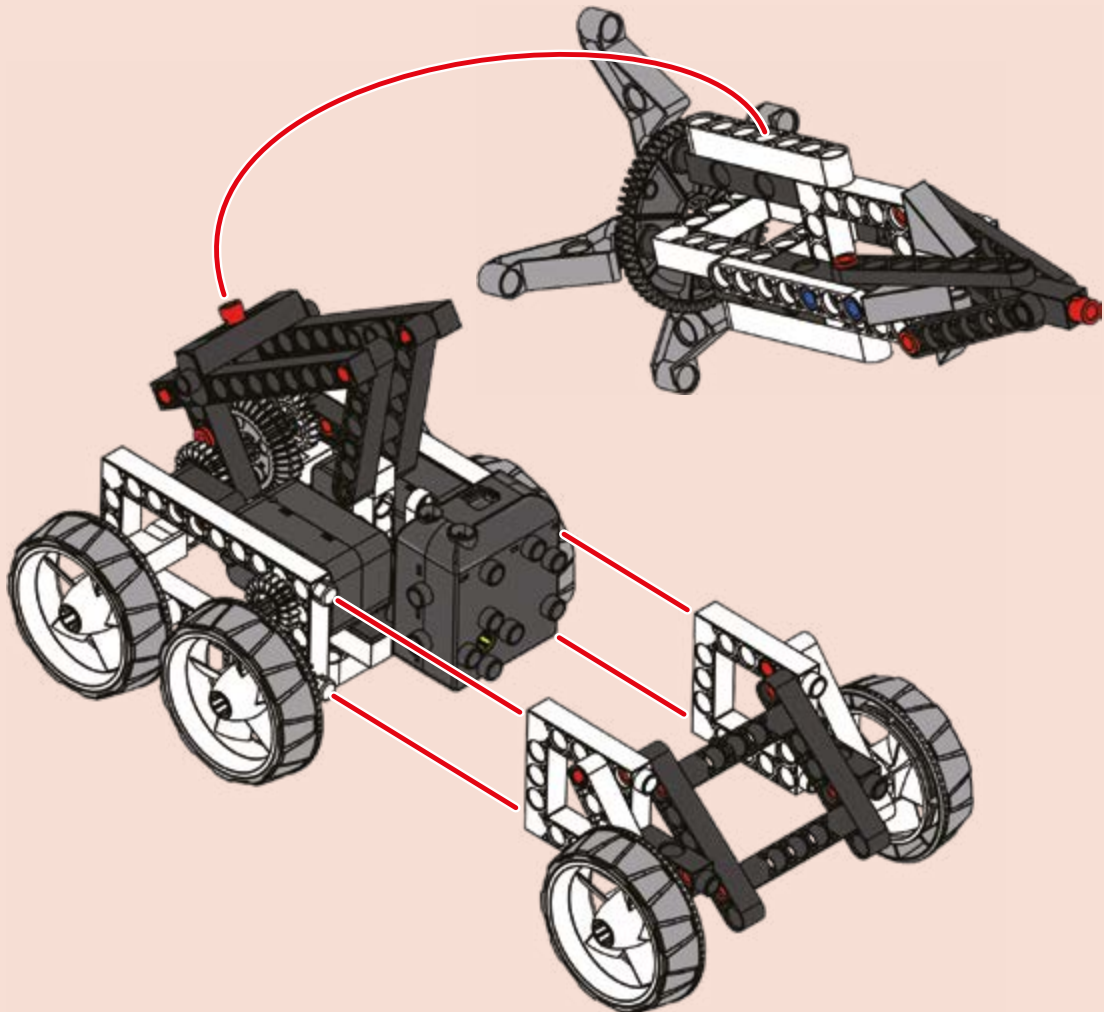




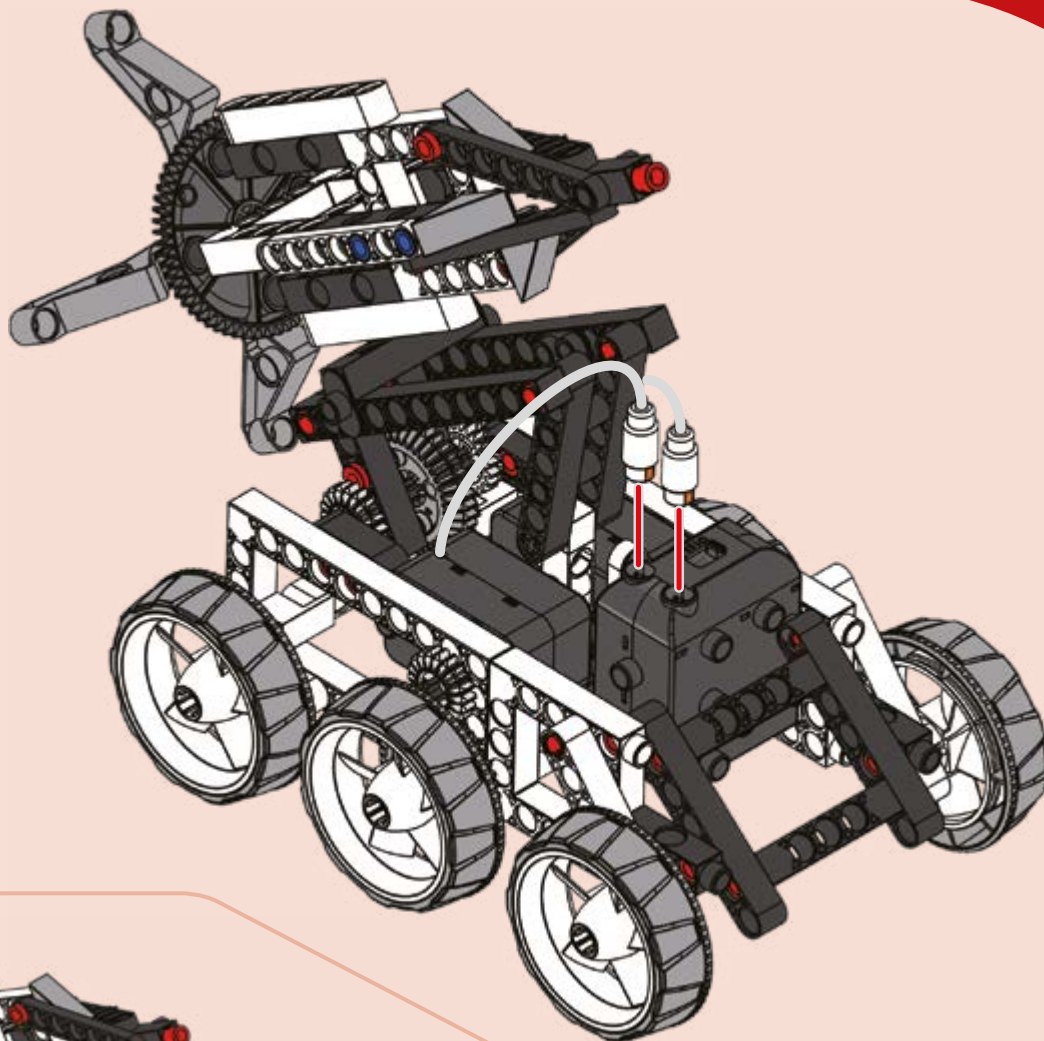
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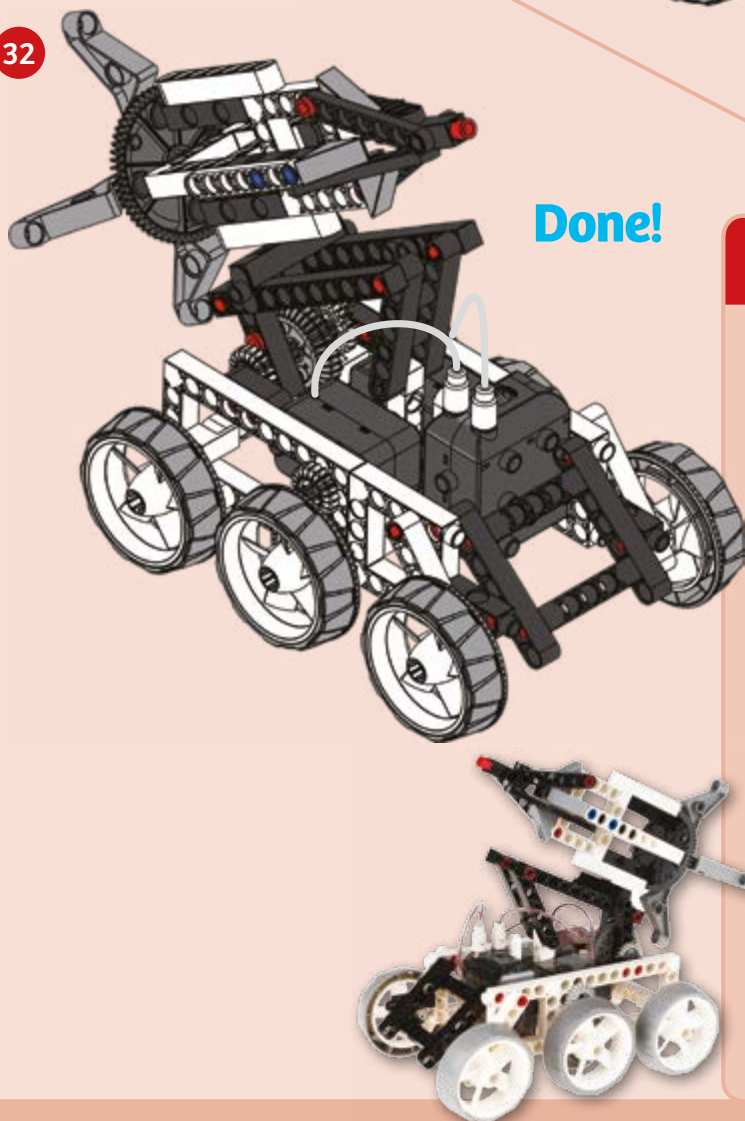
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32



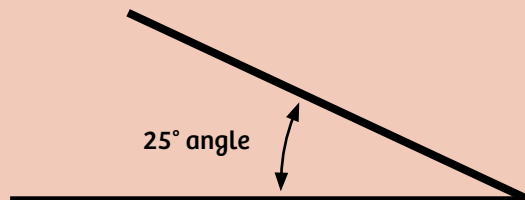
Done!

### EXPERIMENT 5

## Aiming high

### HERE'S HOW

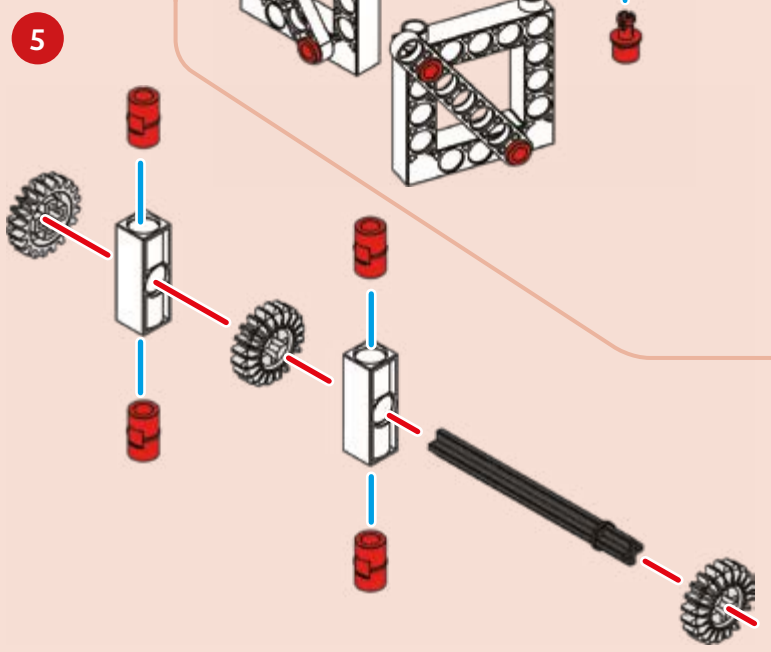
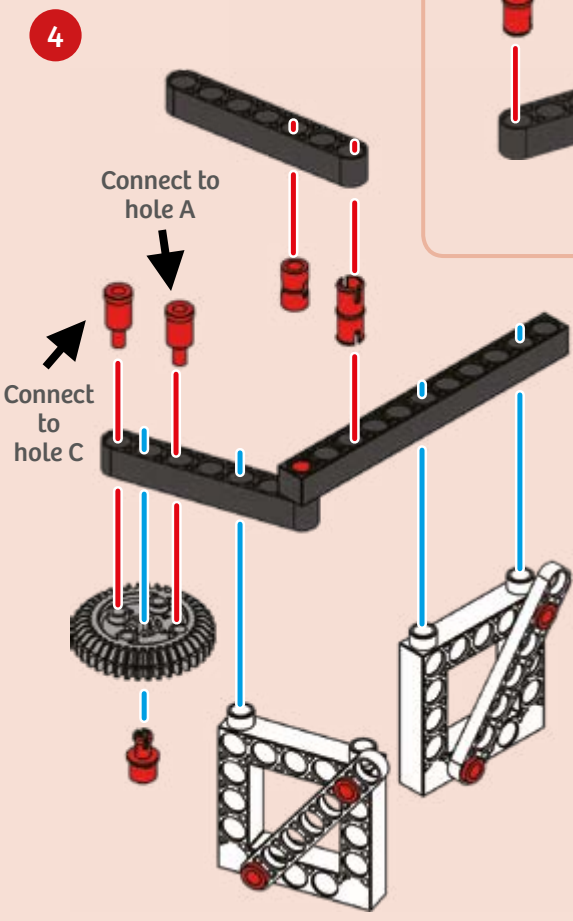
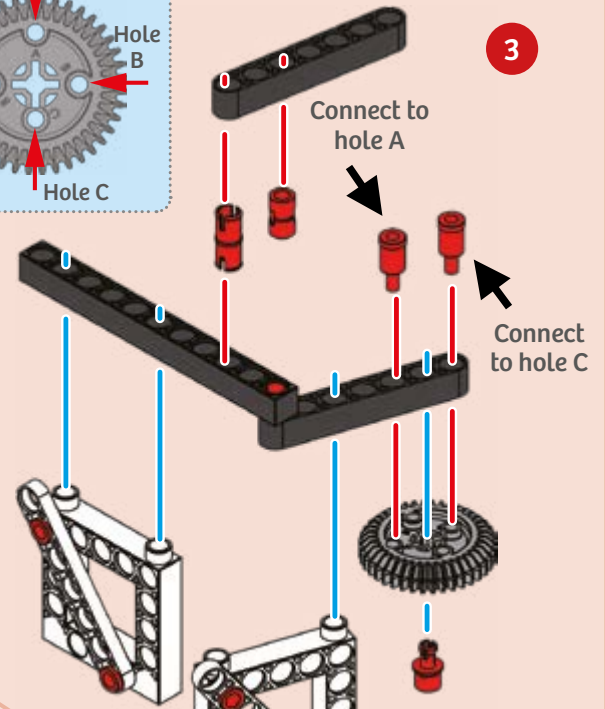
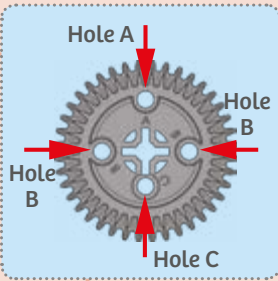
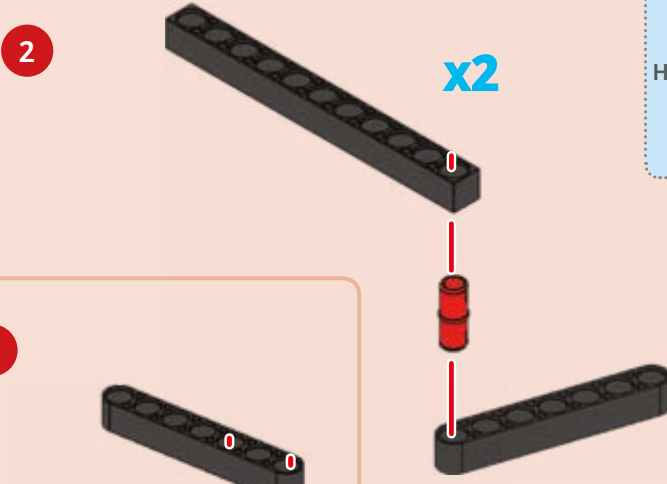
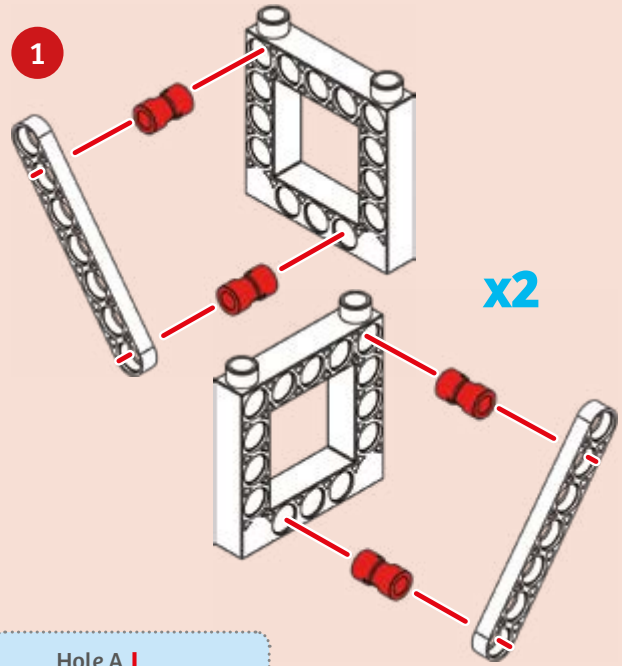
As the operator of this rocket launch car, it's your job to get this rocket, which is carrying a scientific probe, into space. Mission control has given you specific instructions to drive the rocket launch vehicle two meters forward and then position the rocket at a 25-degree angle to prepare it for blast off. Can you measure out two meters and drive the car into position? Can you then angle the rocket at a 25-degree angle? Measure it with a protractor or compare it to the 25-degree angle printed here.



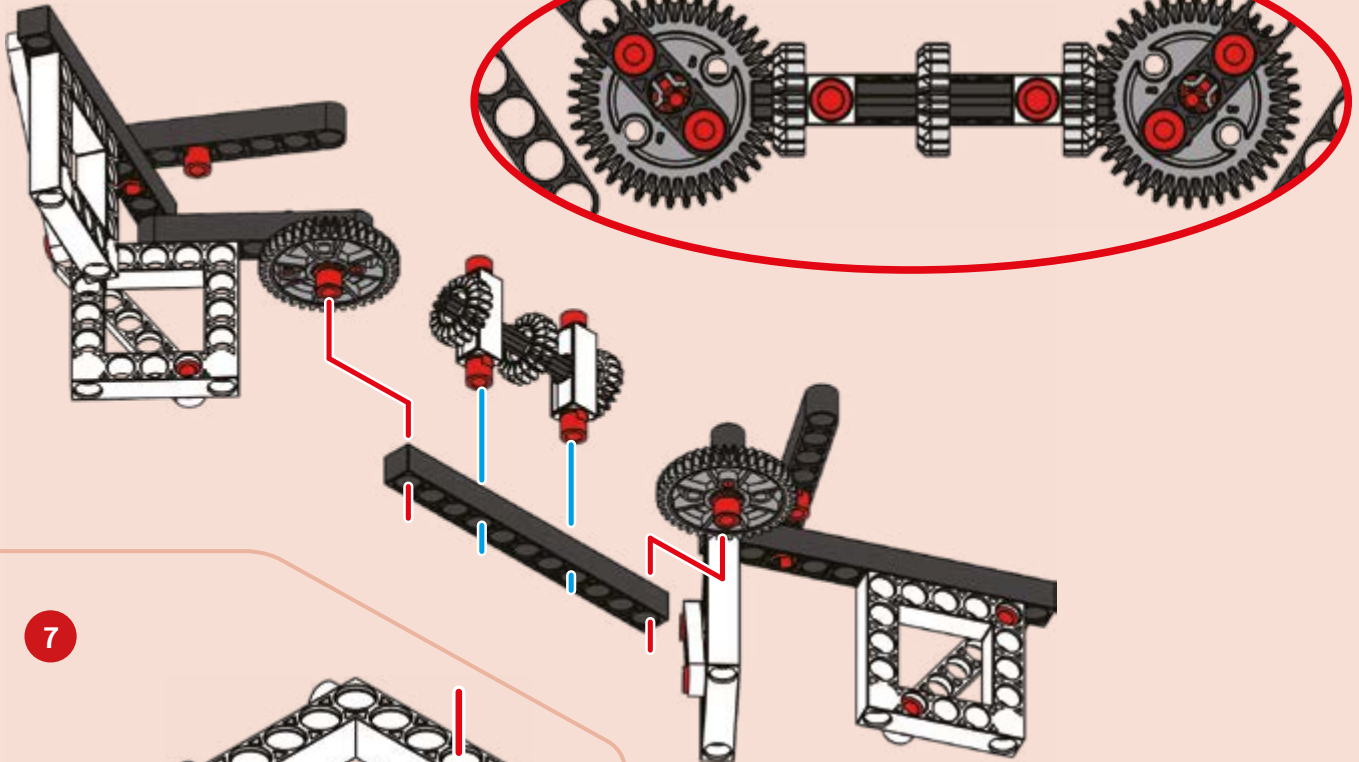




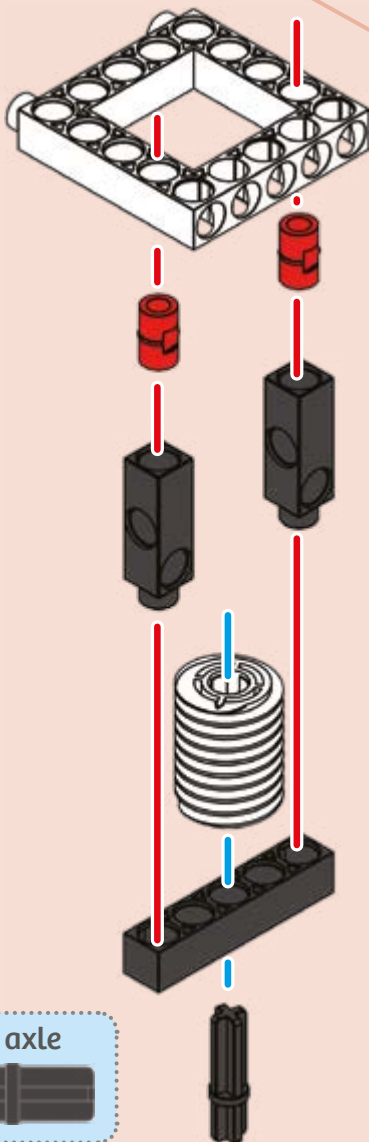
- |    |    |    |     |    |    |    |    |
|----|----|----|-----|----|----|----|----|
| 1  | 3  | 4  | 6   | 7  | 11 | 12 | 13 |
| 6x | 2x | 4x | 3x  | 4x | 5x | 2x | 2x |
| 14 | 16 | 17 | 19  | 20 | 21 | 23 |    |
| 2x | 4x | 4x | 3x  | 4x | 3x | 1x |    |
| 25 | 26 | 28 | 30  | 33 | 36 | 38 | 39 |
| 1x | 4x | 1x | 2x  | 2x | 5x | 1x | 1x |
| 40 | 42 | 44 | 45  | 49 | 50 | 51 | 52 |
| 1x | 2x | 2x | 32x | 2x | 1x | 1x | 1x |



6



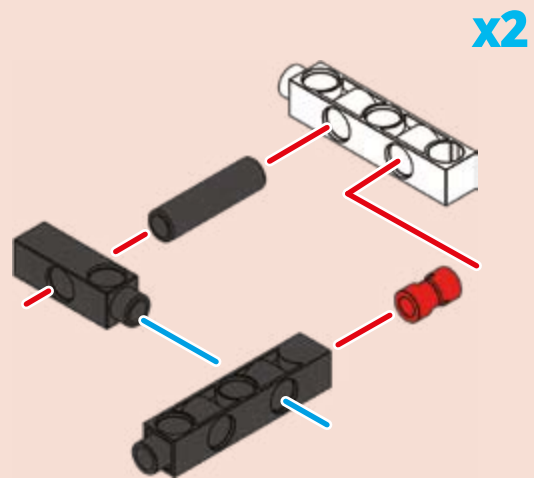
7



30-mm axle



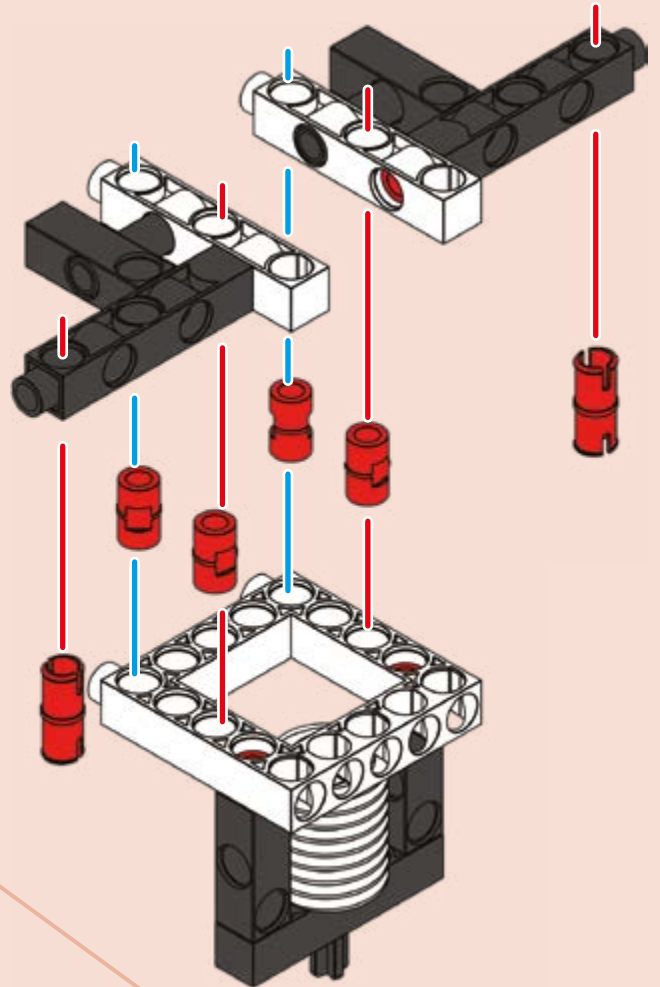
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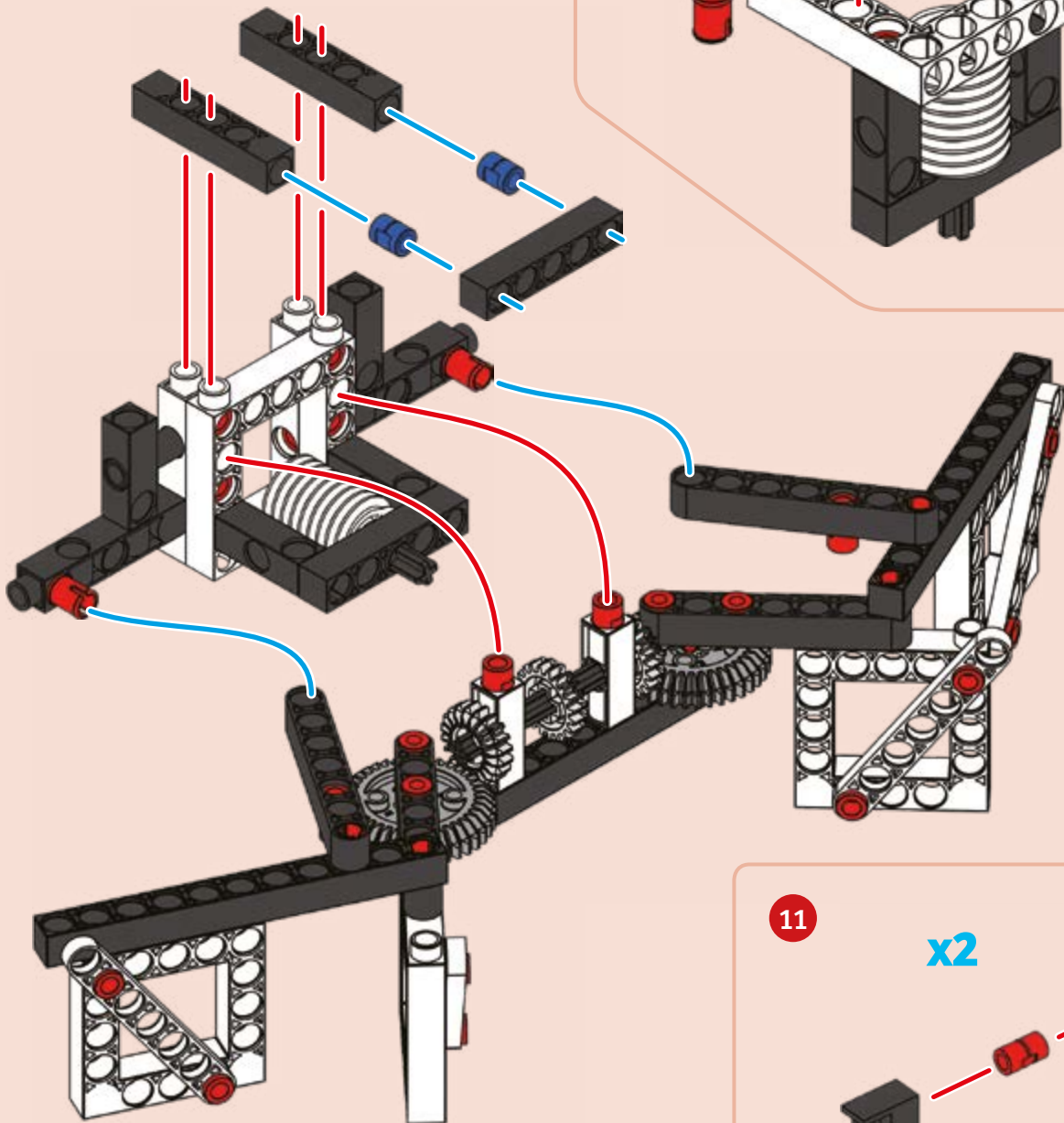




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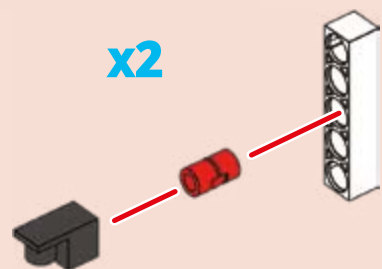


10



11

x2

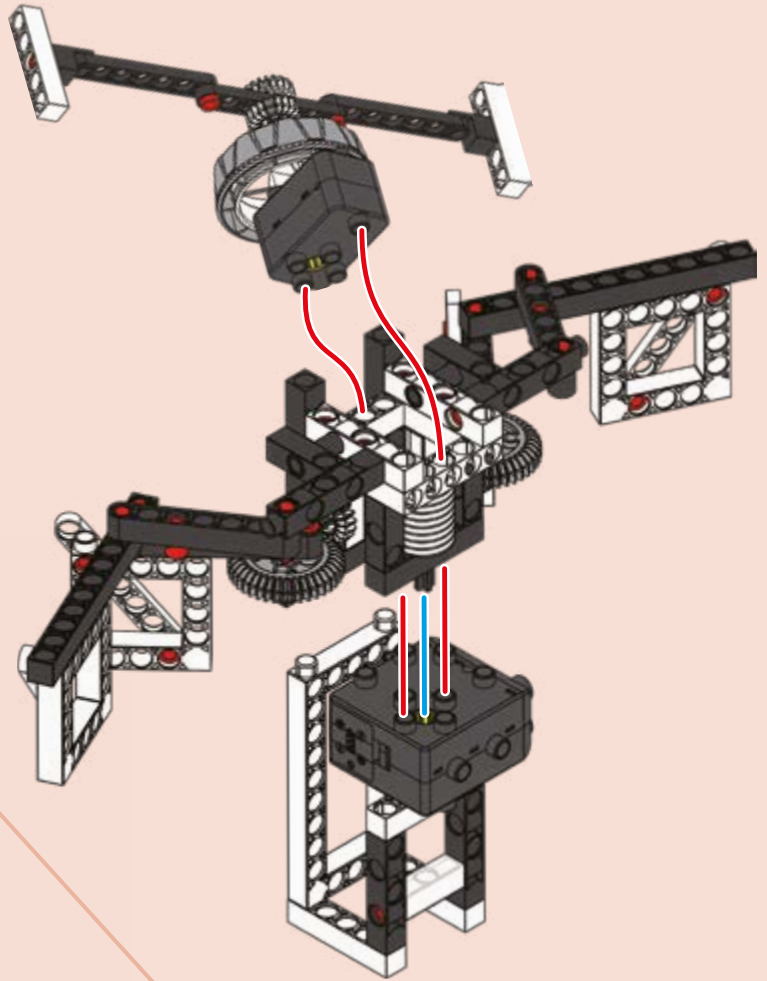




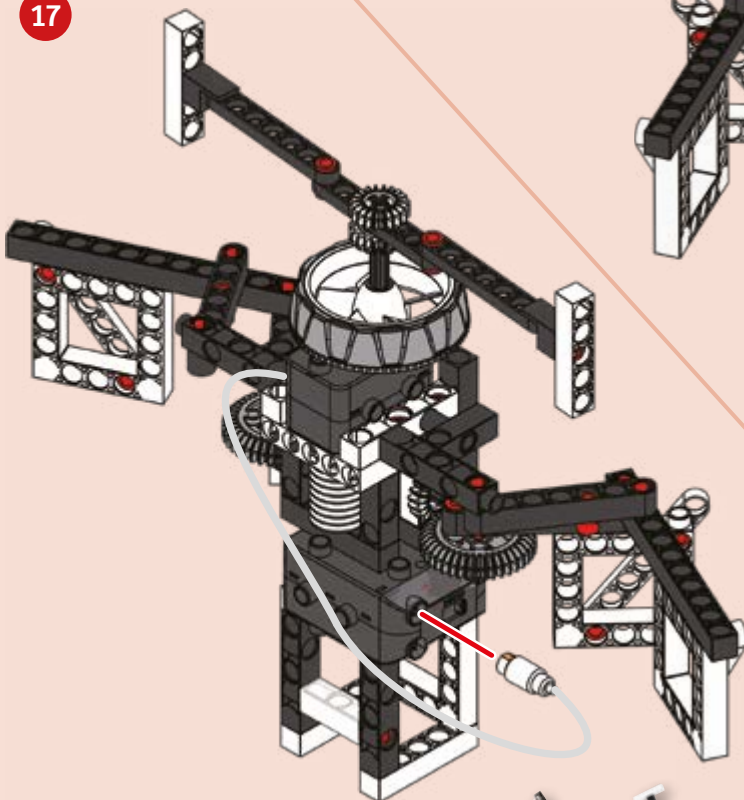




16

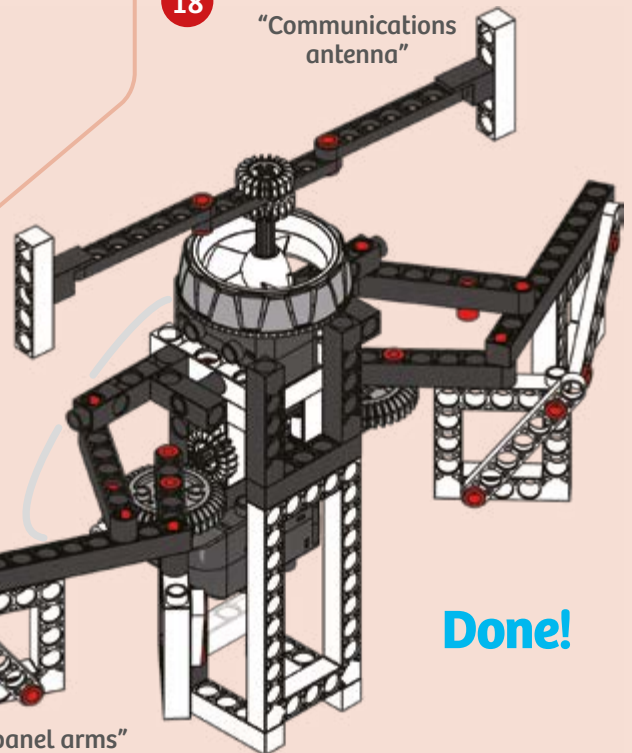


17



18

"Communications antenna"



## EXPERIMENT 6

# Searching far and wide

### HERE'S HOW

Pretend you are a NASA scientist. Your space probe needs to be deployed on a mission to travel far away from Earth and photograph planets as it passes by them. Once it is in space, it has "solar panel arms" that need to be deployed and a "communications antenna" that needs to be set spinning. Can you do it?

# Traveling Through Endless Space

A satellite is an artificial spacecraft. This kind of attendant — which is the literal meaning of the Latin word — orbits around a heavenly body such as a planet or a moon.

Satellites that orbit Earth are known as Earth satellites. Sputnik 1 (1) was the first artificial Earth satellite. Artificial satellites that orbit and study bodies other than the Earth are called orbiters.

A space probe, on the other hand, is an unmanned spacecraft sent into space for the purpose of exploration.

Most fly toward a distant goal in space such as the planet Mars, asteroids, comets, or the moons of Jupiter. Some explore the space between planets.

Supplying the satellite with electrical power (energy) is usually accomplished with solar cells and back-up accumulators or batteries, if just short periods of use are planned. Satellites that are going to move farther away from the Sun can't rely on solar energy. In that case, an atomic battery supplies the power.

## LUNA 2 MARKS THE START

Luna 2 (2) was the very first man-made spacecraft to land on another body. It struck the moon's surface in a targeted collision on September 13, 1959. Luna 2 was a mission of the Soviet Union, the name for Russia at the time.

Voyager 2 (3) was a NASA space probe designed to explore the outer planetary system. It was launched on August 20, 1977 from Cape Canaveral.

## OVER 15 BILLION KILOMETERS FROM EARTH

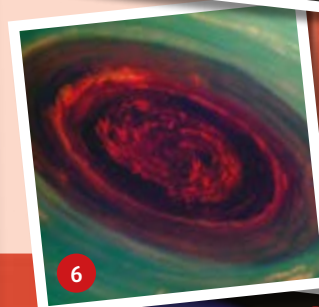
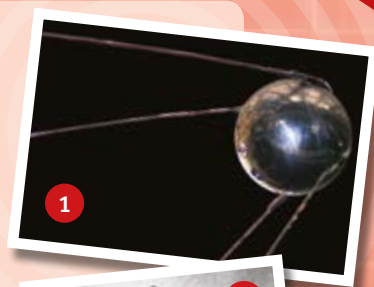
The Voyager 2 mission counts as one of the greatest successes of NASA, and of space travel in general. It continues to transmit data regularly to Earth. In addition, it is the second-farthest man-made object from Earth (after its sister probe, Voyager 1, which actually launched after Voyager 2 but moved faster). The distance of Voyager 2 from the Sun was 15.74 billion km on July 1, 2014.

## COULD WE LIVE SOMEWHERE ELSE IN SPACE?

The space probe Galileo (4) was launched by NASA on October 18, 1989 for the purpose of exploring Jupiter and its moons. It got its name from the Italian inventor and scientist Galileo Galilei. NASA's Kepler (5) space observatory was named after a great researcher as well: the German astronomer Johannes Kepler. He was the first to recognize the laws of planetary orbits. The Kepler spacecraft was launched in 2009. Just like the Galileo probe, one of Kepler's missions is to search for extrasolar planets (exoplanets) — planets like ours, in other words, that might be capable of sustaining life in other solar systems.

On February 2, 2011, NASA announced that 1235 planetary candidates had been identified since the start of the mission. Many others have been added since then.

Space probes have given us some very cool images of planets we could never get from here on Earth! A swirling storm on Saturn (6) and Neptune (7).

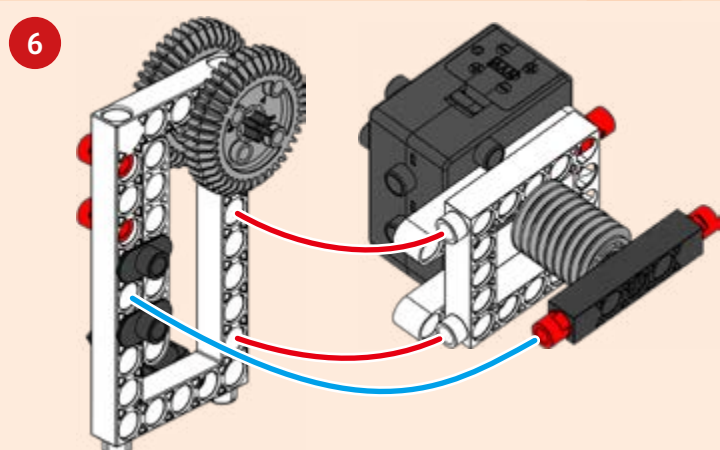
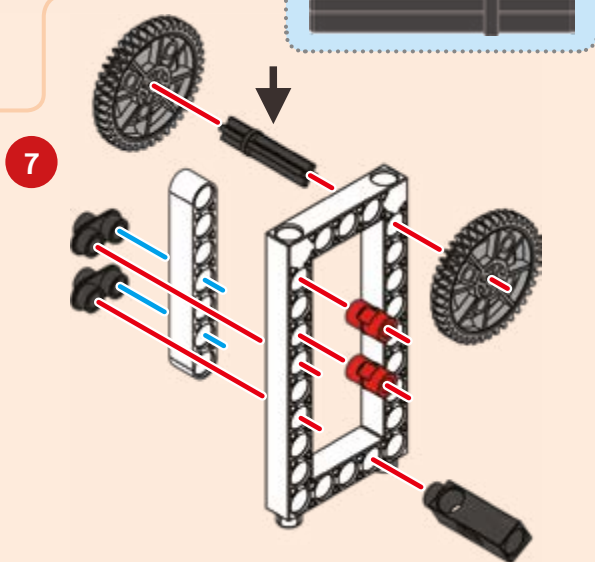
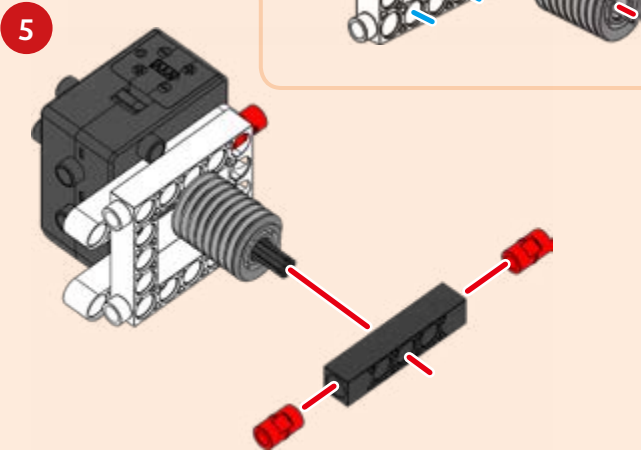
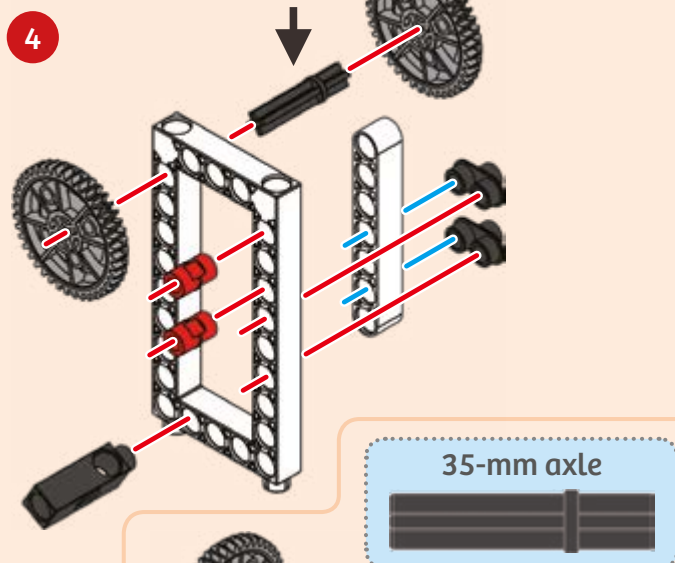
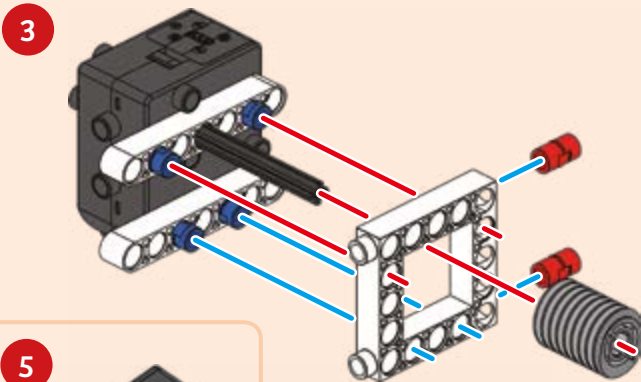
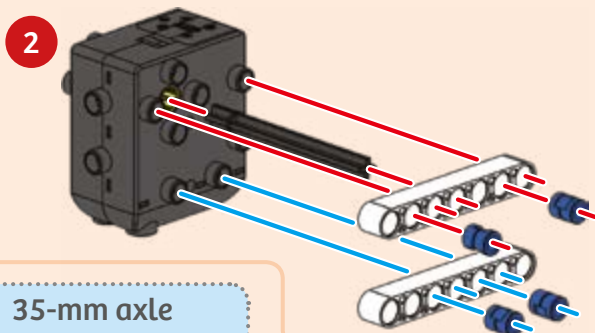
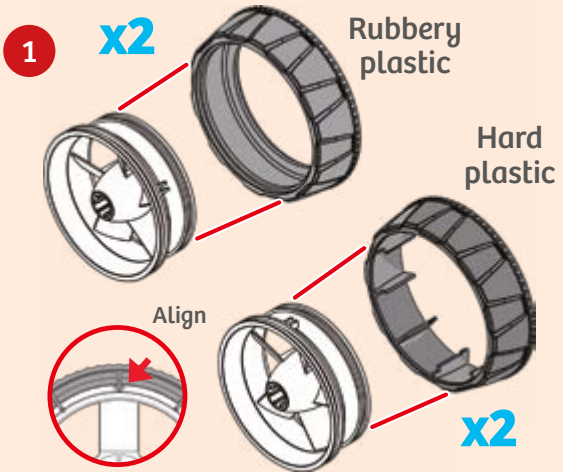




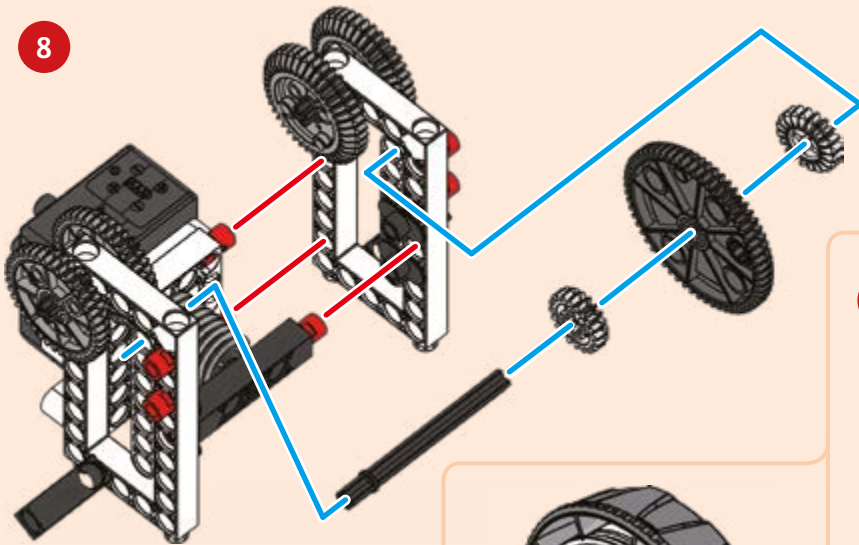


# SPACE DROID

1	4	7	8	9	11	12	13	16	
6x	4x	2x	2x	2x	2x	1x	3x	2x	
17	18	20	21	22	23	24	25	26	
2x	4x	6x	4x	4x	2x	2x	1x	4x	
28	29	30	33	34	36	37	38	39	40
6x	4x	2x	2x	4x	10x	1x	1x	6x	2x
41	42	44	45	46	49	50	51	52	
2x	1x	6x	27x	9x	4x	2x	1x	1x	

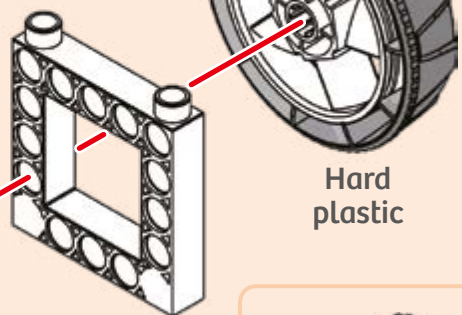


8



9

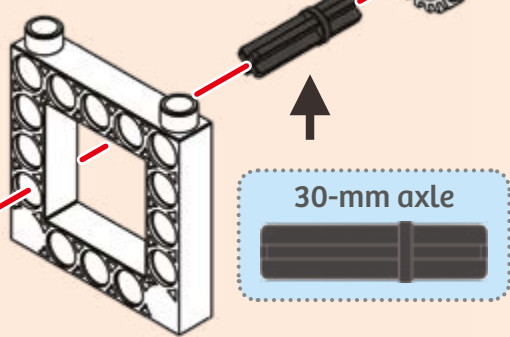
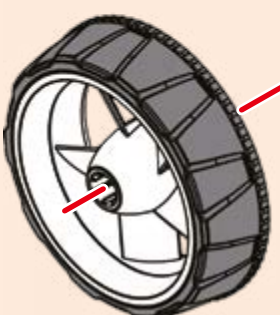
30-mm axle



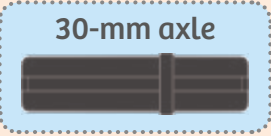
Hard plastic

10

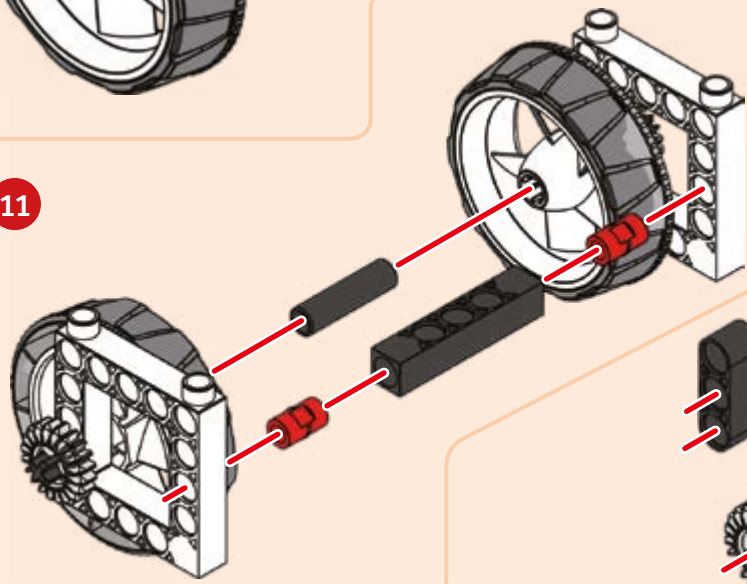
Hard plastic



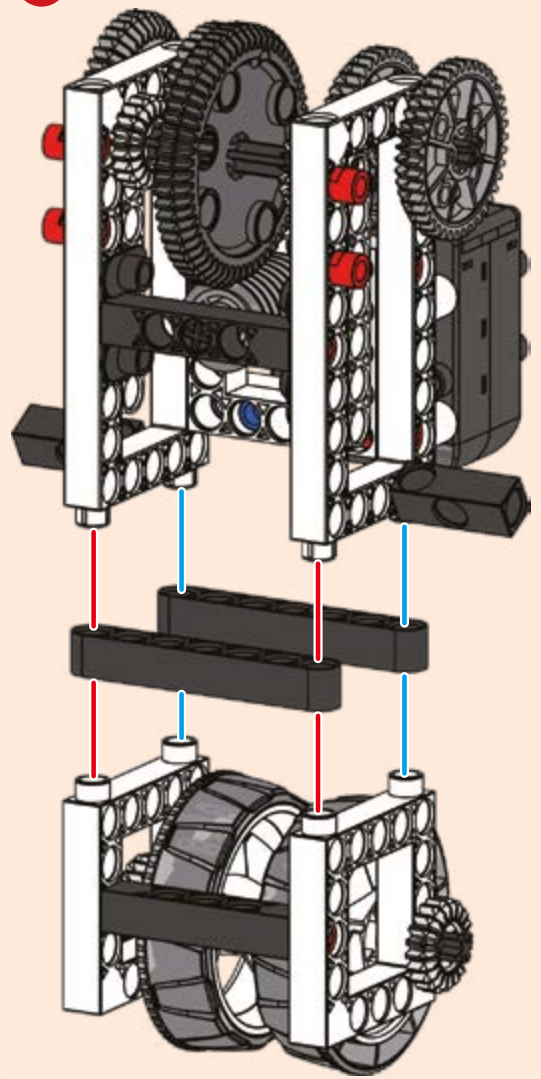
30-mm axle



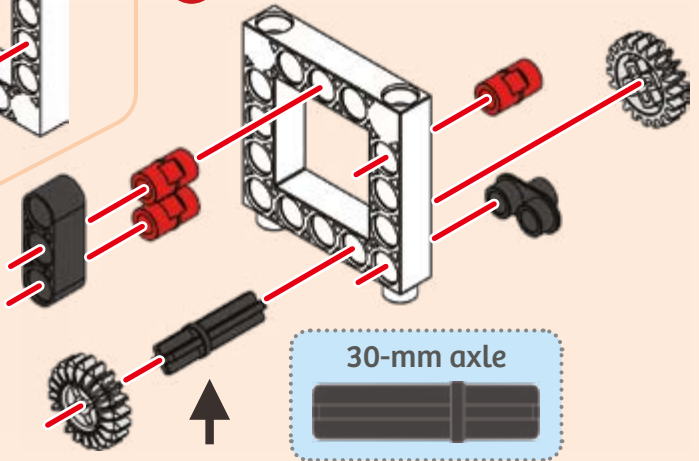
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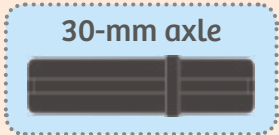
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13



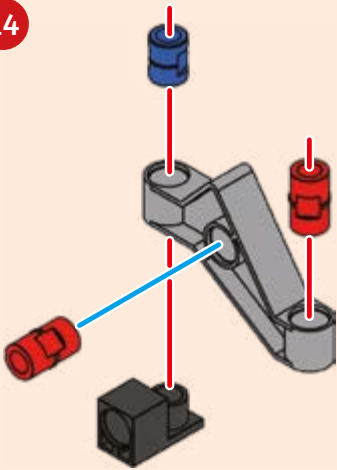
30-mm axle



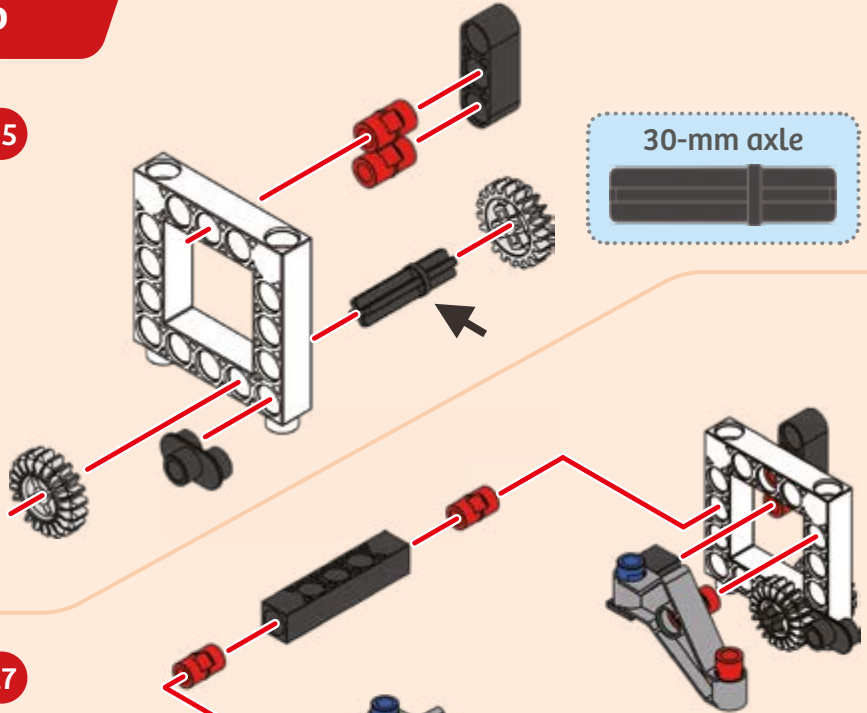




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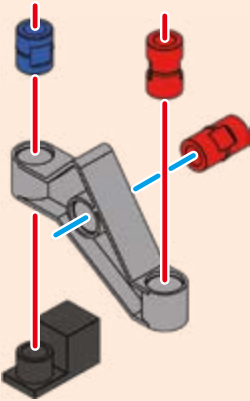


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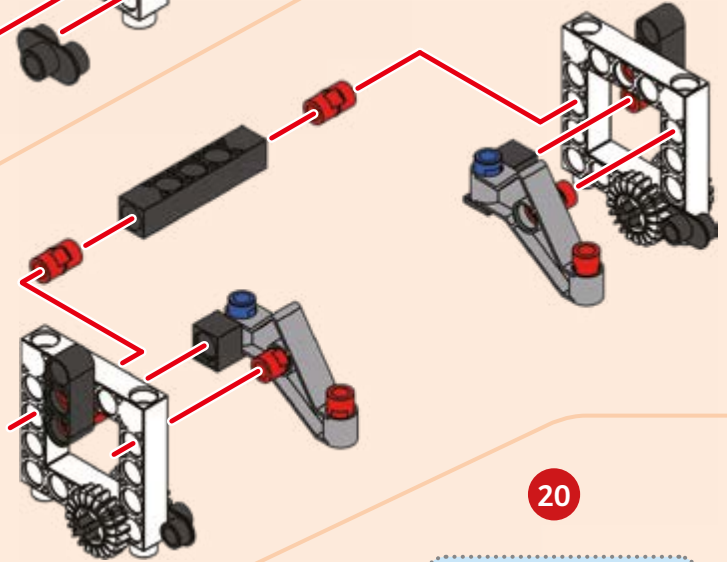


30-mm axle

16



17

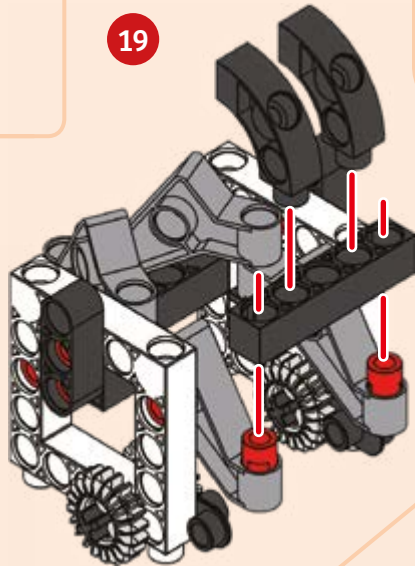


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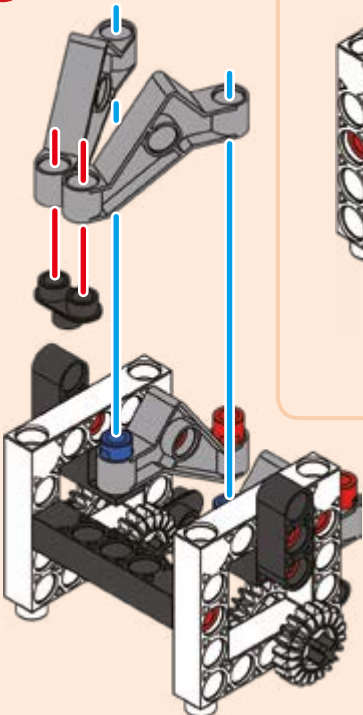
30-mm axle

x2

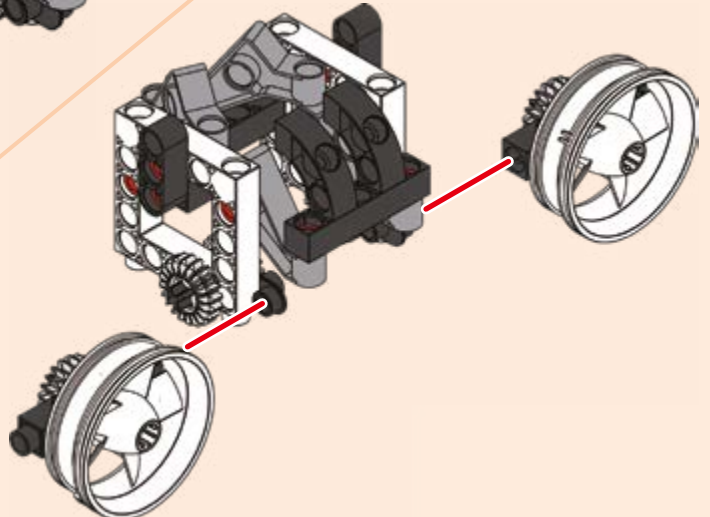
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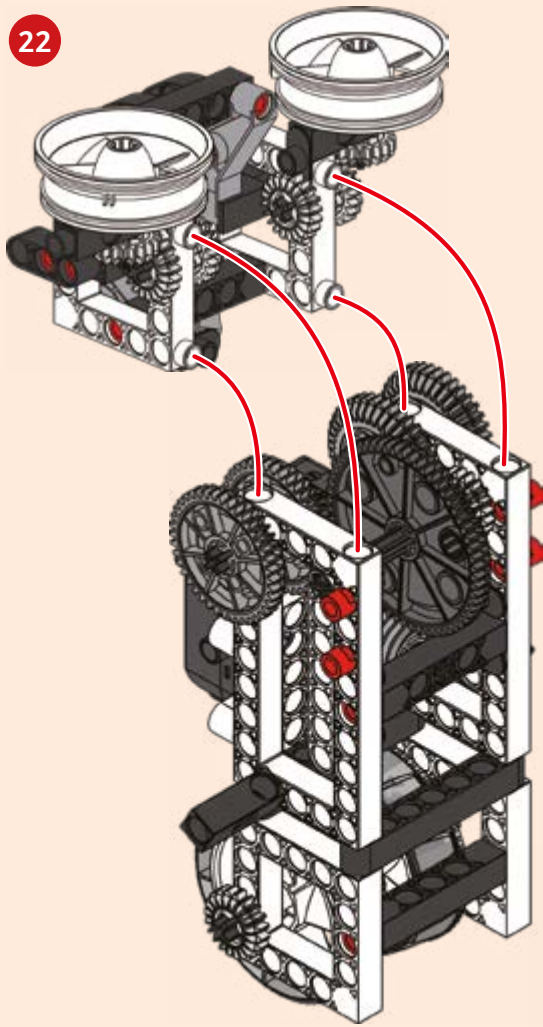
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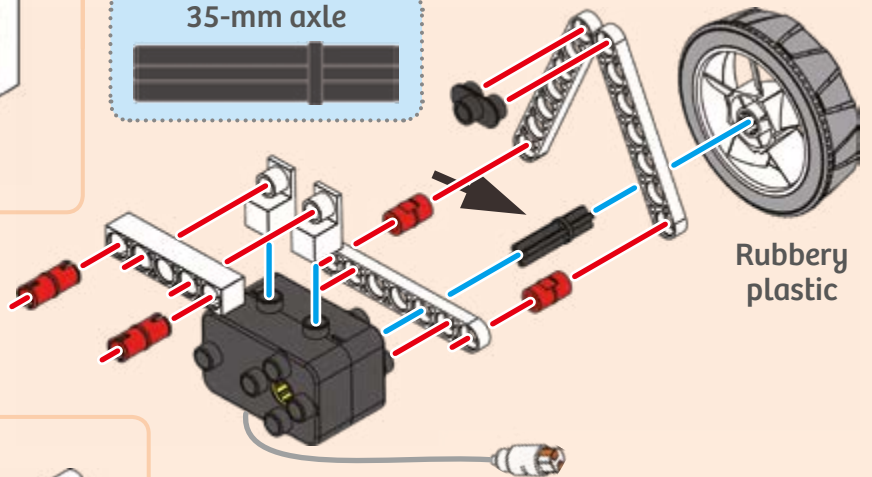
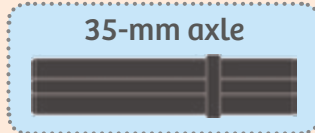
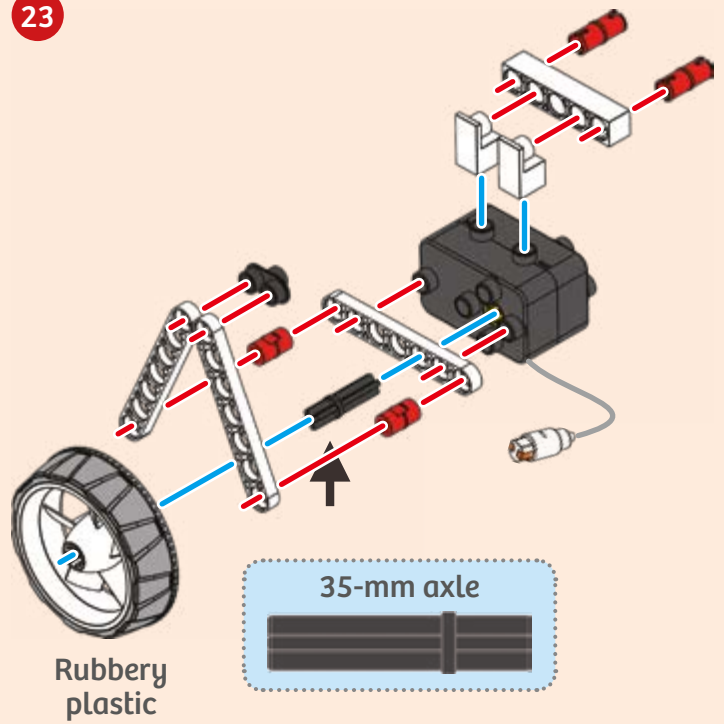
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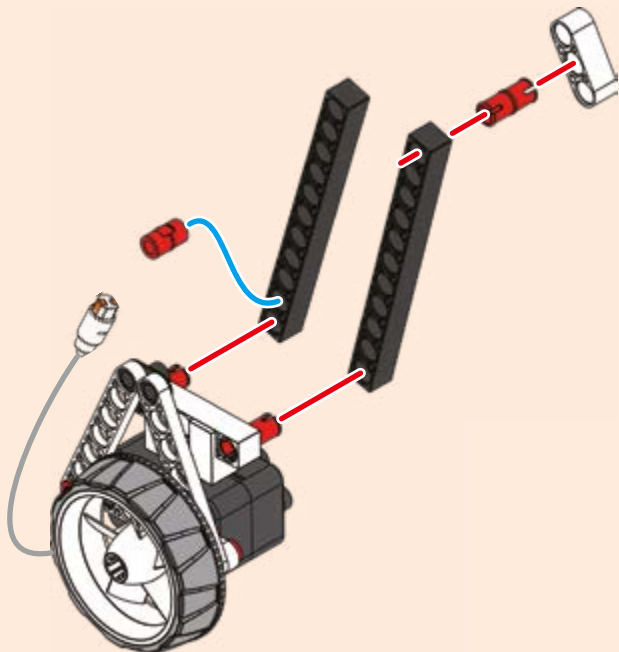
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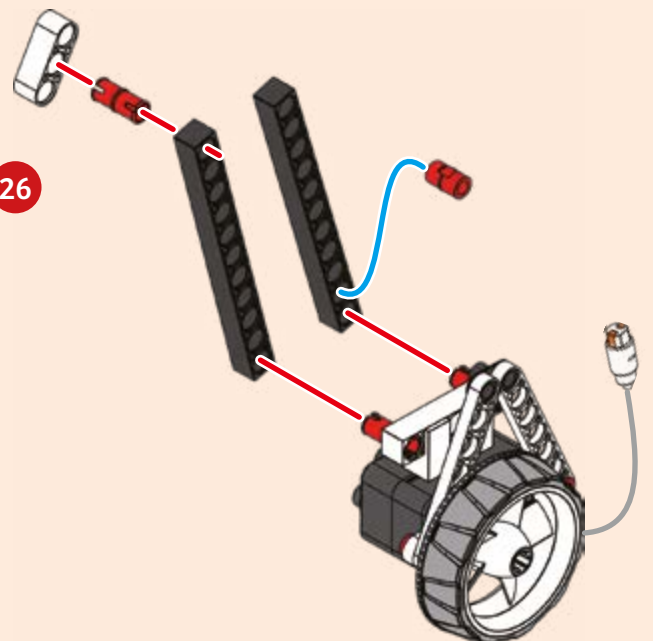


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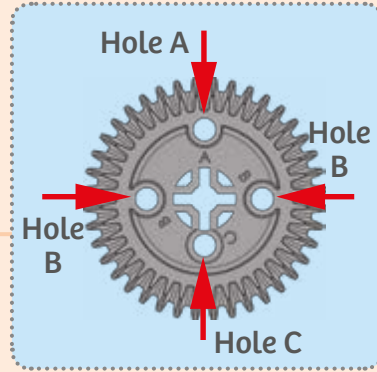
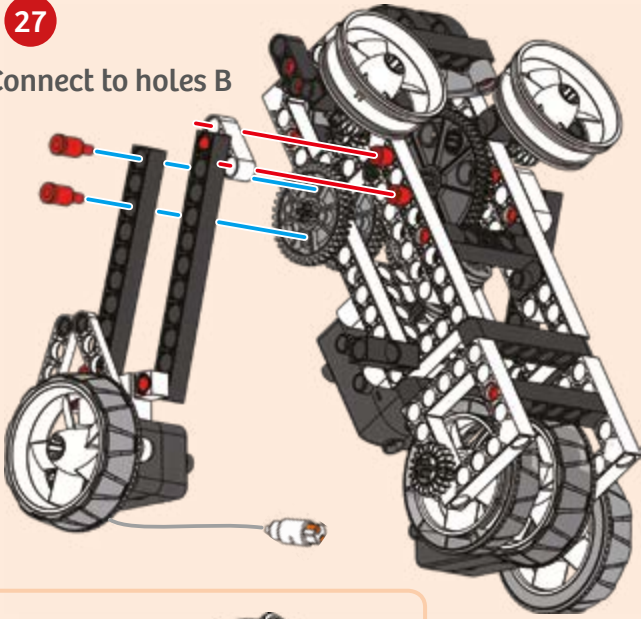






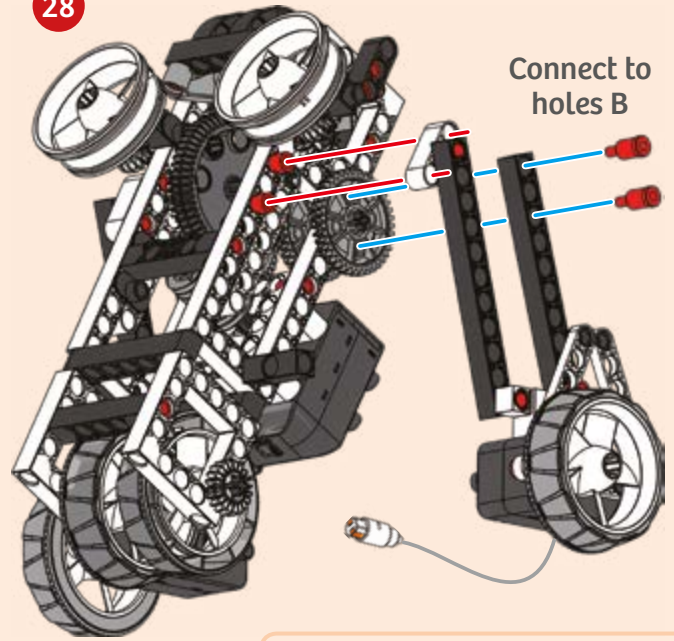
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Connect to holes B

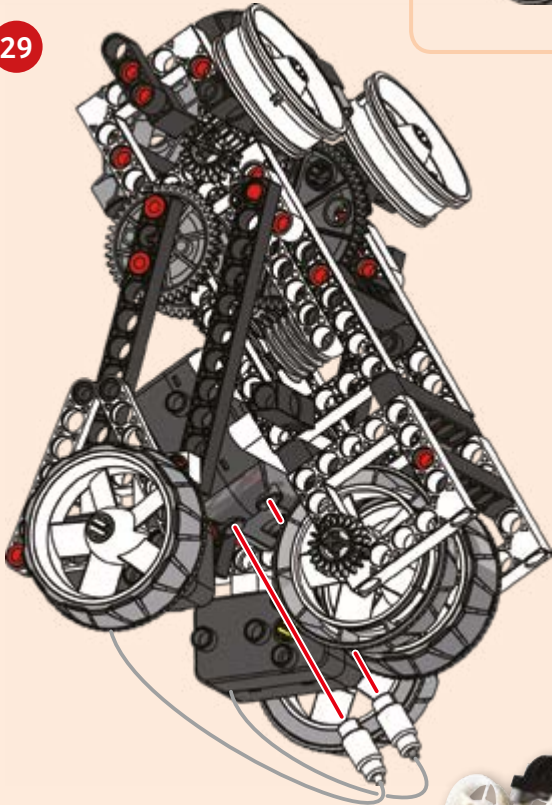


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Connect to holes B

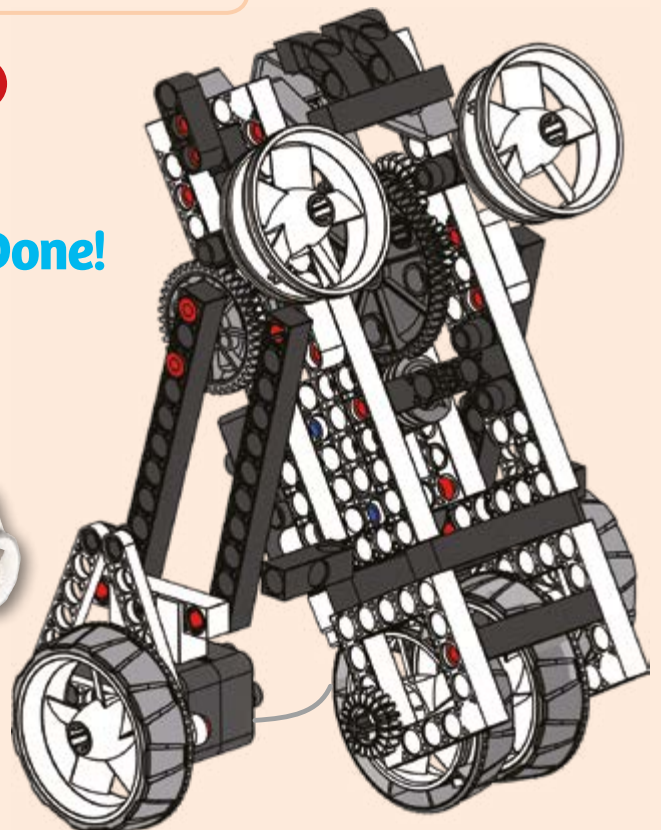


29



30

Done!

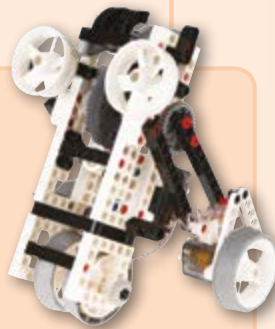


### EXPERIMENT 7

## At your service

### HERE'S HOW

Your personal assistant droid is ready to serve you. Can you control it to move forward and backward in a straight line? Can you control it to turn left and right by only powering one motor at a time? Can you make it stand upright as if to greet a newly discovered alien friend?



## CHECK IT OUT



## The Famous Robots of Hollywood

Droids, or human-like robots, have already existed for a while in the fantasy worlds of science fiction books and movies. Science fiction conceives of worlds in which new technological possibilities and speculations are woven into the story. The stories often take place in the future or far away in space.

Let's take a look at a few of the best-known and coolest examples from the world of science fiction:

### ROBOTS STEAL THE SHOW

Let's start with George Lucas's "Star Wars," which featured two robots who stole the show: C-3PO and R2-D2.

**C-3PO** (1) is a "protocol droid" designed to mediate human-robot interactions. **R2-D2** (2) is a droid designed to repair space ships much as a human mechanic might.

Or how about the garbage robot **WALL-E** (3)? He's the short-statured trash cleaner in the film of the same name. He's also fond of gazing at the starry sky and watching kitschy musicals from the 60s, and falls in love with a robot named **EVE**.

**Gort** (4) is another famous android. He plays an important role in the film "The Day the Earth Stood Still." Not very talkative or athletic, this giant chunk of metal spends most of the time standing around motionless. But he disarms his adversaries at lightning speed with the help of Laser beams, and is able to bring his faithful companion Klaatu back to life.

**Bumblebee** from "Transformers" is an Autobot. He starts by taking the shape of a 1977 Chevrolet Camaro. Later on in the film, he transforms himself into the 2009 version of the same model. That's a pretty versatile robot.

### PRACTICAL, SERIOUS, OR ILL-TEMPERED — ROBOTS CAN BE LIKE THAT, TOO

**Robby** (5) from "Forbidden Planet" would be an asset to any household. Because he obeys Isaac Asimov's Laws of robotics, he cannot do any harm to humans. And his ability to reproduce things can be pretty handy when you've broken the neighbor's window or whatever.

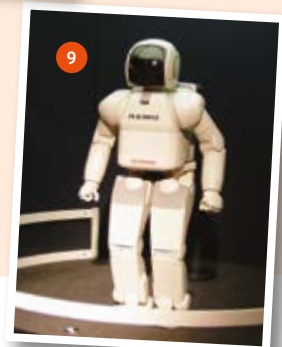
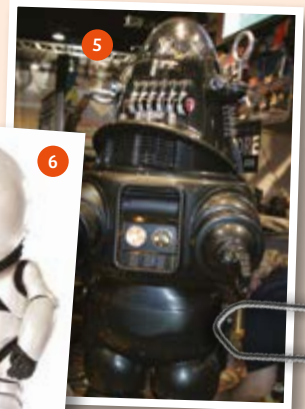
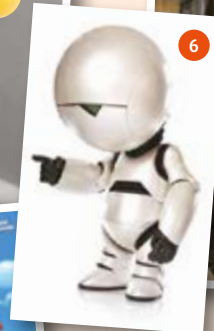
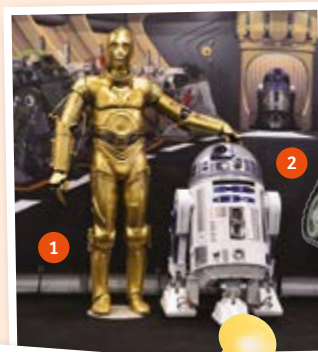
**Number 5** from "Short Circuit," on the other hand, is not just really nice, he's always looking for new input. His boundless curiosity even lets him win over a few (human) hearts.

The life of a robot is no simple thing — at least, that's how **Marvin** (6) sees it. He is the secret hero of "The Hitchhiker's Guide to the Galaxy." Bad moods and headaches are just two of the problems that he always has to contend with. But when the chips are down, he's a cool guy to have around to help you out of a tight spot.

### SINGIN' IN THE OIL

**Rodney** (7) and **Fender** (8) from "Robots" are another comical robotic duo.

Rodney is a young inventor, and Fender is always losing his parts. While the two may not be exactly cool, they are nevertheless rather amusing, such as when Fender covers a classic Gene Kelly tune. His version, of course, is a little different — "Singin' in the Oil."



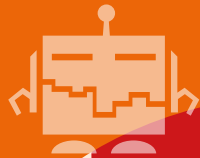
### ALMOST HUMAN

What would it be like if humanoid robots existed among us in everyday life? We're not quite there yet. In real life, today's robots have a hard enough time just standing on their own two legs.

But the most fundamental problems have already been solved. So robots such as Honda's **ASIMO** (9) can walk all by themselves and use their artificial hands and arms to do work.

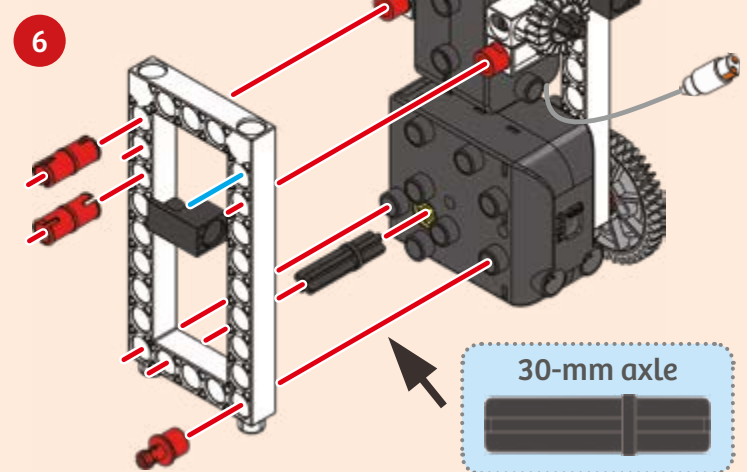
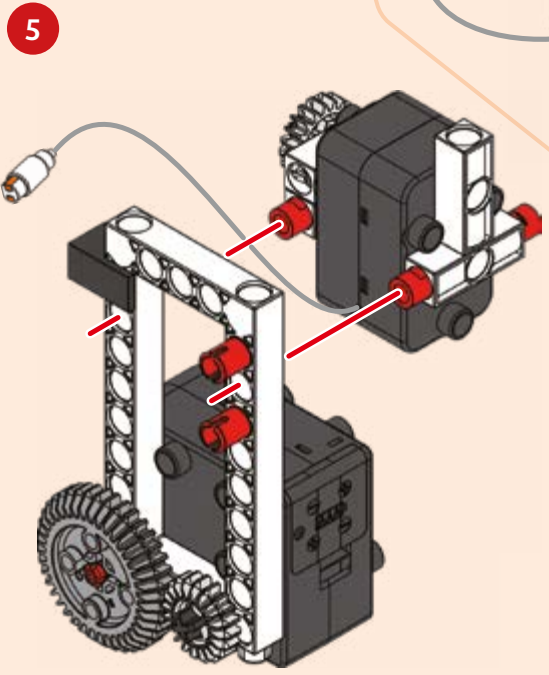
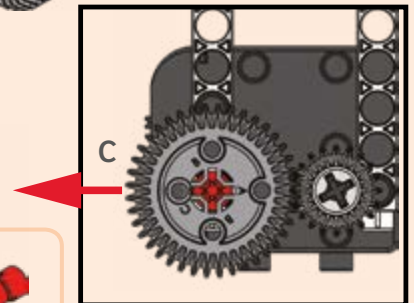
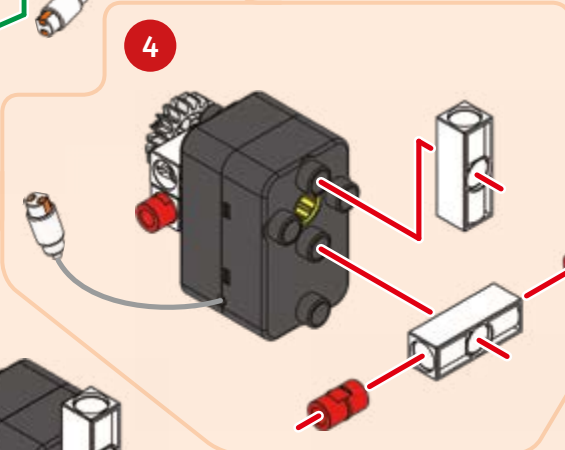
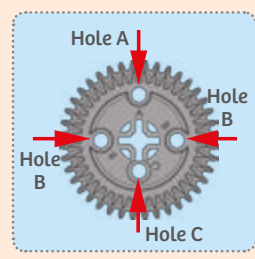
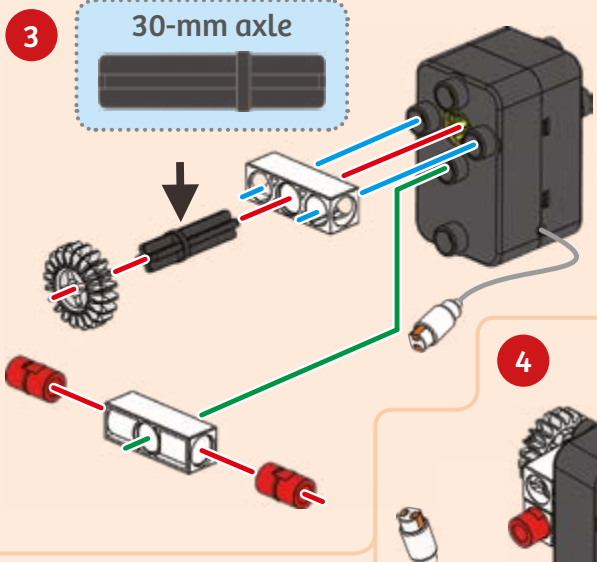
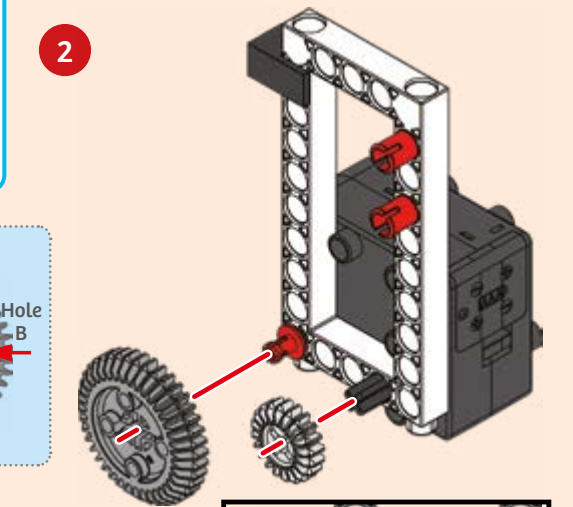
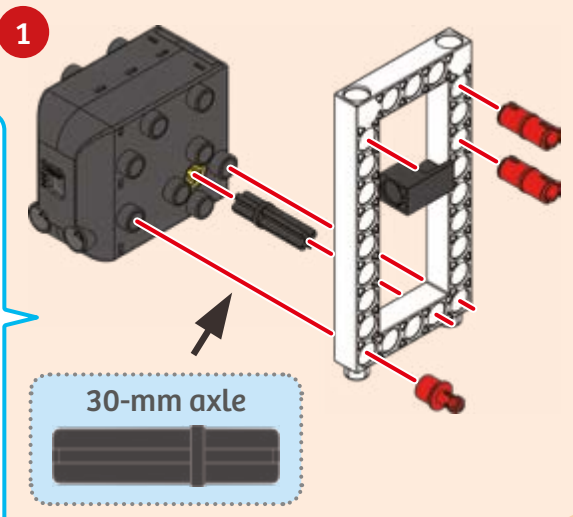
Maybe science fiction will soon become reality. For that to happen, personal robots will have to be able to communicate with their surroundings, with other robots, and with people, and work together with them as well. They still have a lot to learn before they can do that. They have to learn to move around better and more safely, they have to be able to recognize things in their environment, and they have to be able to understand human speech. Just like the robot movie stars in Hollywood.



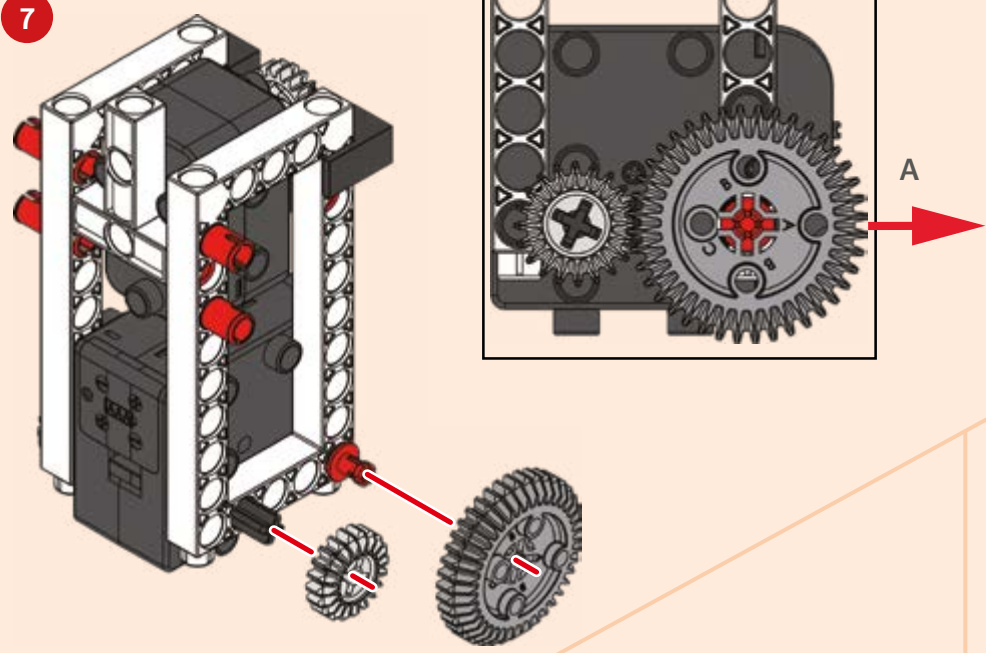


# WALKING BOT

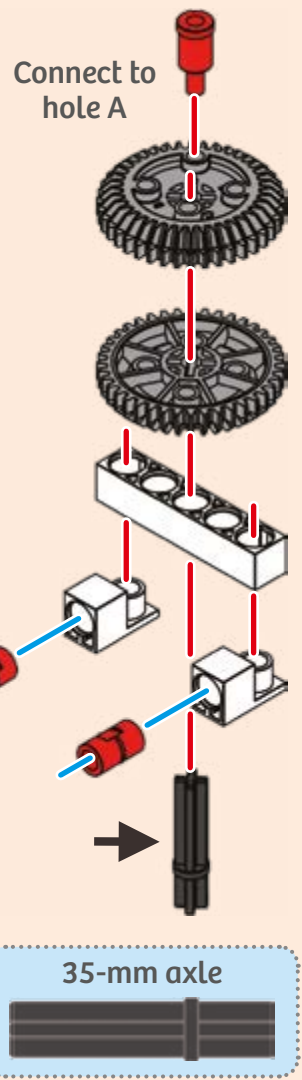
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| 11x | 2x | 3x  | 1x | 6x | 2x | 4x | 2x | 1x | 3x | 2x |
| 14  | 16 | 18  | 19 | 21 | 22 | 23 | 24 | 25 |    |    |
| 2x  | 2x | 3x  | 4x | 2x | 4x | 2x | 2x | 1x |    |    |
| 26  | 27 | 28  | 29 | 30 | 31 | 32 | 33 | 34 | 36 | 39 |
| 4x  | 1x | 3x  | 1x | 1x | 1x | 2x | 2x | 4x | 3x | 2x |
| 40  | 44 | 45  | 46 | 49 | 50 | 51 | 52 | 54 | 55 | 56 |
| 2x  | 8x | 26x | 5x | 4x | 1x | 1x | 1x | 1x | 1x | 1x |



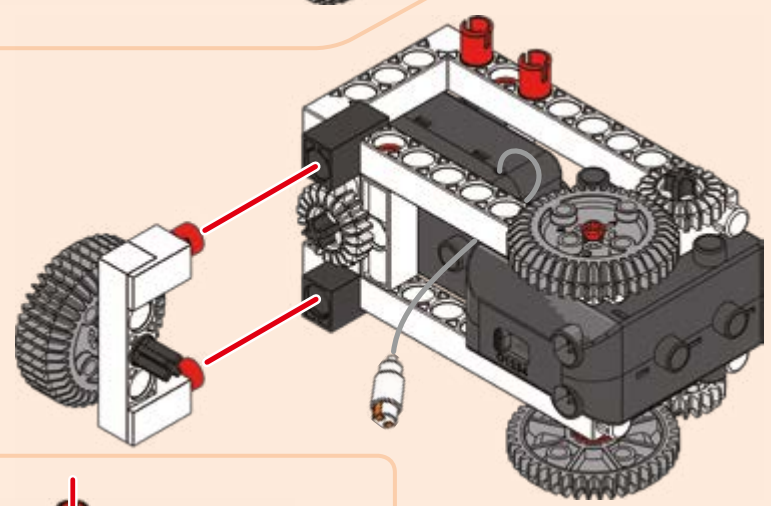
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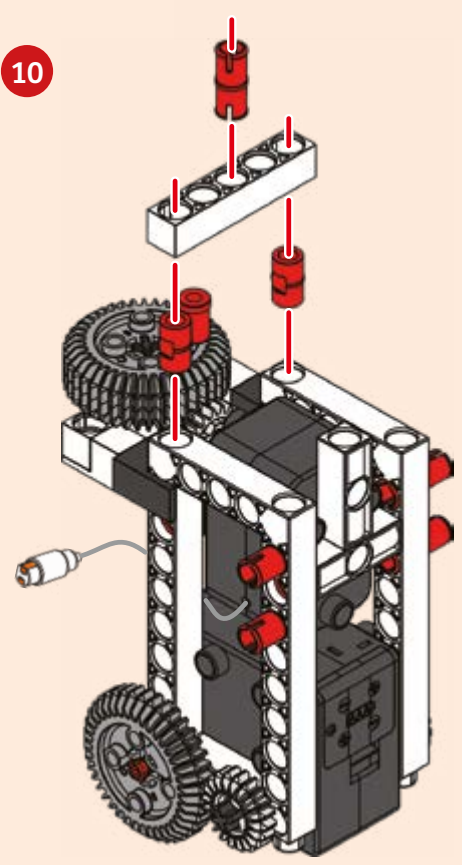
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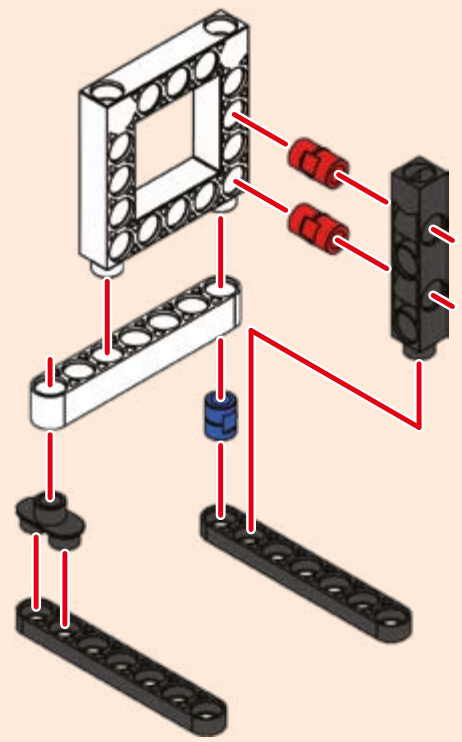
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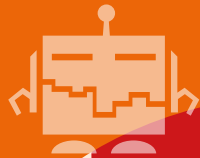
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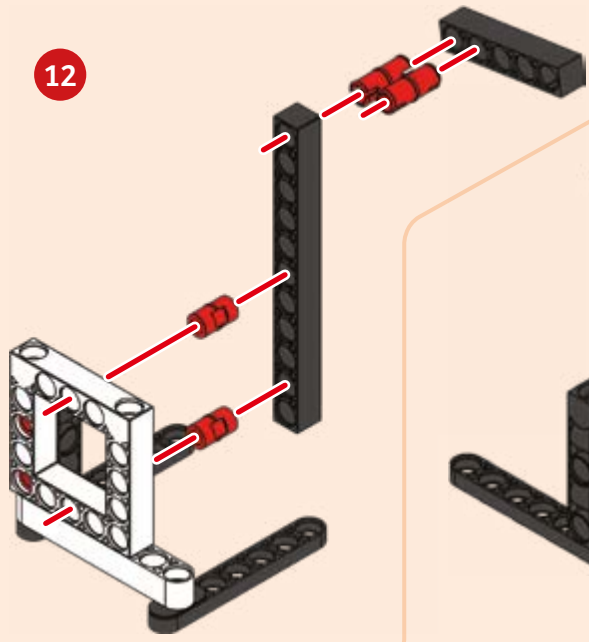




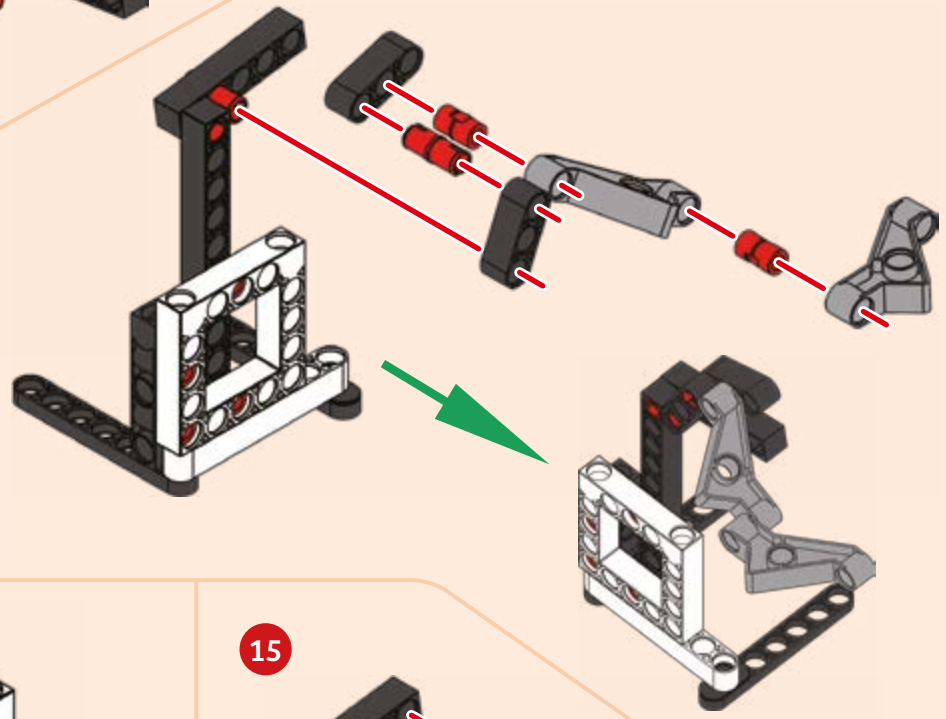


● ● ● WALKING BOT

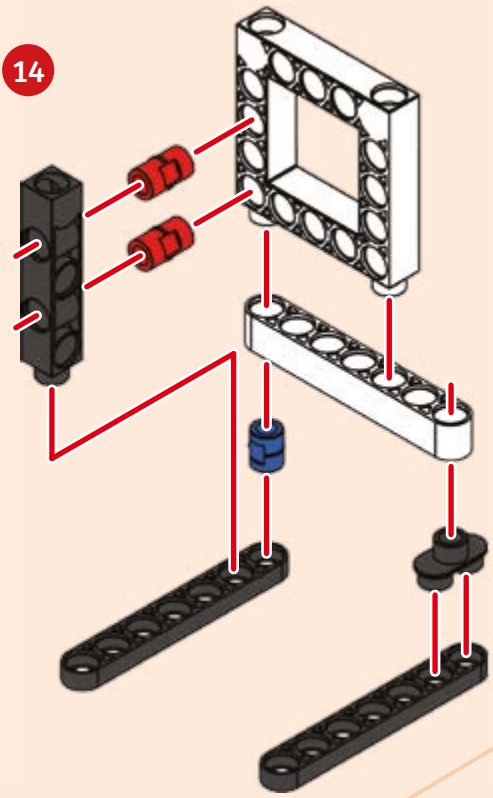
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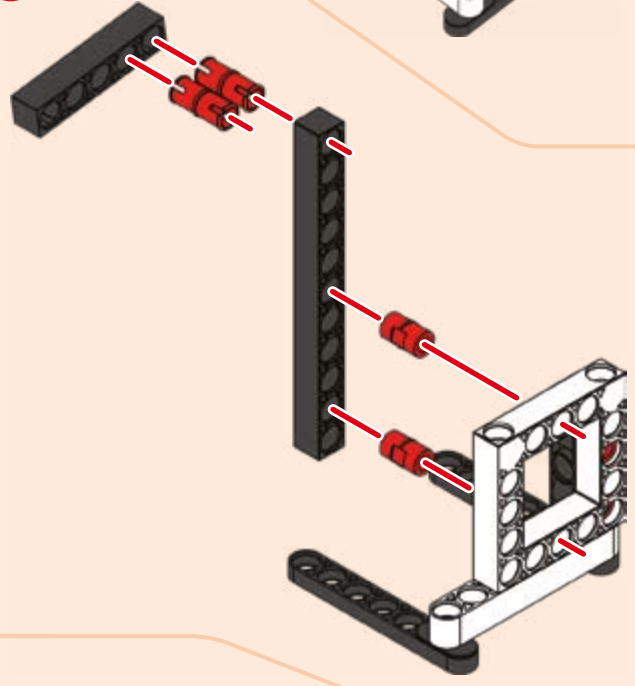
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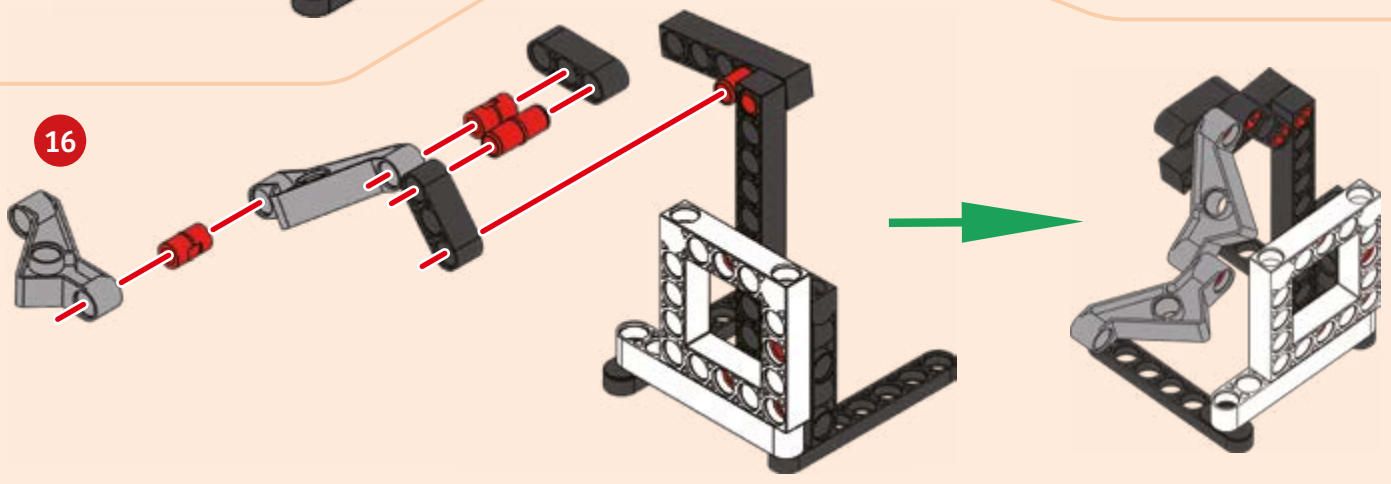
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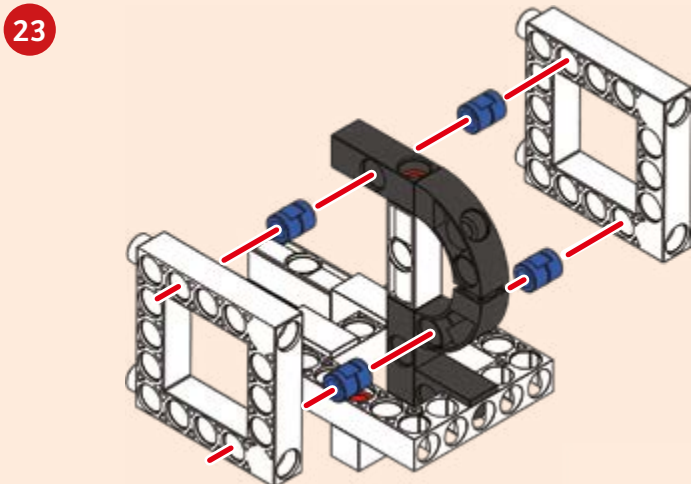
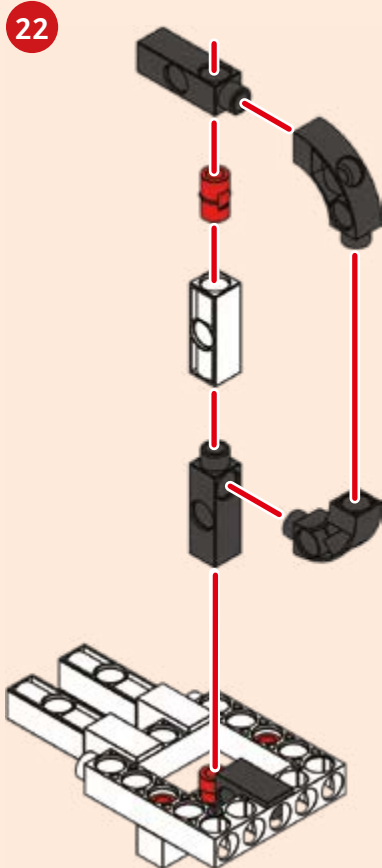
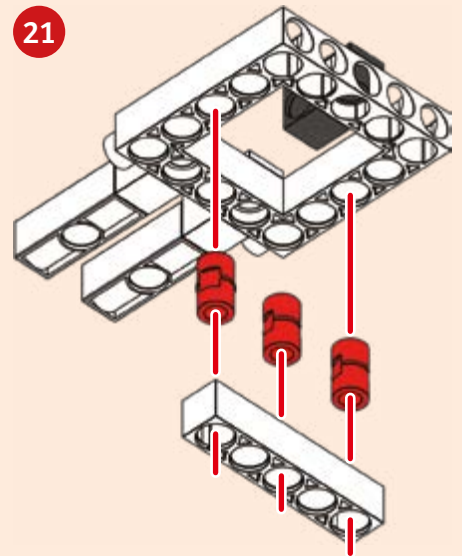
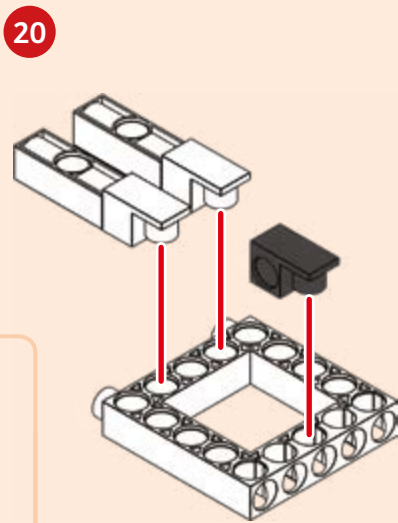
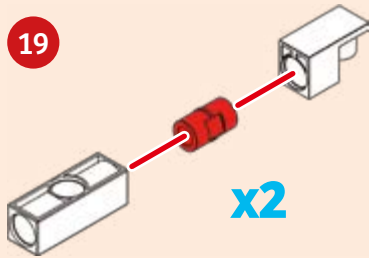
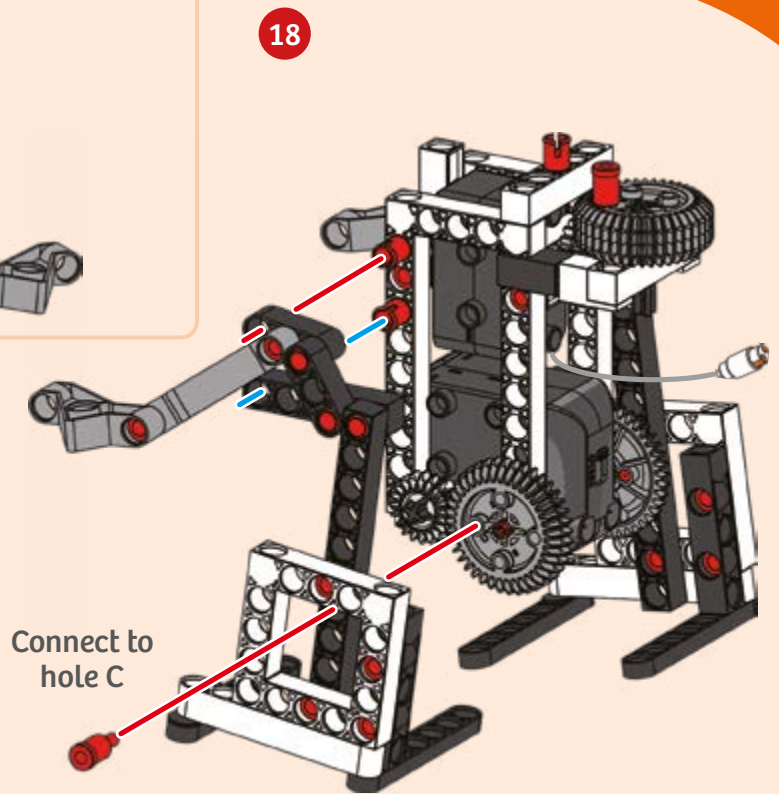
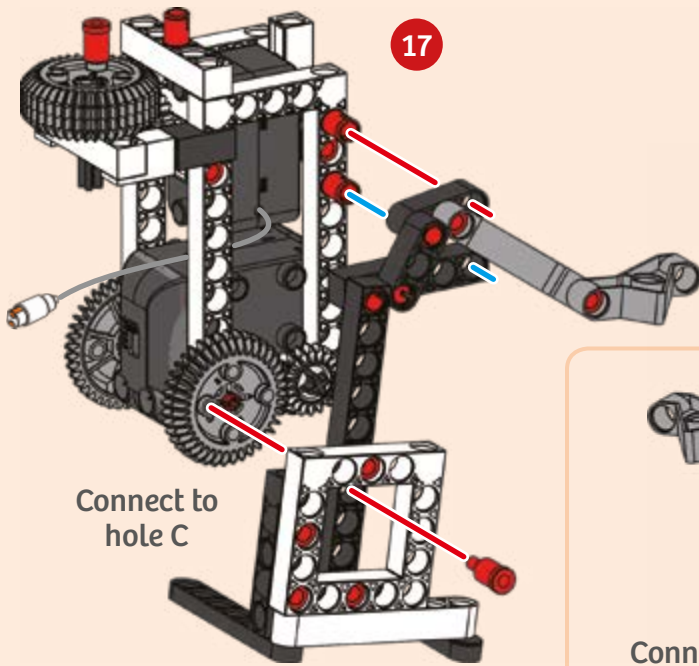


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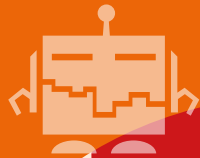


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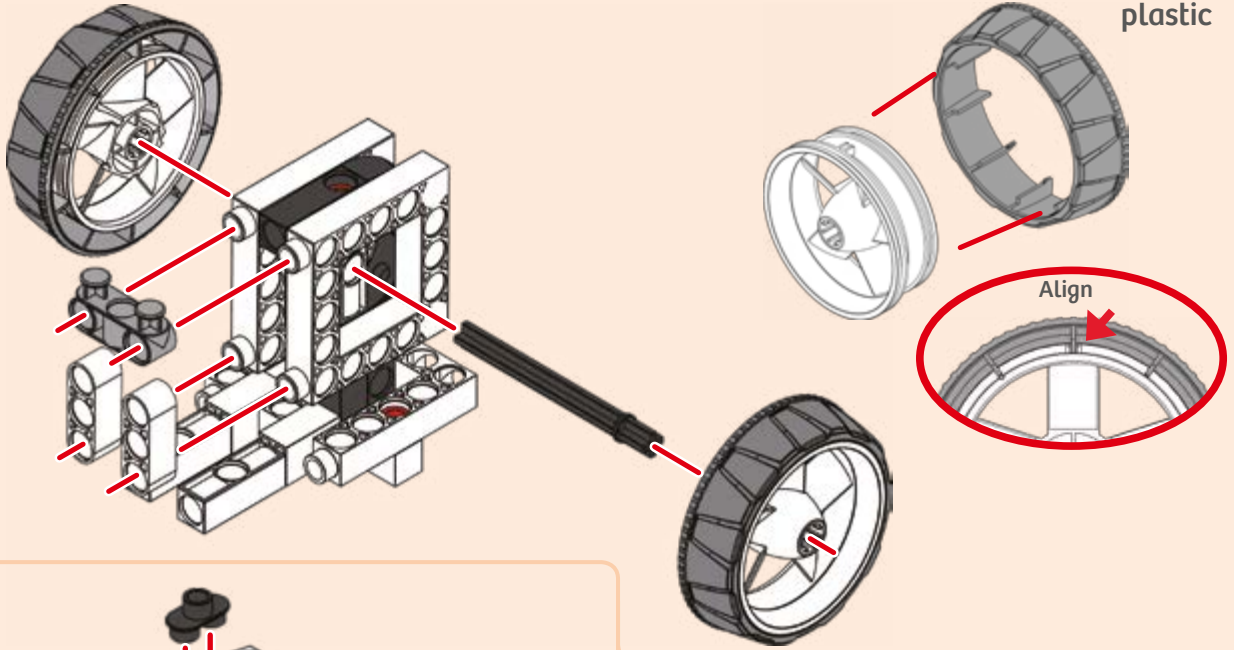




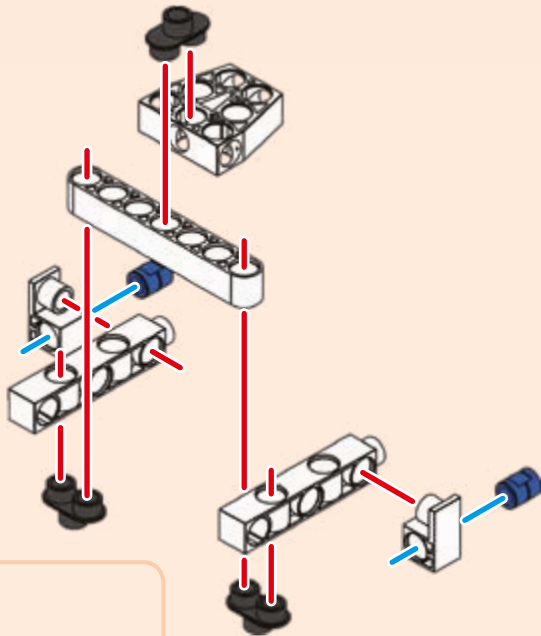


● ● ● WALKING BOT

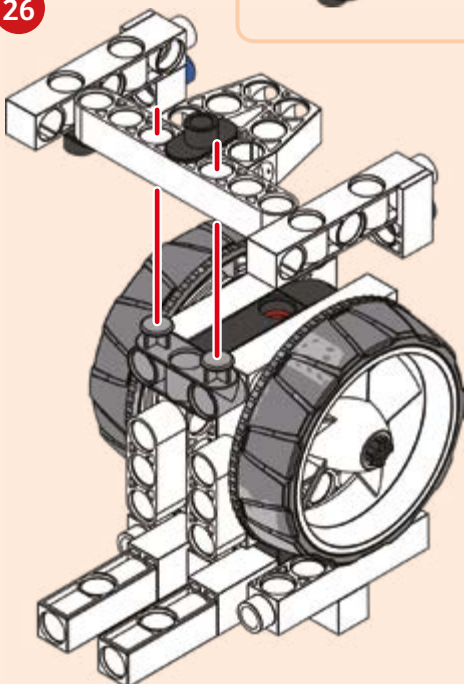
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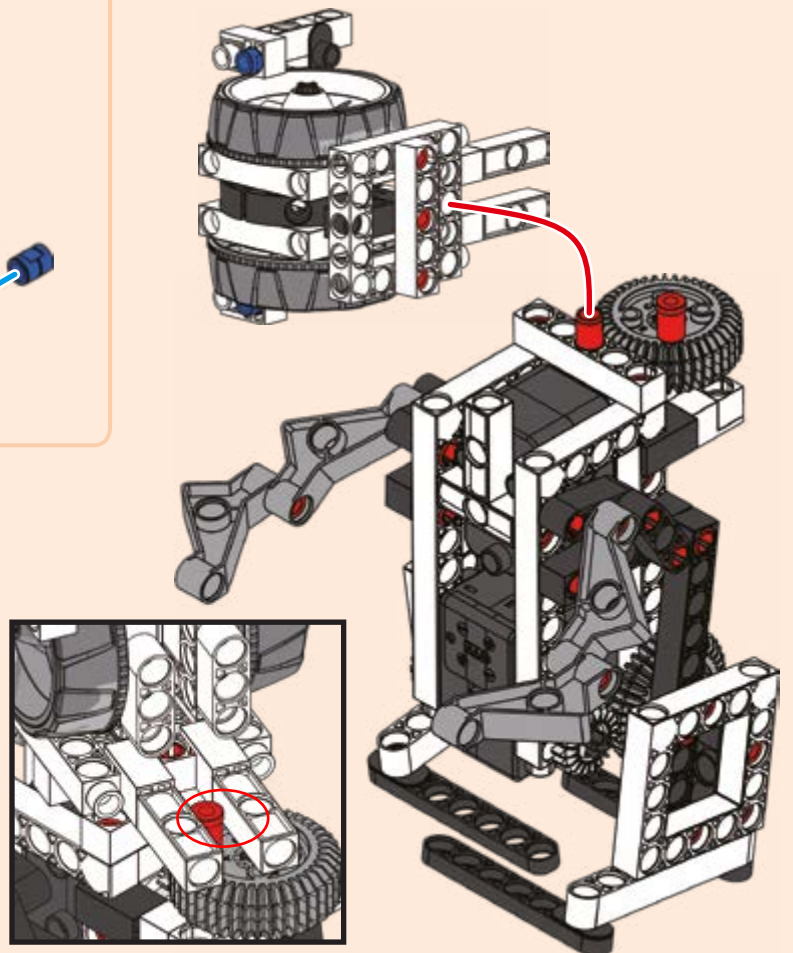
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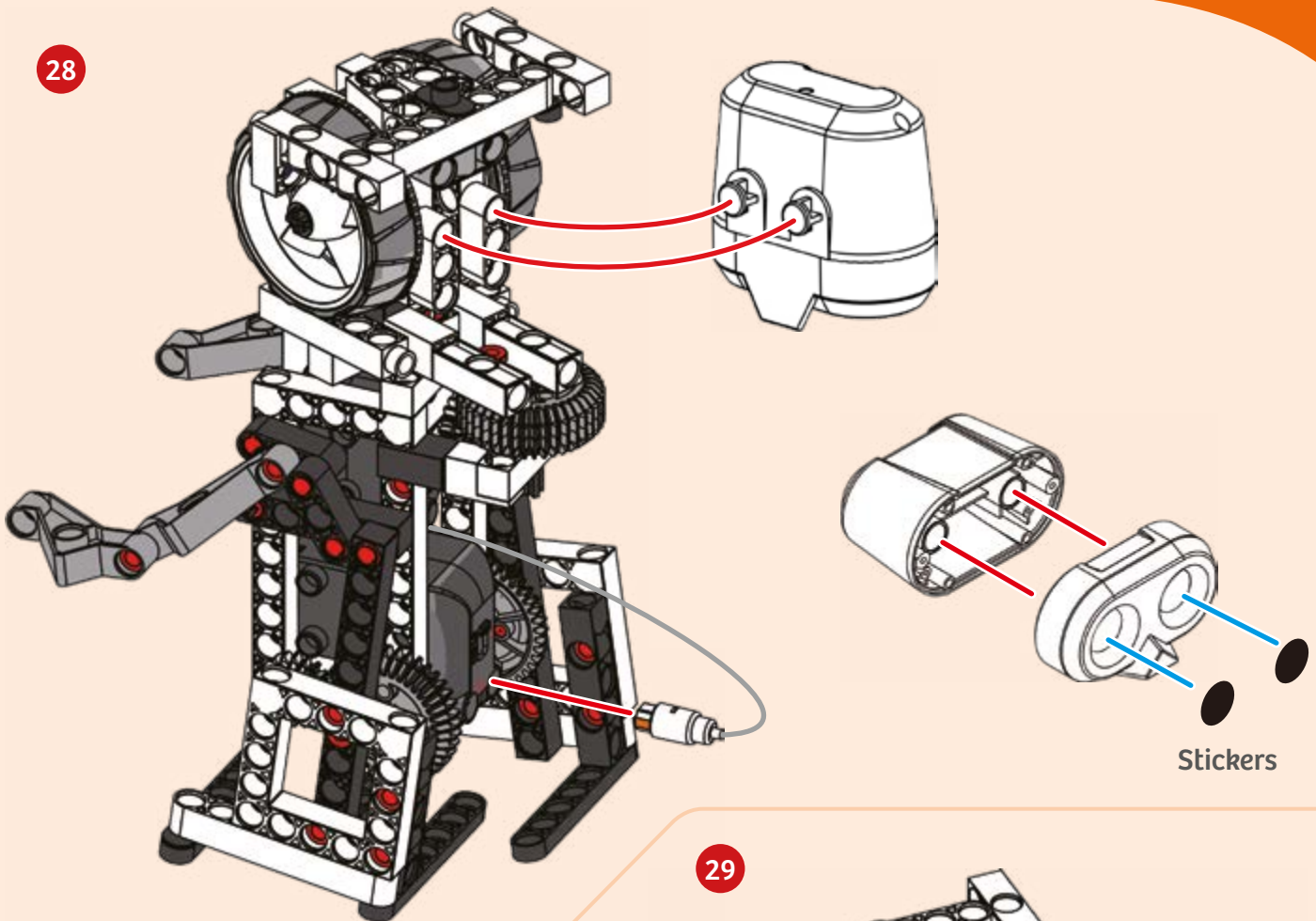
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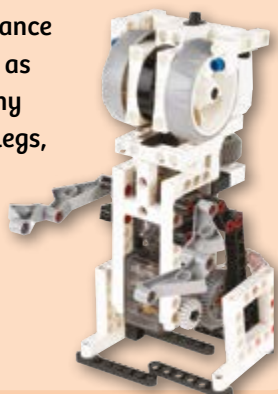
## EXPERIMENT 8

## Walking the walk

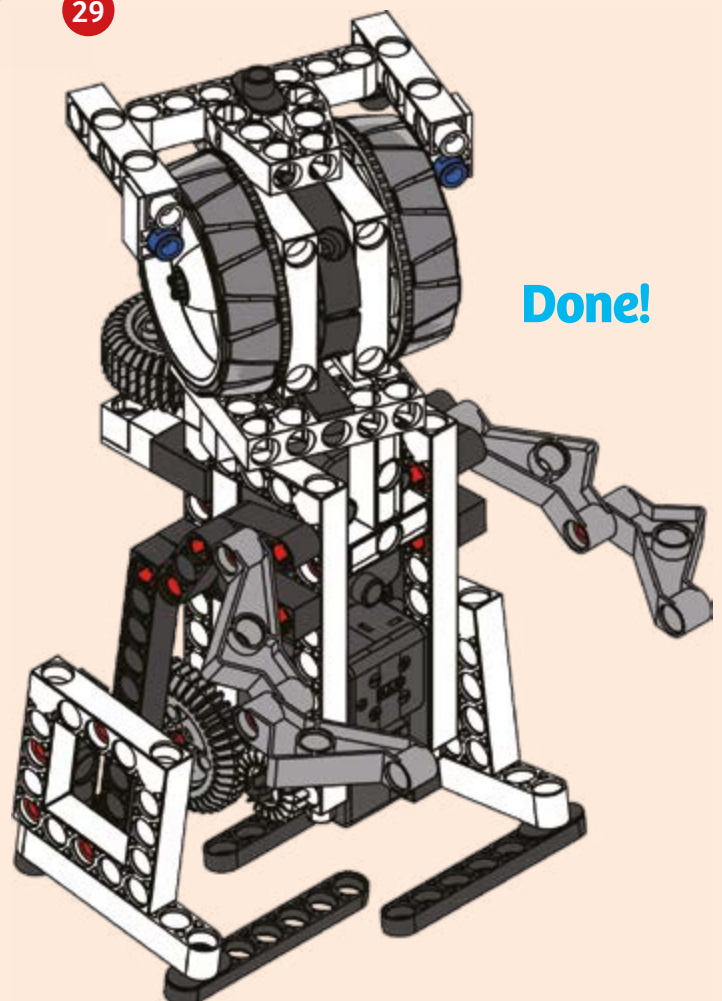
## HERE'S HOW

This robot pal is designed to walk on two legs. Experiment with the positioning of the rods that make up its feet. Can you get it to balance on one foot and then the other, to slowly shift its weight back and forth between legs, and thus move forward or backward?

Bipedal robots — robots with two feet — are quite an engineering challenge. It is very difficult to get a robot's heavy electronic and mechanical equipment to balance on two legs and walk around as easily as a human might. Many legged robots use four or six legs, which makes balancing much easier. But robotics engineers continue to strive to mimic the bipedal locomotion of humans.



29

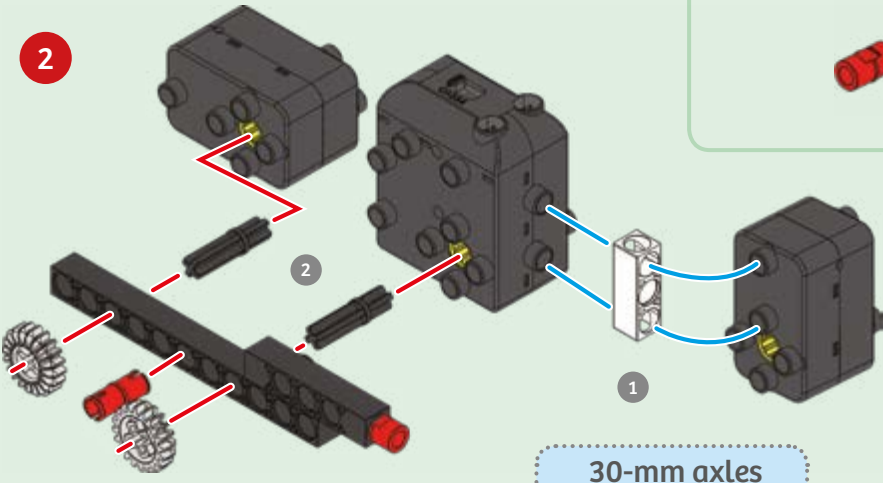
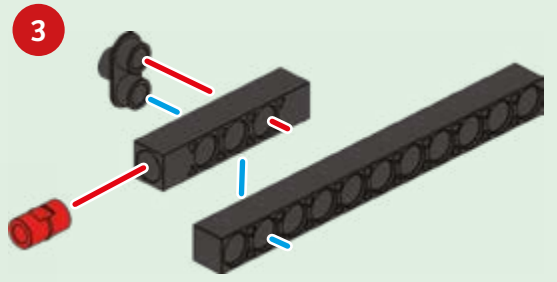
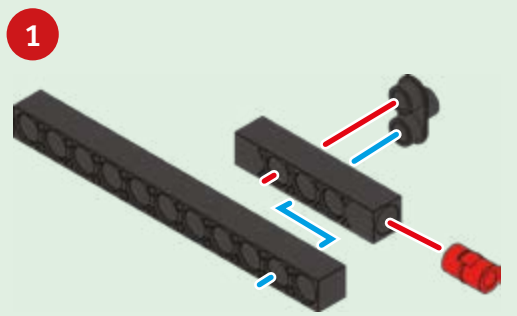




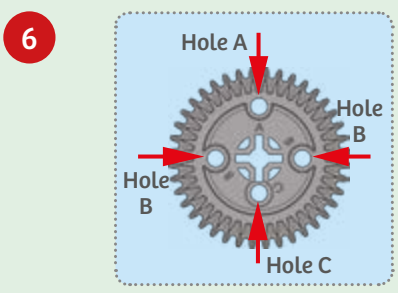
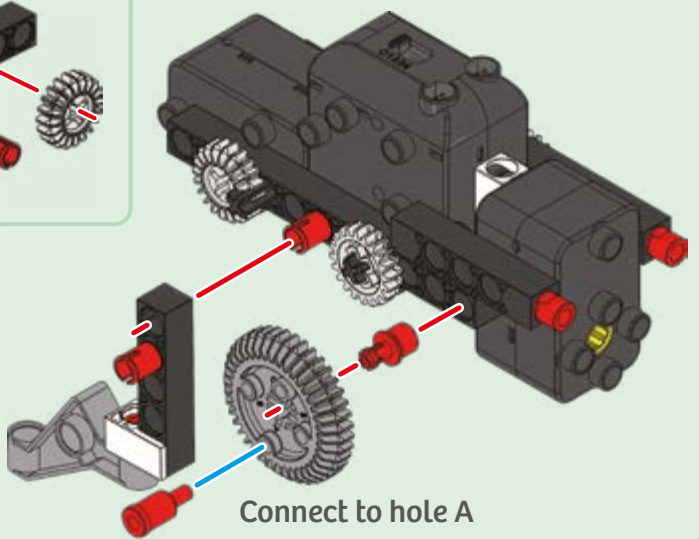
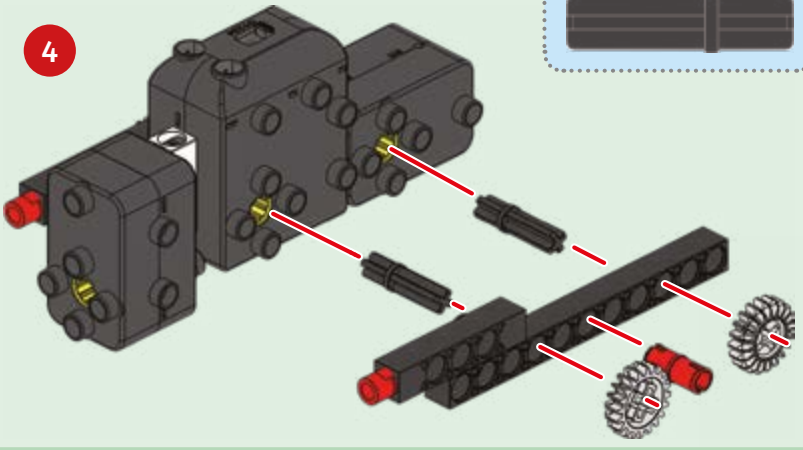
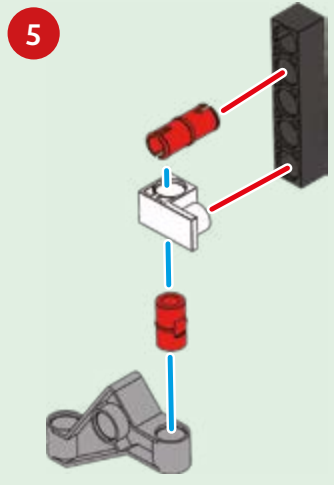


# CROSS-WING STARSHIP

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| 1   | 3  | 4  | 5  | 6   | 7  | 8  | 9  | 10 | 12  |    |
| 11x | 2x | 6x | 1x | 9x  | 3x | 4x | 2x | 1x | 2x  |    |
| 13  | 14 | 16 | 17 | 18  | 19 | 21 | 22 | 23 |     |    |
| 4x  | 4x | 4x | 4x | 2x  | 4x | 4x | 4x | 2x |     |    |
| 25  | 26 | 27 | 28 | 29  | 30 | 31 | 32 | 34 | 36  | 38 |
| 1x  | 4x | 1x | 5x | 4x  | 2x | 2x | 2x | 2x | 11x | 1x |
| 39  | 40 | 42 | 44 | 45  | 46 | 47 | 49 | 50 | 51  | 52 |
| 2x  | 2x | 1x | 4x | 41x | 5x | 3x | 4x | 2x | 1x  | 1x |



30-mm axles



Connect to hole A

7

35-mm axle

Connect to hole B

8

9

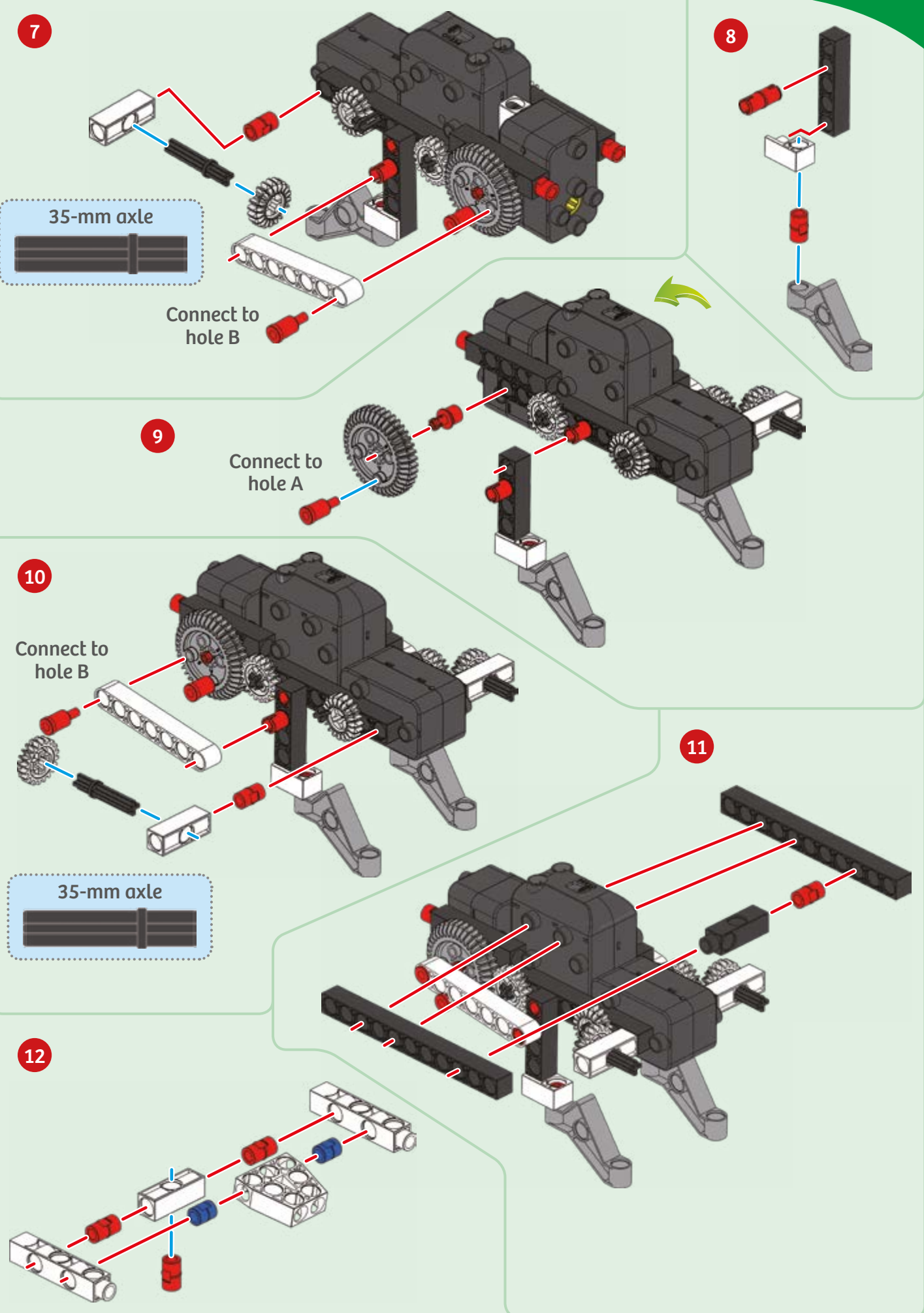
Connect to hole A

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Connect to hole B

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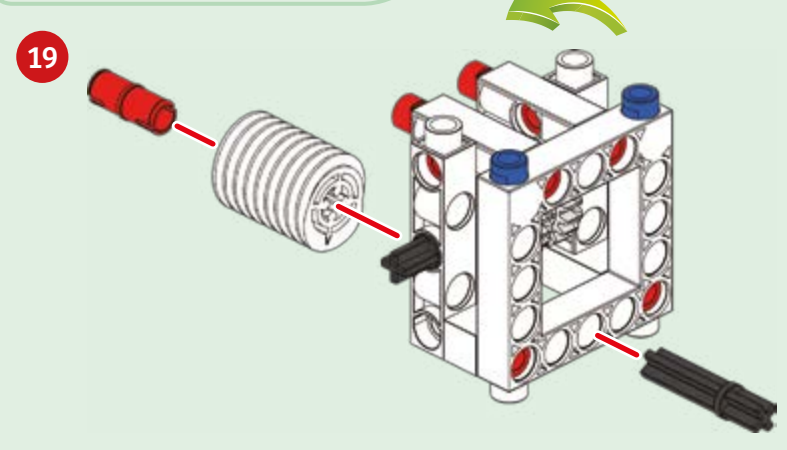
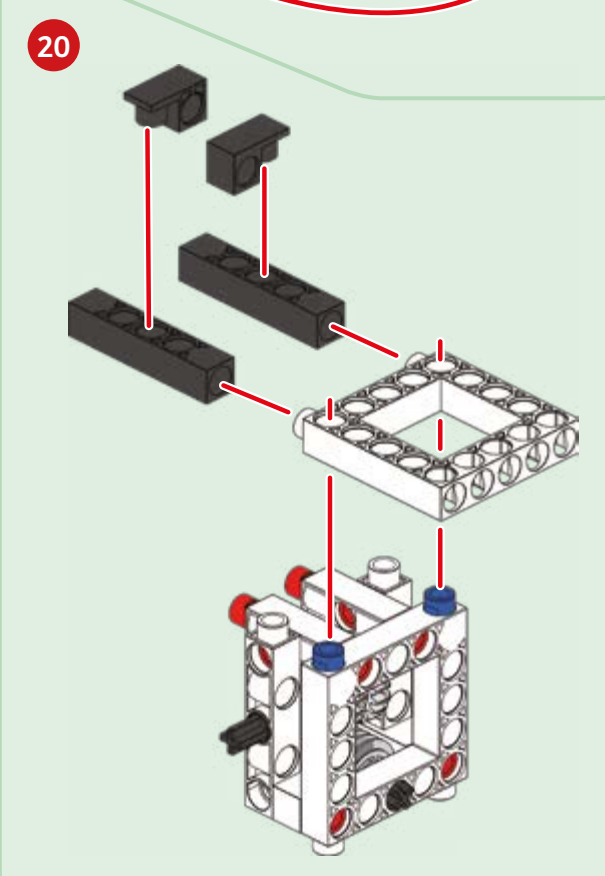
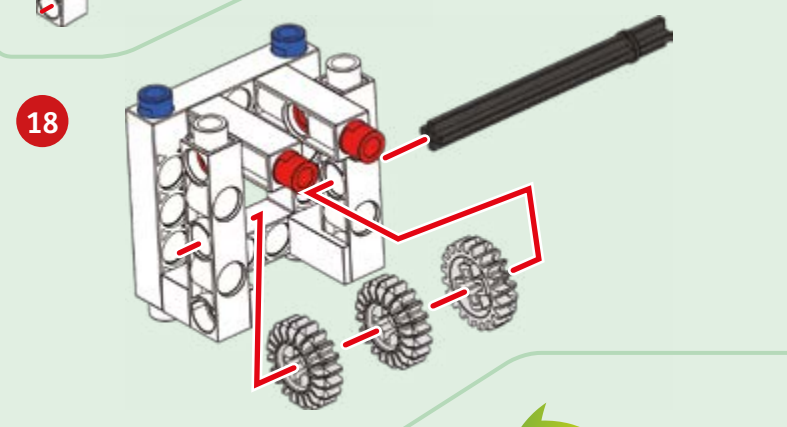
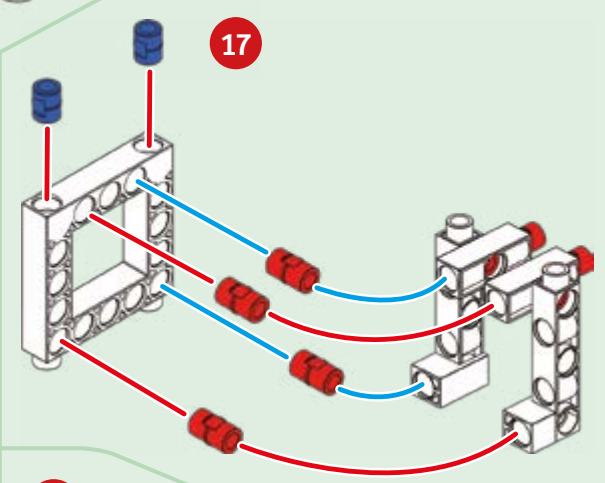
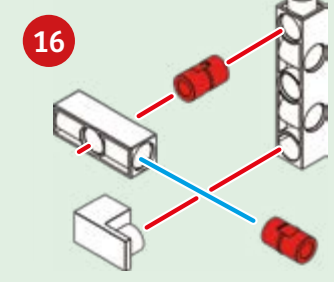
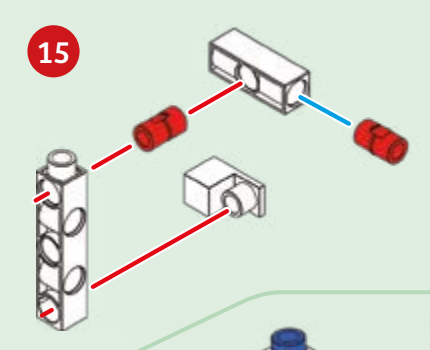
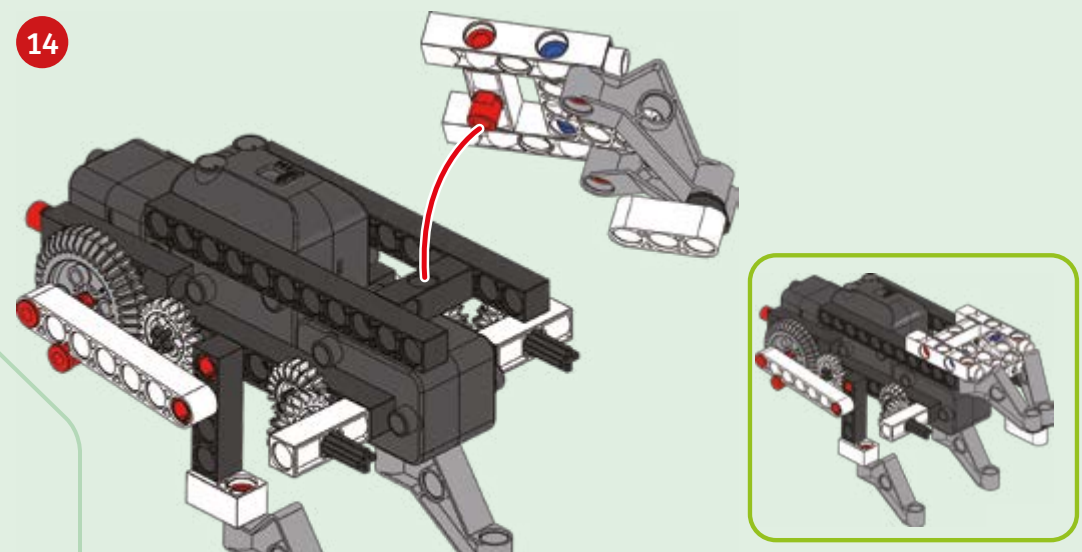
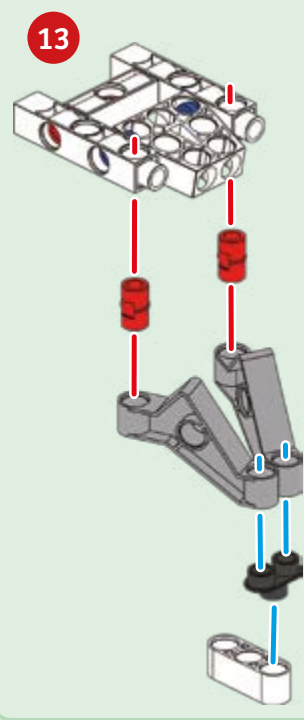
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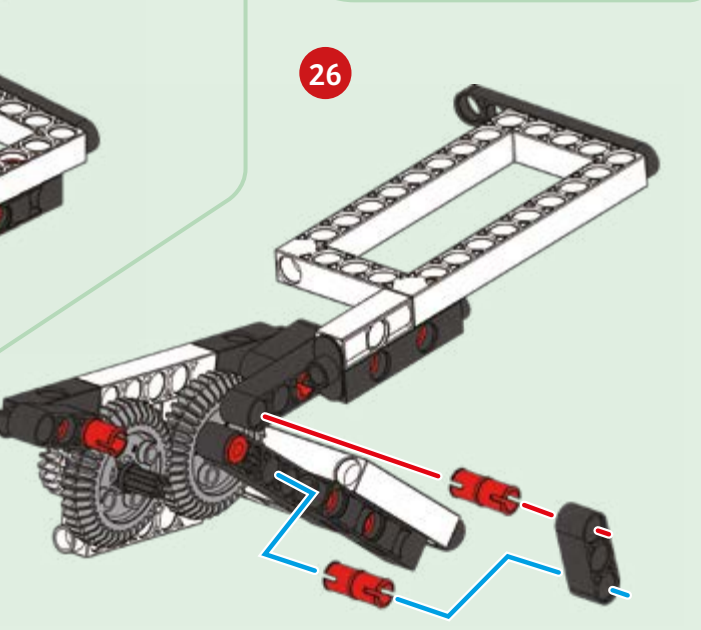
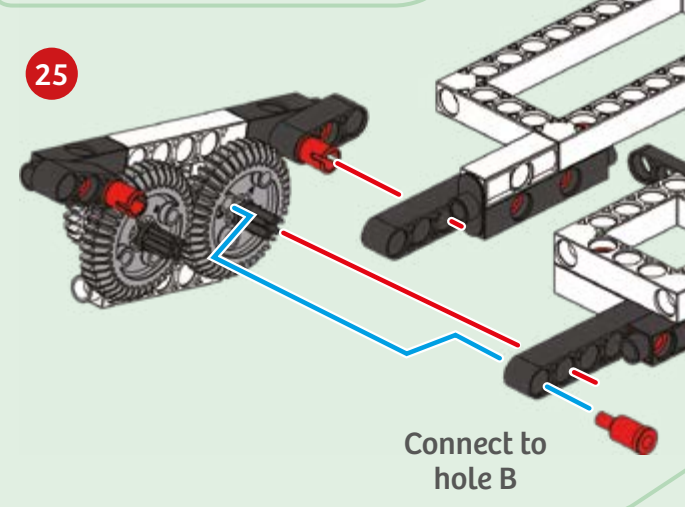
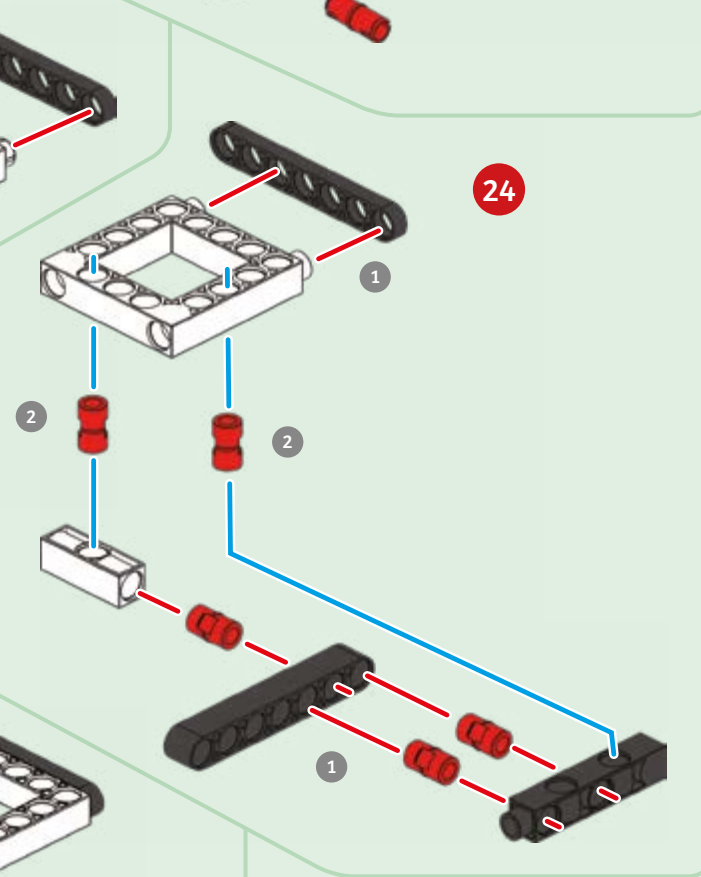
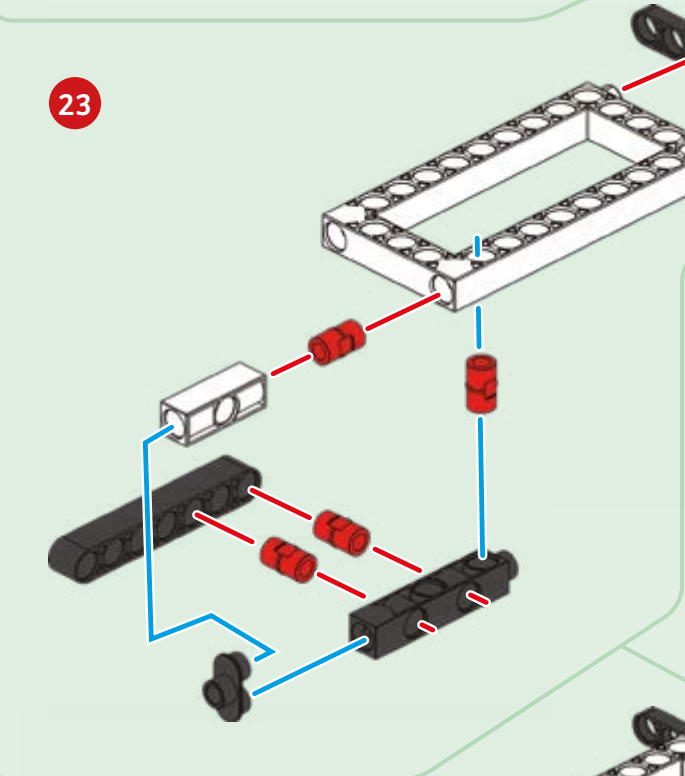
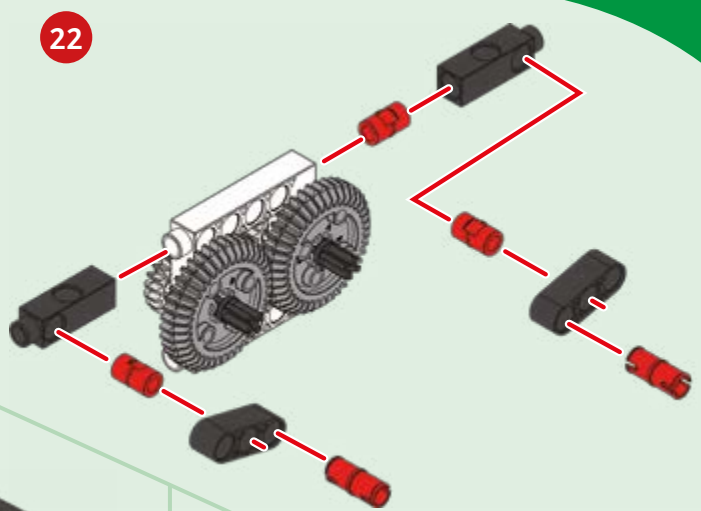
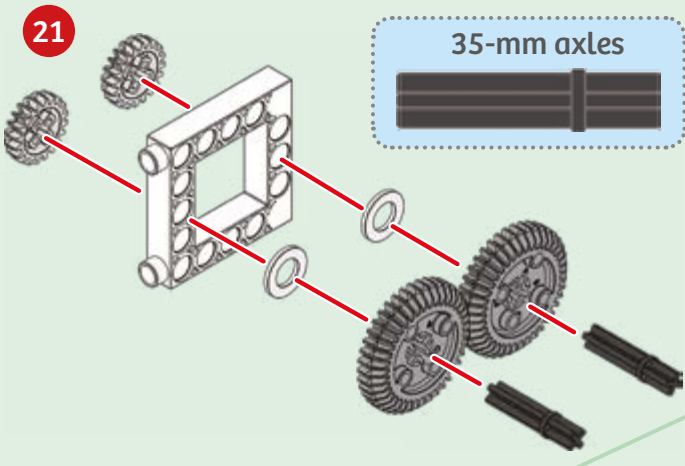






# CROSS-WING STARSHIP



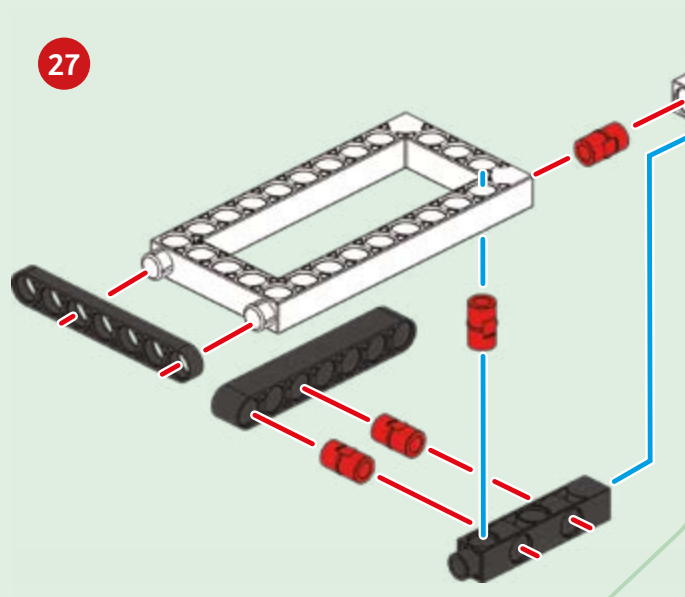




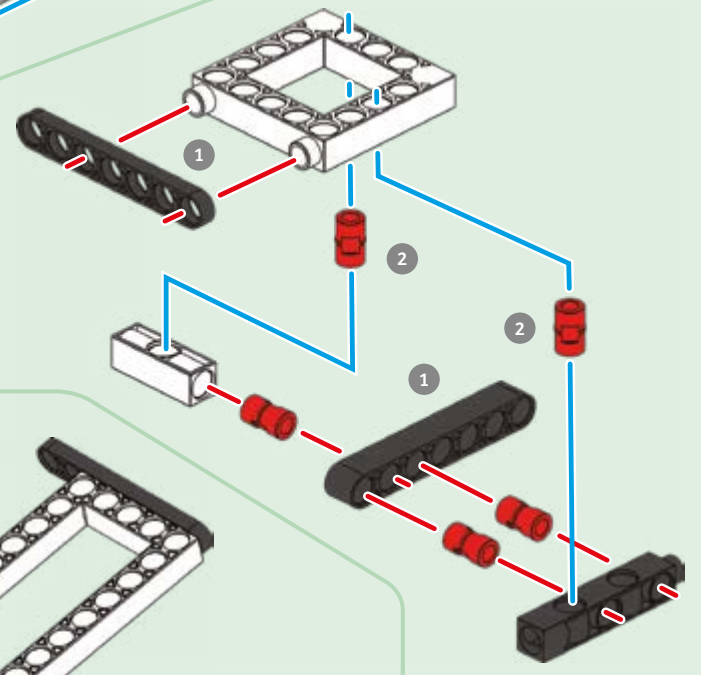


CROSS-WING STARSHIP

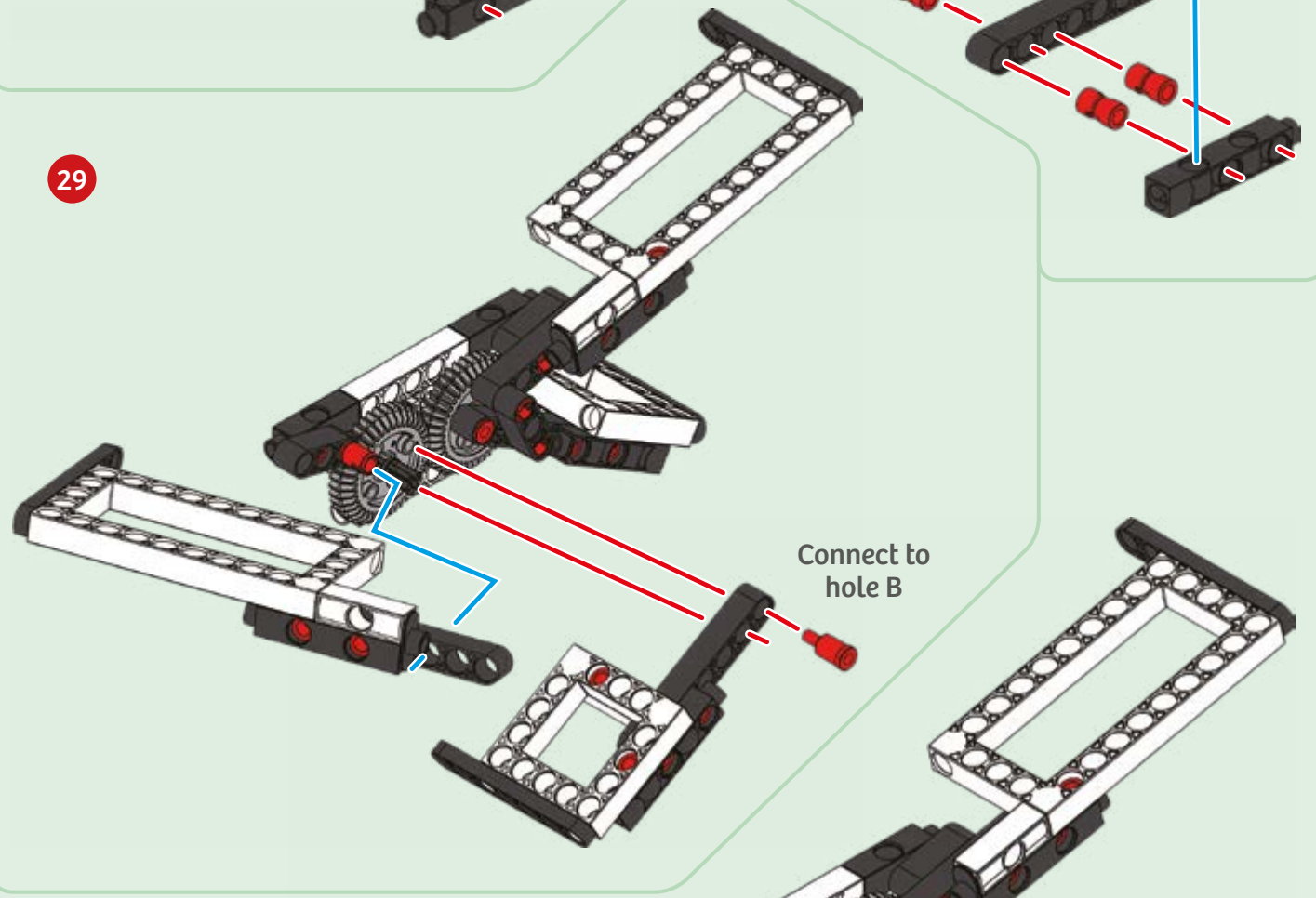
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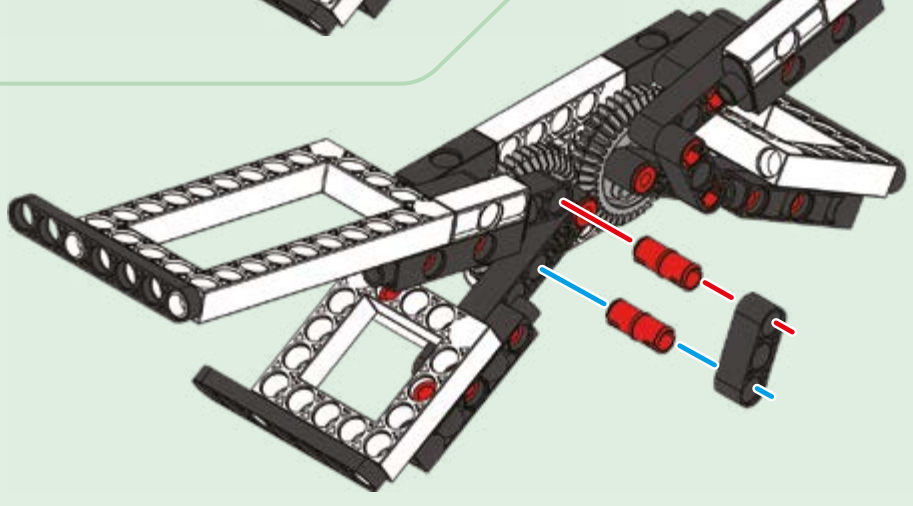
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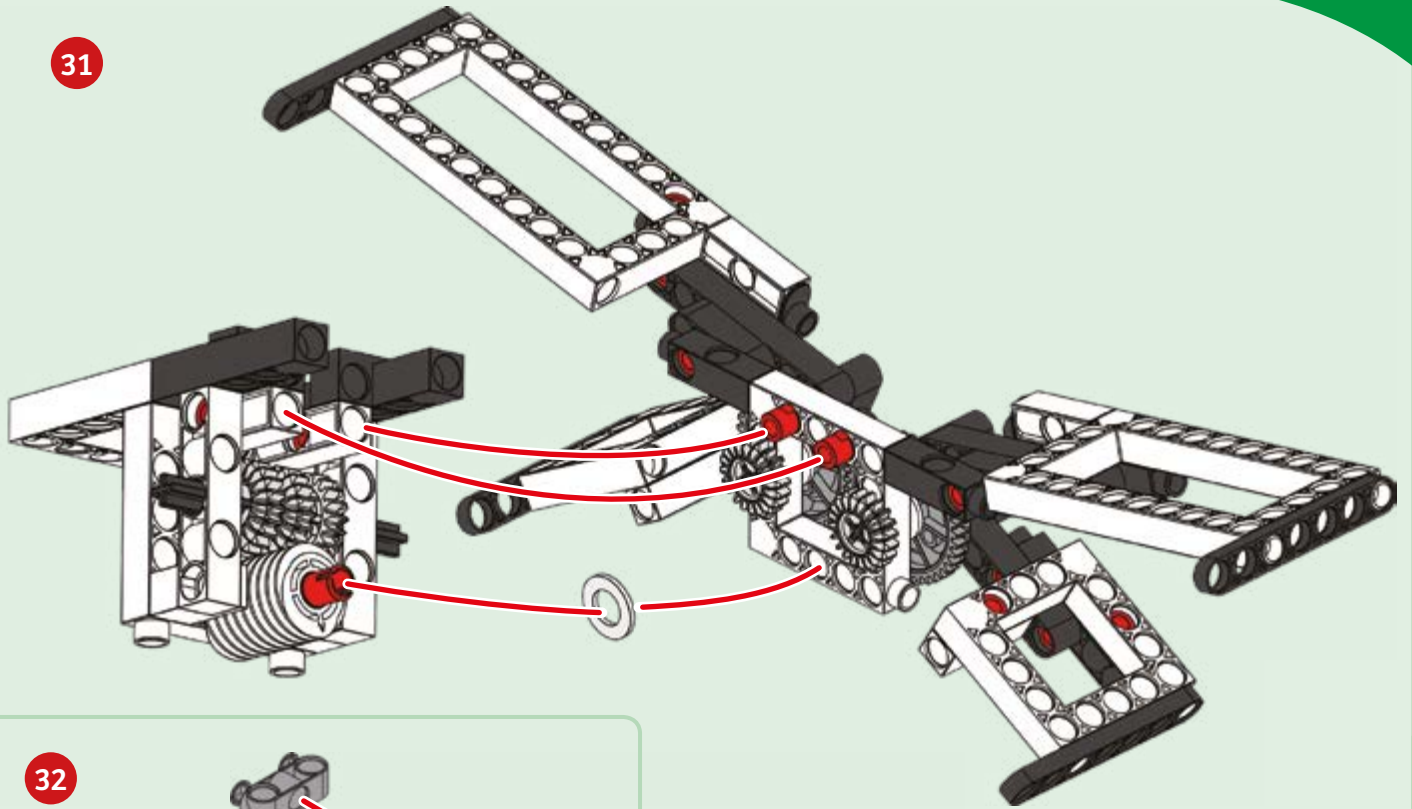
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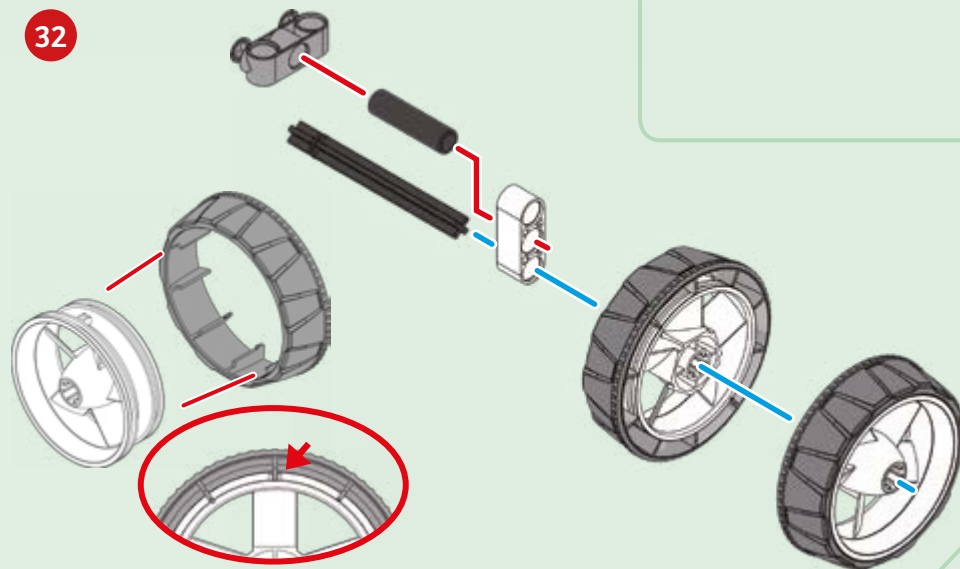
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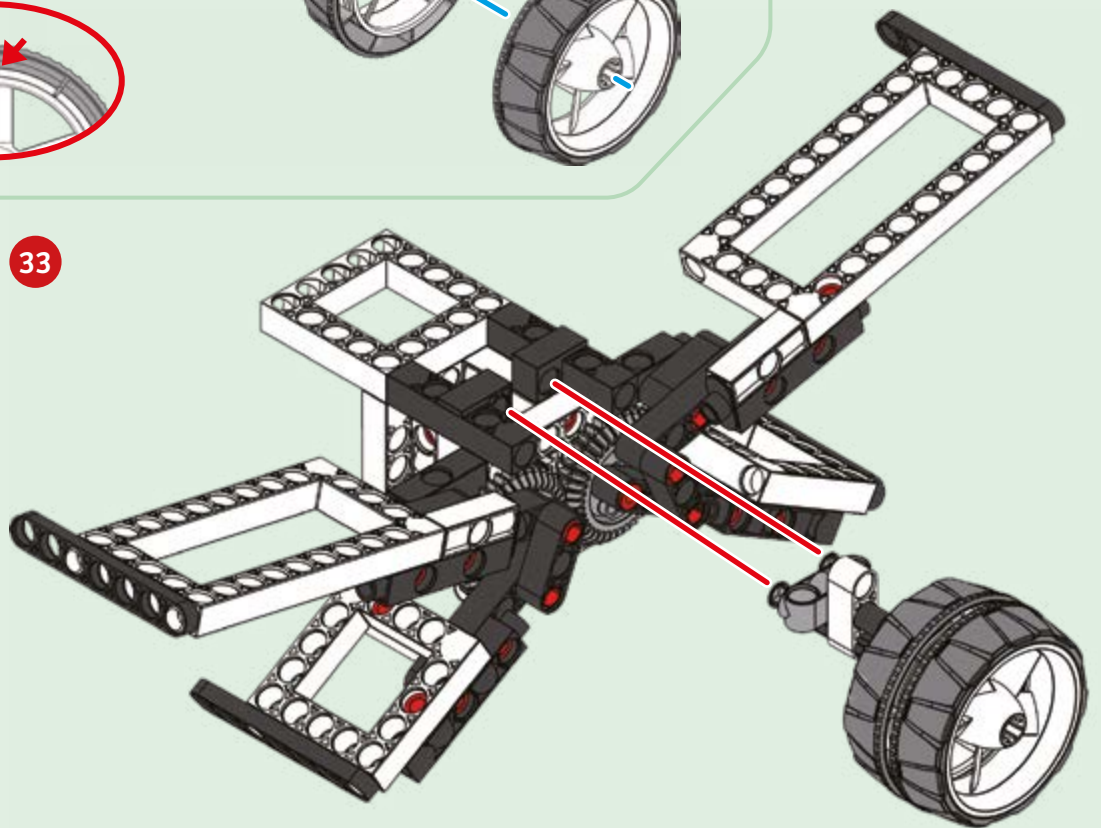
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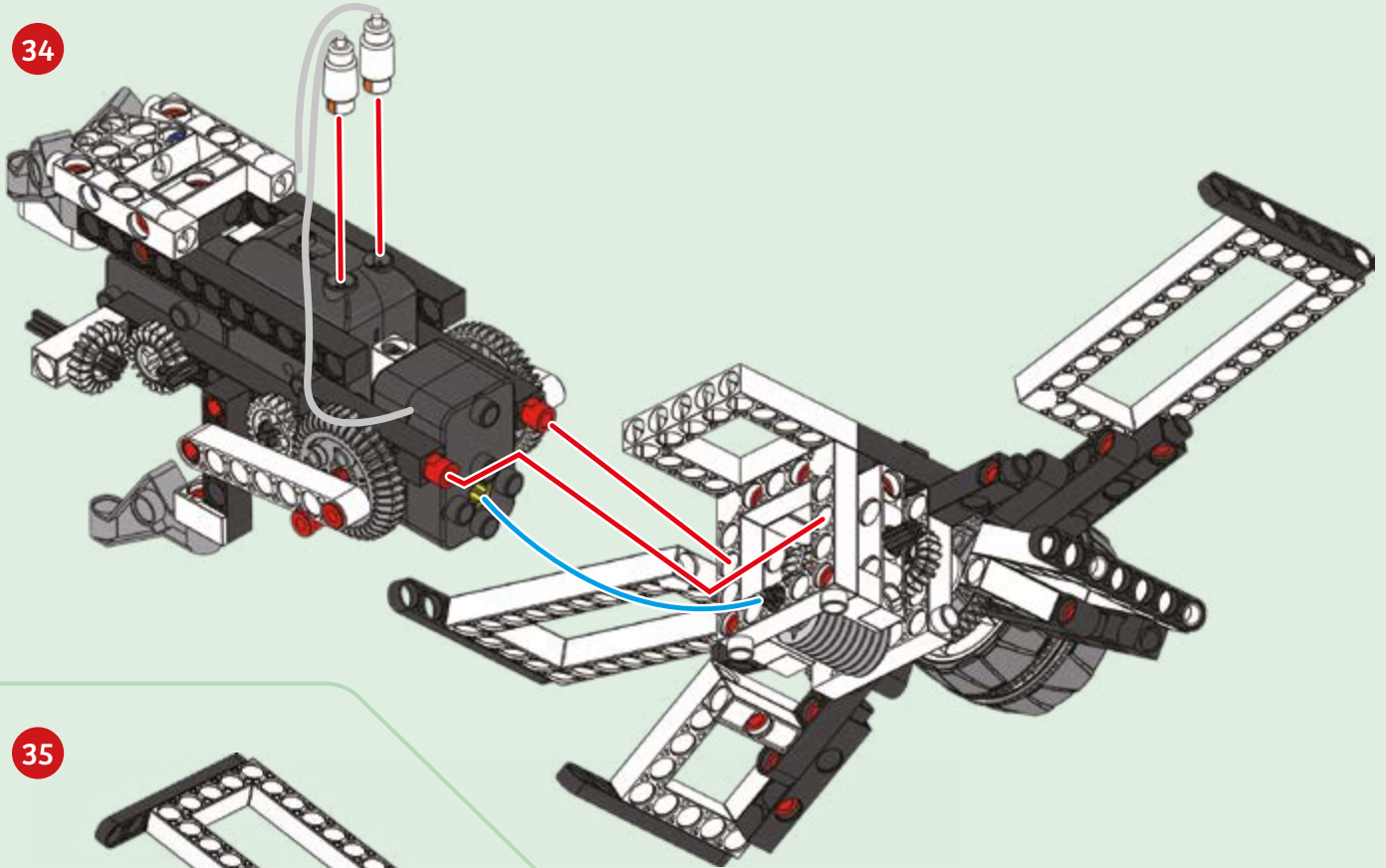
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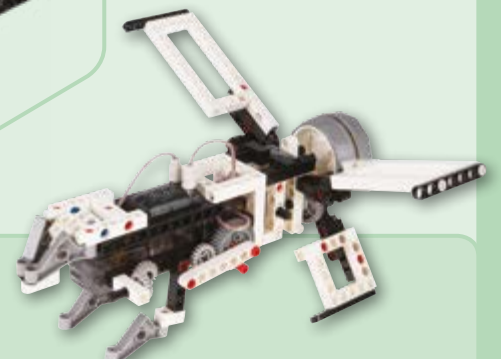
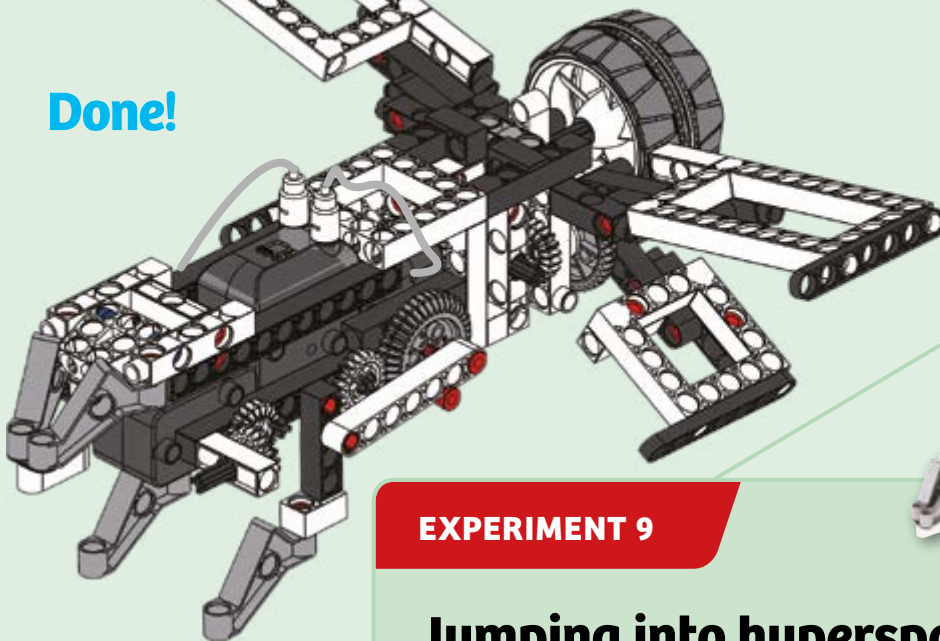


34



35

Done!



### EXPERIMENT 9

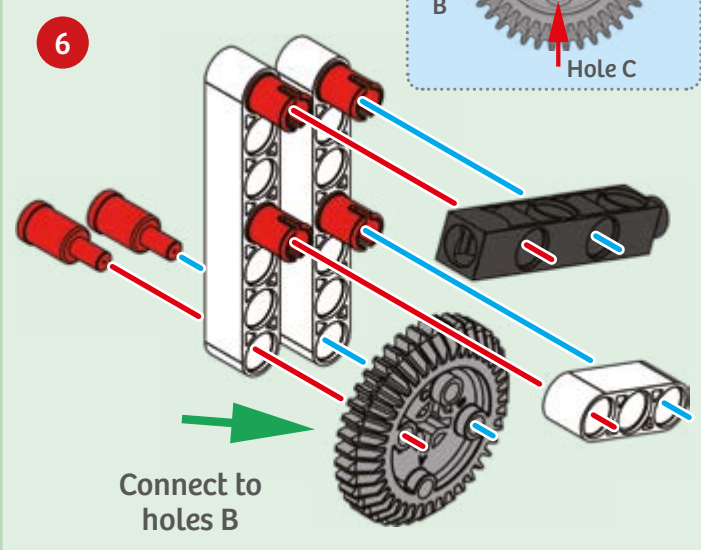
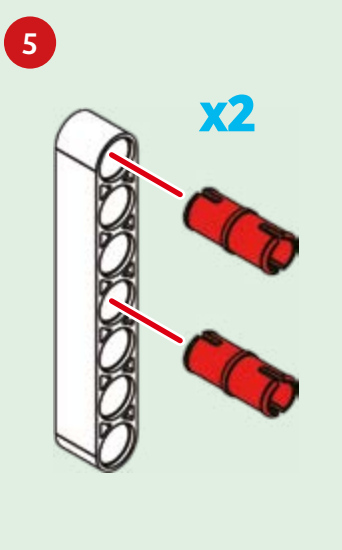
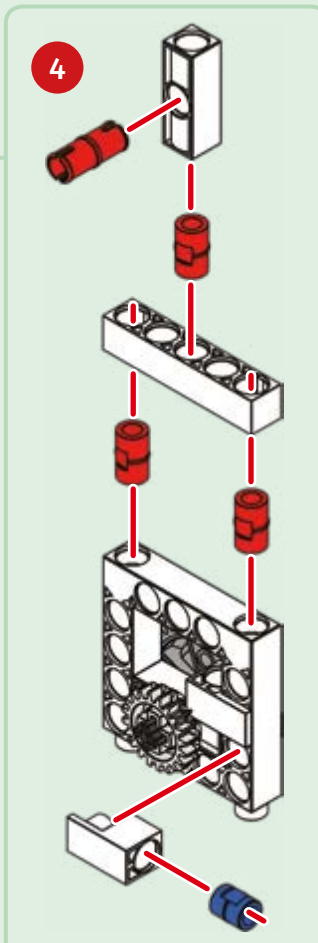
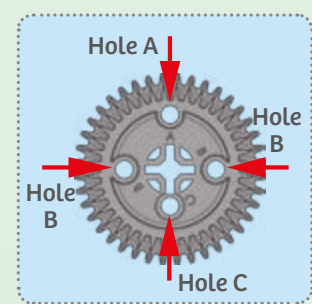
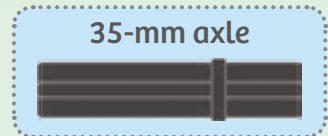
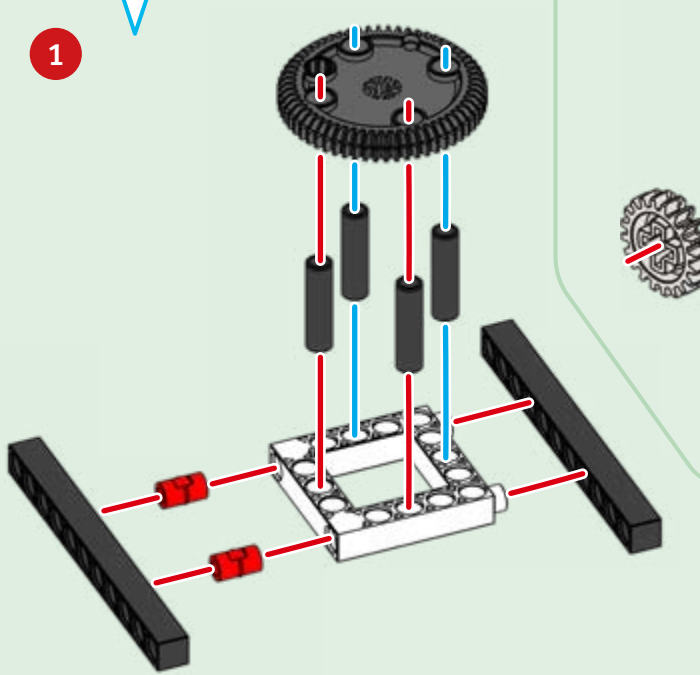
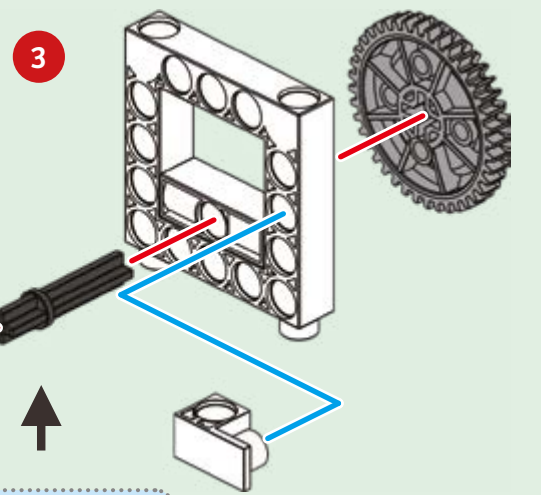
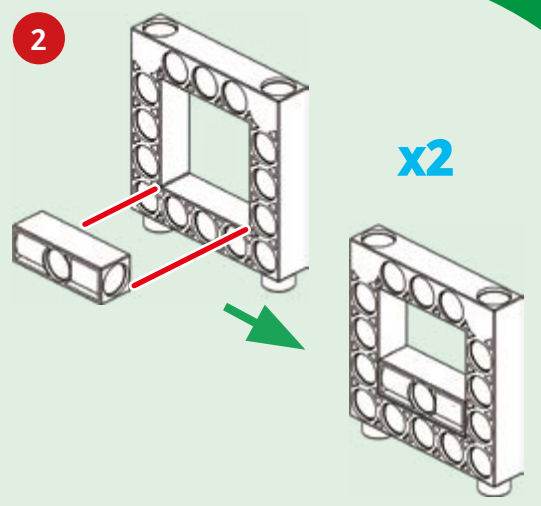
## Jumping into hyperspace

### HERE'S HOW

This fantastic model imagines a time in the future when hyperspace travel — faster than light speed travel — is possible. The thruster wings in the back lock together during light speed travel and separate to provide greater maneuverability when flying through atmosphere. The landing gear in the front retracts to further streamline the shape of the starship. Turn your model on to test out the operation of the wings and the landing gear.

SPACESHIP CONTROLLER

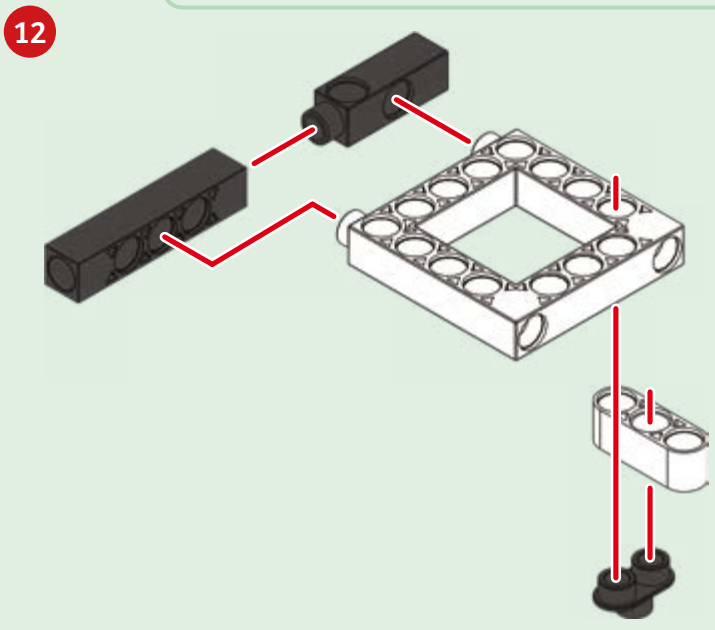
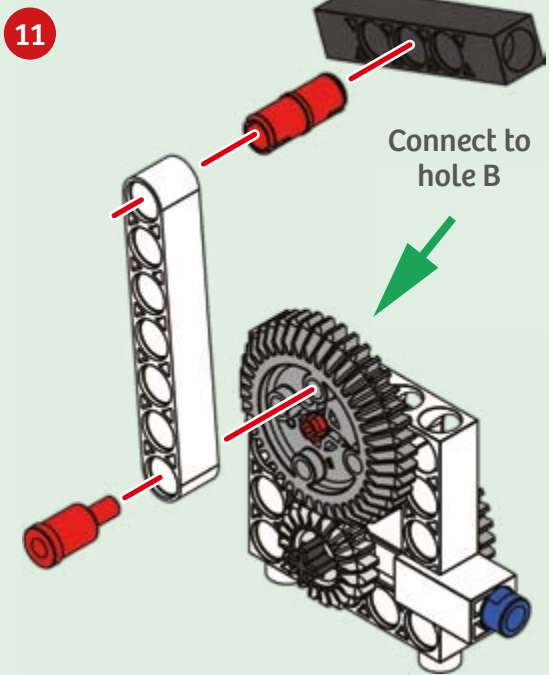
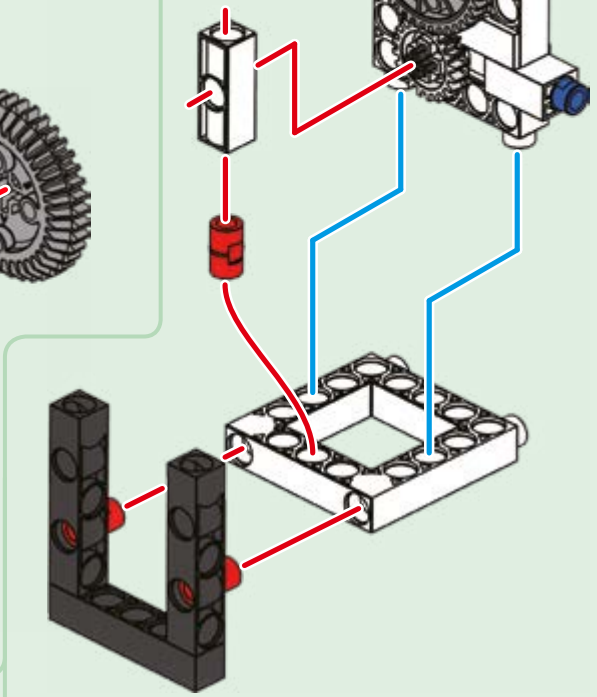
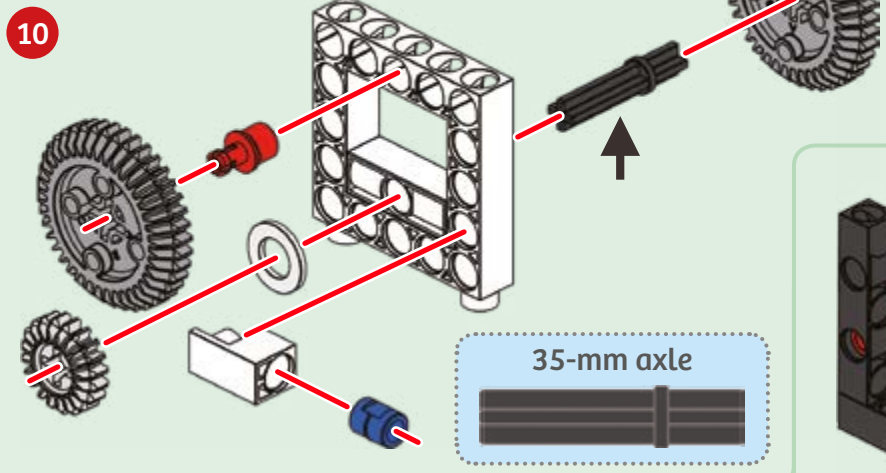
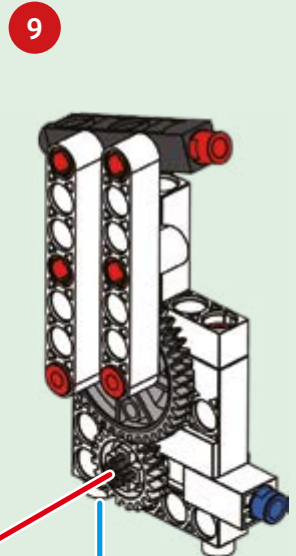
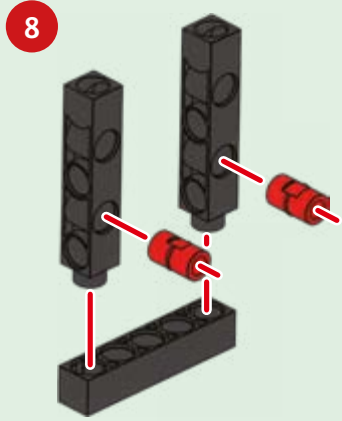
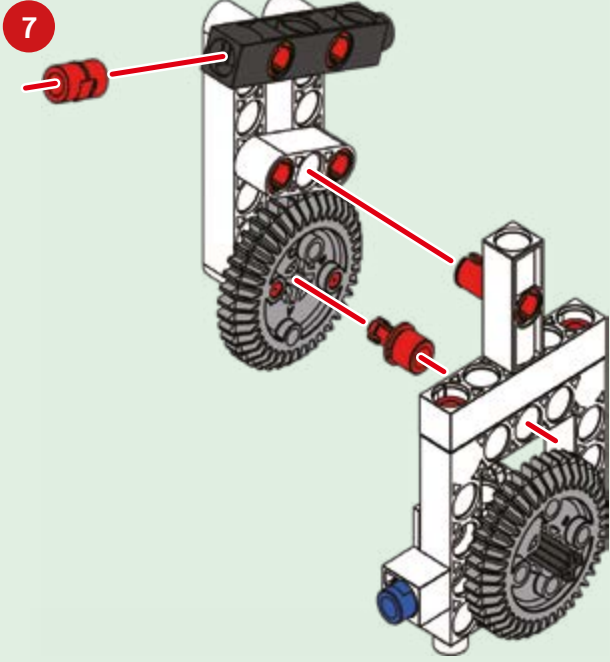
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|-----|----|----|-----|----|----|----|----|----|----|----|
| 1   | 3  | 4  | 6   | 7  | 8  | 9  | 10 | 11 | 12 | 13 |
| 10x | 2x | 3x | 6x  | 3x | 4x | 2x | 1x | 2x | 2x | 4x |
| 16  | 18 | 19 | 20  | 21 | 22 | 23 | 25 | 26 |    |    |
| 3x  | 5x | 4x | 1x  | 2x | 4x | 2x | 1x | 4x |    |    |
| 27  | 28 | 29 | 30  | 31 | 32 | 33 | 34 | 35 | 36 | 37 |
| 1x  | 1x | 4x | 1x  | 2x | 2x | 2x | 4x | 2x | 4x | 1x |
| 38  | 42 | 44 | 45  | 46 | 47 | 49 | 50 | 51 | 52 |    |
| 1x  | 6x | 4x | 23x | 5x | 3x | 4x | 2x | 1x | 1x |    |



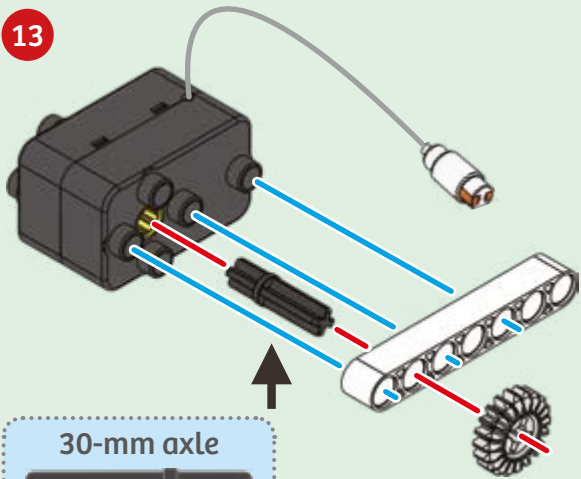




SPACESHIP CONTROLLER



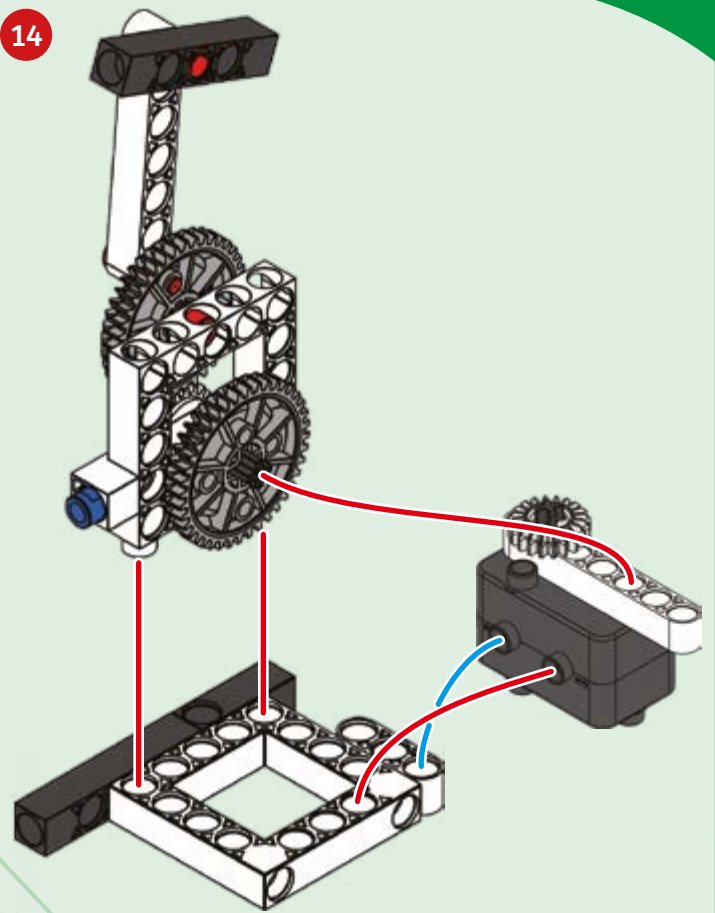
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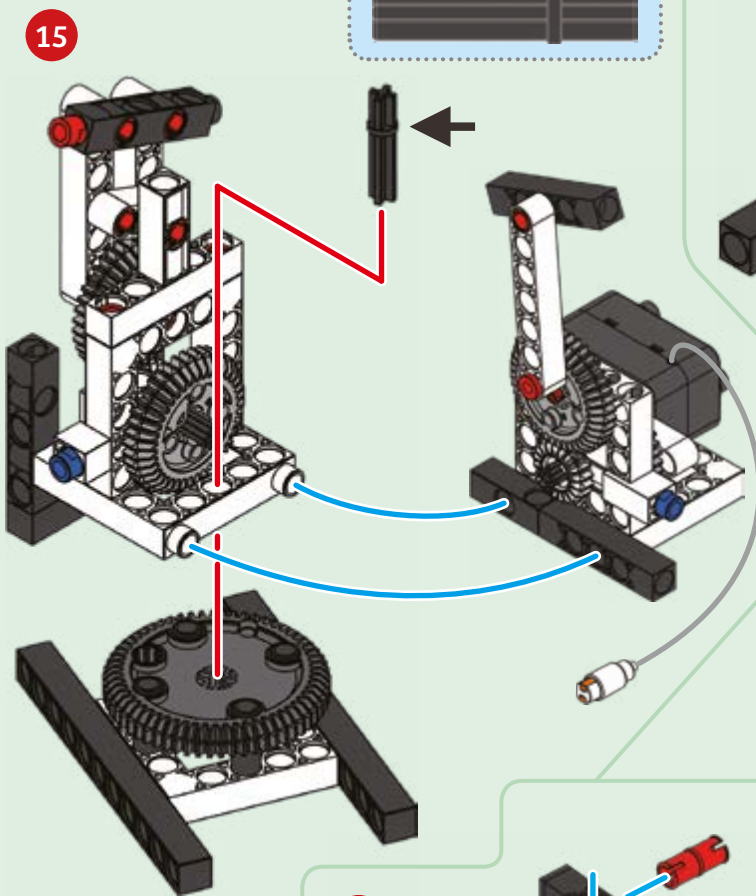
30-mm axle

35-mm axle

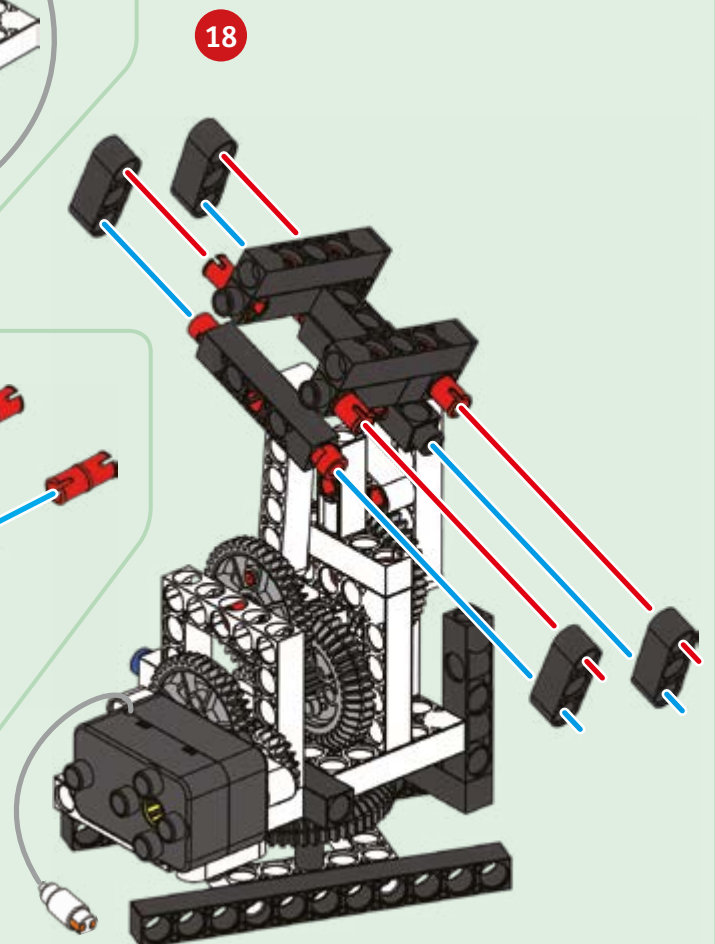
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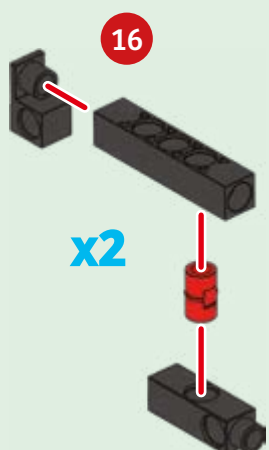
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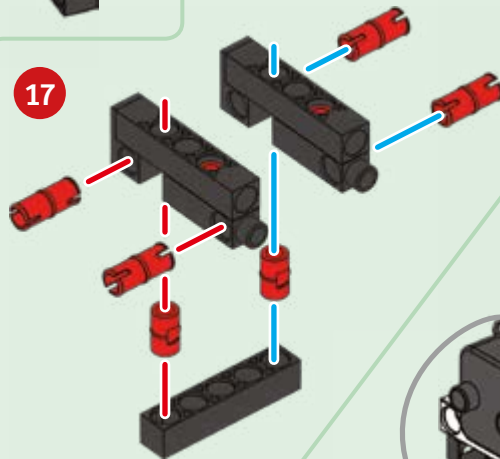
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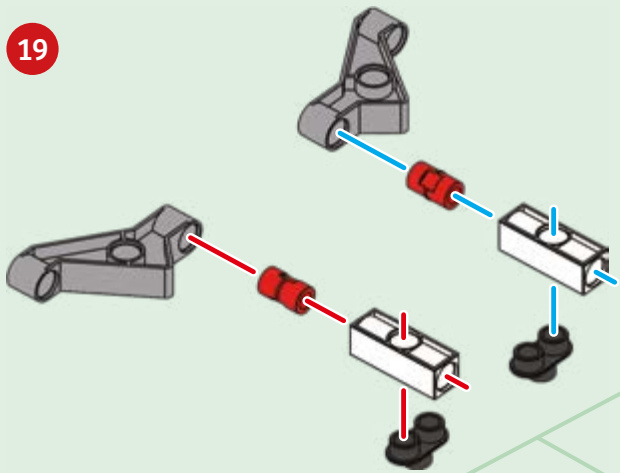




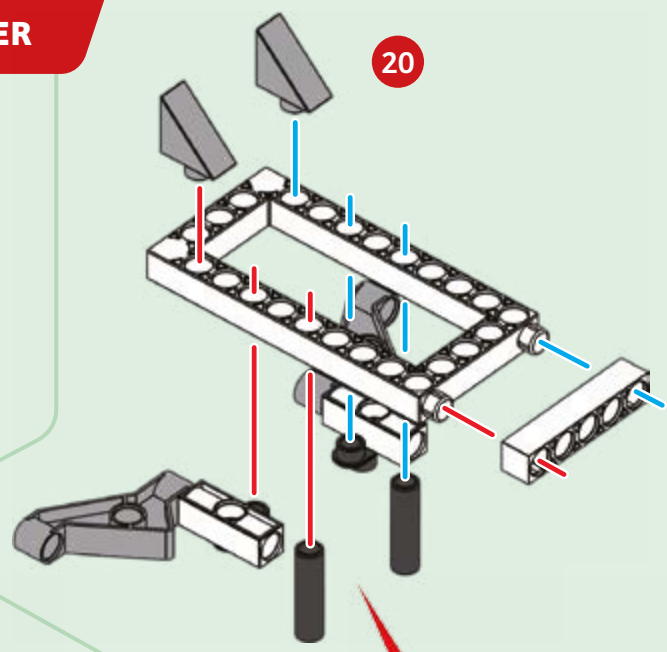


● ● ● SPACESHIP CONTROLLER

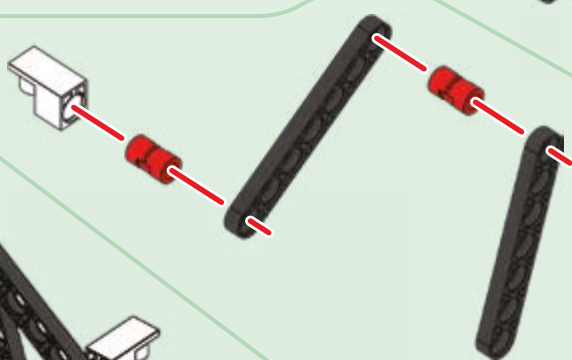
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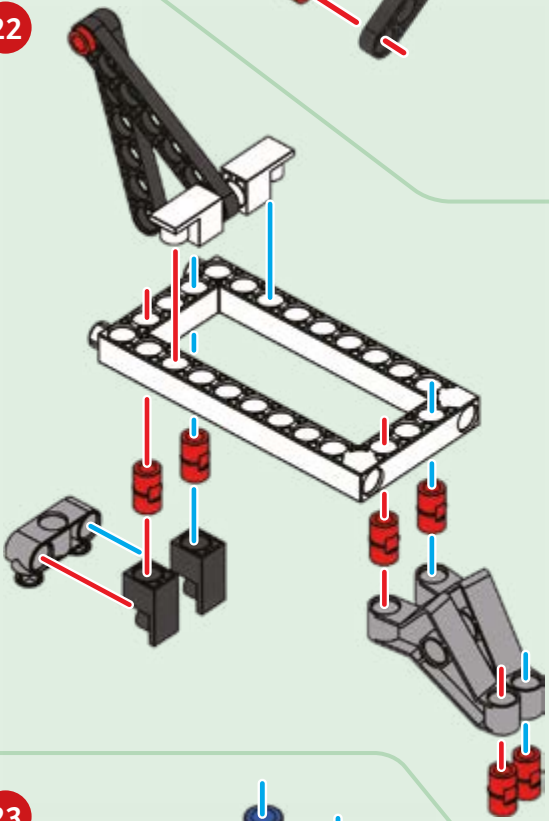
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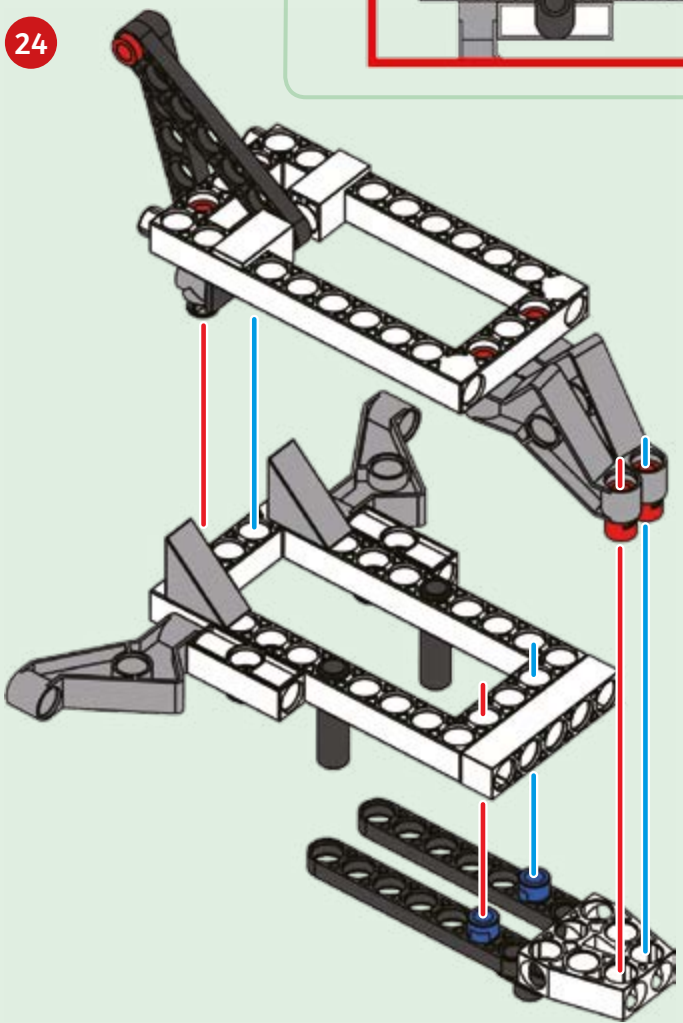
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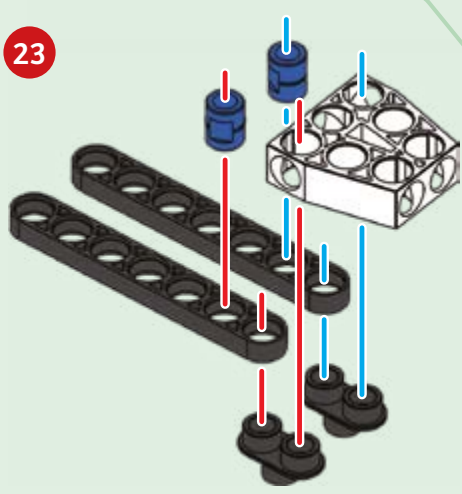
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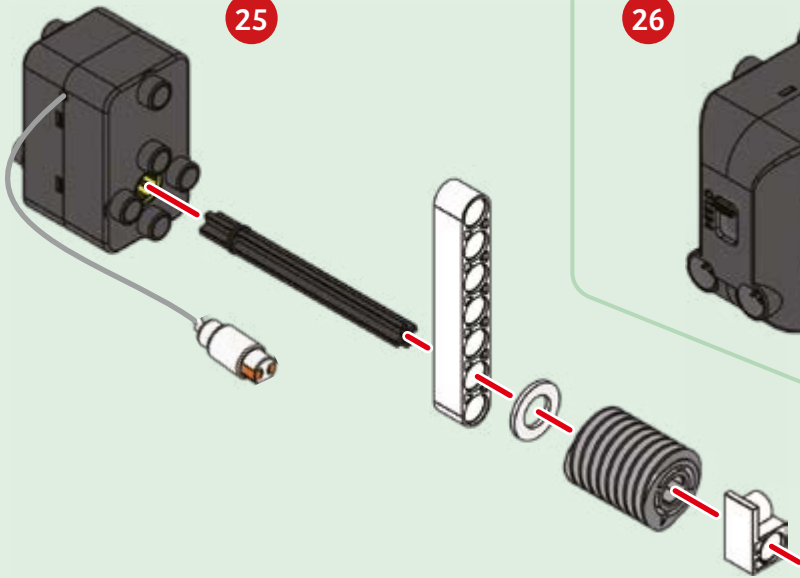
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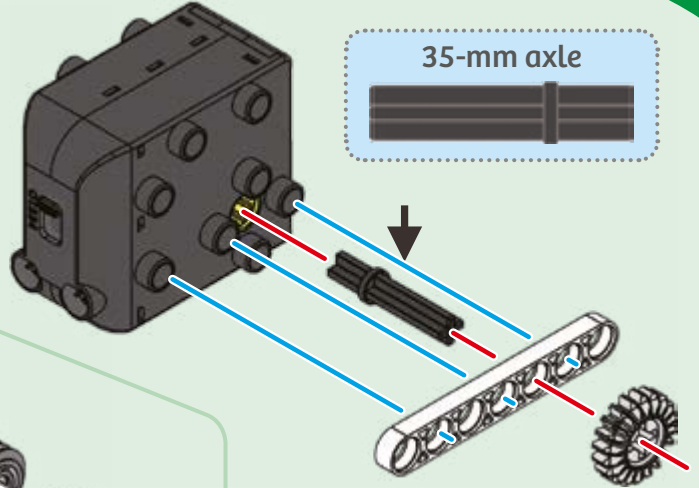
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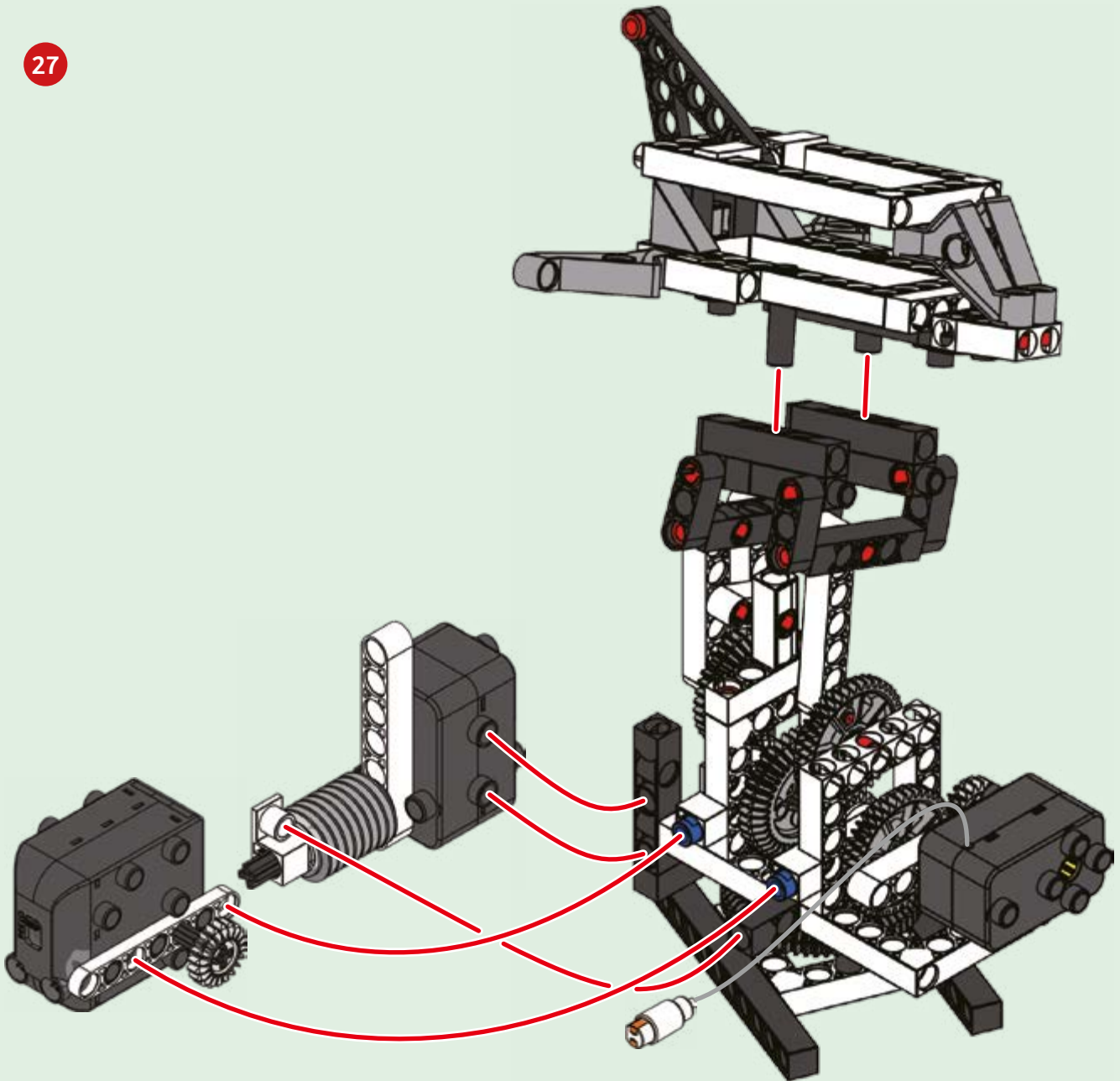
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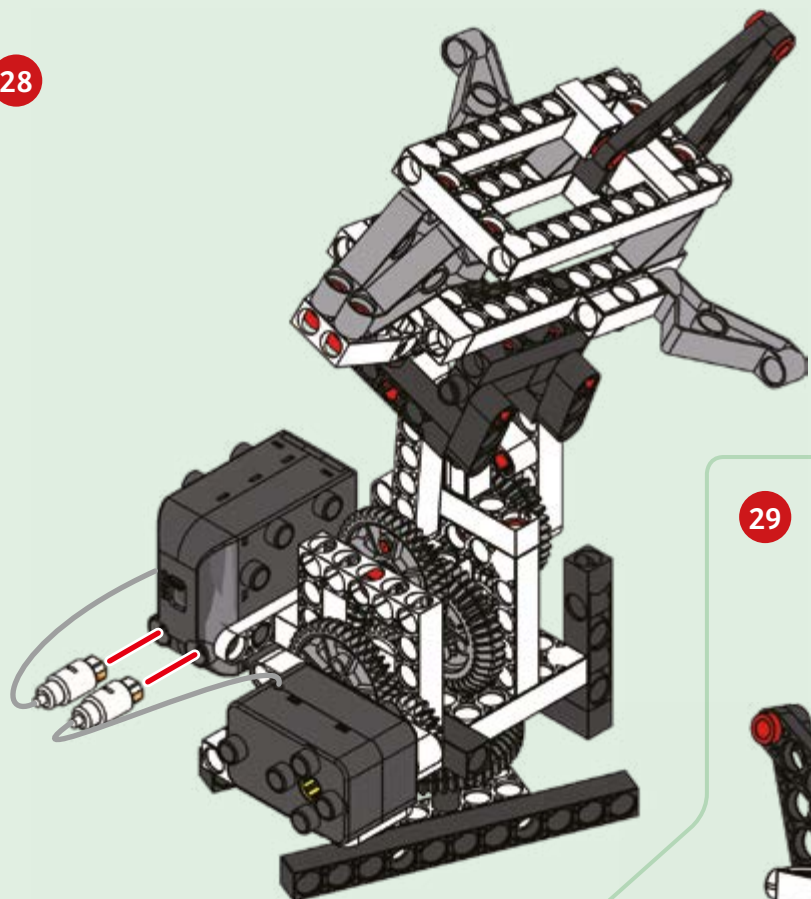
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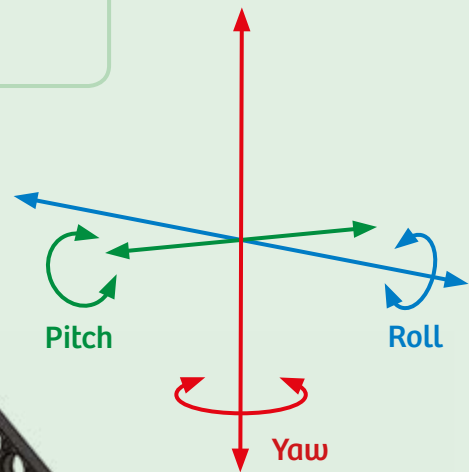




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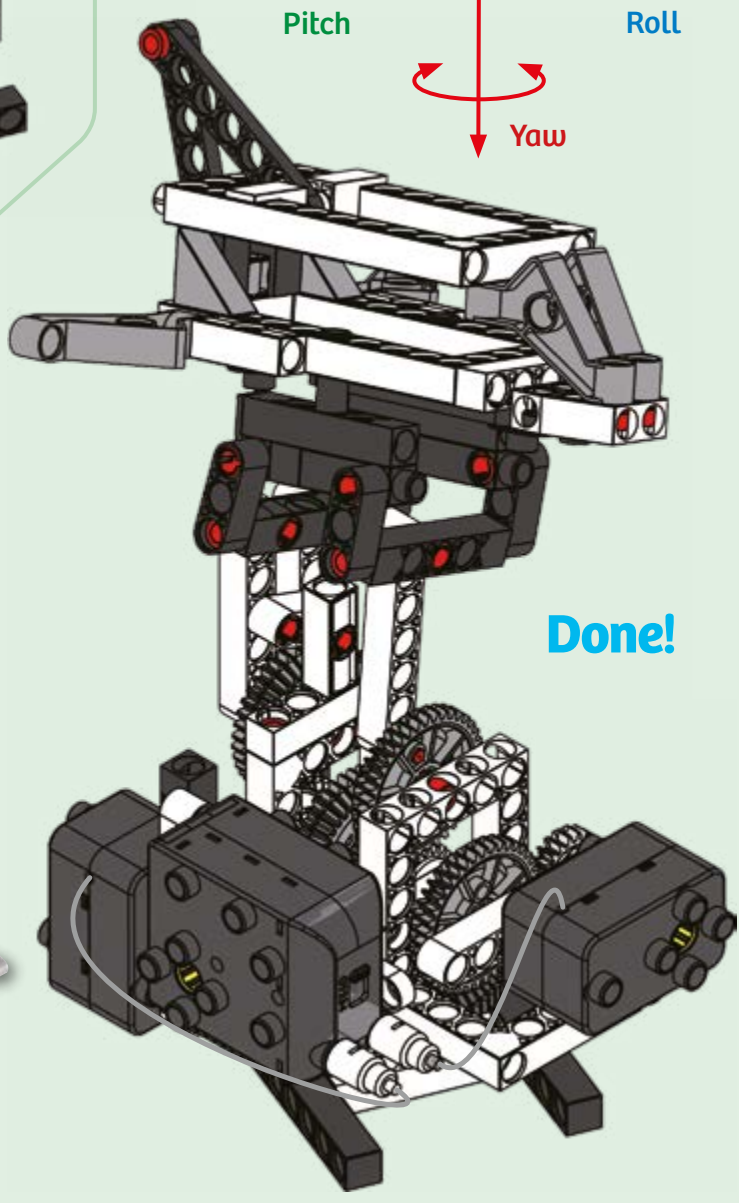
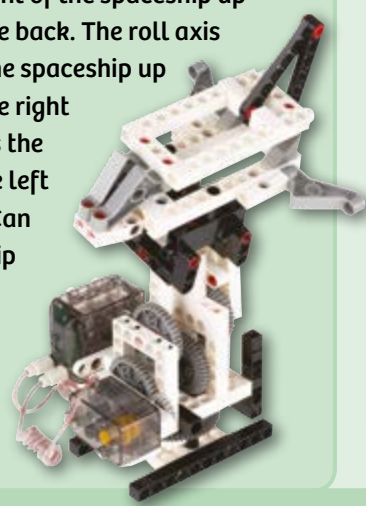


EXPERIMENT 10

Space flight simulator

HERE'S HOW

In space, the concepts of "up" and "down" don't mean what they do on Earth! If you had a spaceship, you could point it in any direction and go. This model lets you control a model spaceship in many directions, on three axes. The pitch axis moves the front of the spaceship up and down relative to the back. The roll axis moves the left side of the spaceship up and down relative to the right side. The yaw axis spins the spaceship around to the left or the right. Try it out! Can you point your spaceship toward every corner of the room you are in?



Done!

## CHECK IT OUT



## Where do we go from here?

Robot technologies have long been successfully used in the exploration of planets and space. Without them, there would be no spectacular missions to Mars or anywhere else.

But researchers have also been working on other astounding ideas and solutions. Let's start by taking a look at two projects that have already been realized.

### Landing 510 million kilometer away

Space engineers have already shown what they are capable of with one of the most difficult missions in the history of space travel: the landing of the **European probe "Philae" on the comet 67P/Churyumov-Gerasimenko, or Chury for short.** Comets are the remains from the creation of our Solar System. They are made of ice and frozen gases mixed with bits of rock, metal, and dust.

Philae is the first human-made device to land on a comet. To understand the magnitude of this achievement, think about the fact that Philae had to travel over ten years through space with the Rosetta probe. At the time of the landing, Chury was **over 510 million kilometers** from Earth. And the comet only had a diameter of just under 4 kilometers.

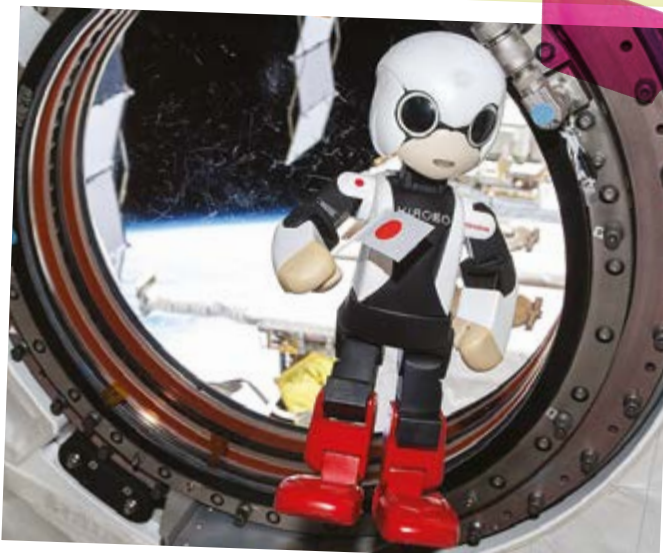
Even though Philae's landing wasn't perfect, the probe achieved 80 percent of its scientific goals shortly afterwards.

The results should contribute to our understanding of the Solar System. One of the questions to be answered is whether the Earth could have gotten its water and its first biomolecules from comets.



### "GOOD MORNING, PEOPLE OF EARTH"

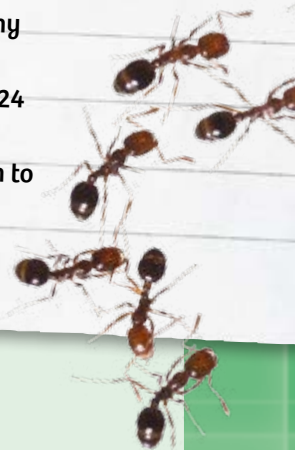
There is, in fact, already a personal robot in space. His name is **Kirobo**, and he was flown to ISS in August 2013. Once there, the 34-centimeter-tall and one-kilogram-light robot was supposed to "host" the Japanese astronaut Koichi Wakata and accompany him in space. Kirobo is considered a good listener, can recognize faces, and makes small talk with his human colleagues. He was created based on the cartoon character Tetsuwan Atomu, or "Astro Boy," Japan's all-time most famous robot hero.



### ANT ROBOTS IN SPACE

And what do researchers have planned for the future?

Dreams for the future include **ant robots** from Harvard University, which are intended to work together without any outside input. The researchers have created a homogeneous swarm of 1024 artificial machines that can even reproduce at will. The idea is for them to be used to help fight oil disasters or maybe even fly into space.







CHECK IT OUT



## Are robots the astronauts of the future?

A **Robonaut (robotic astronaut)** is a humanoid robot developed by NASA along with the Defense Advanced Research Projects Agency (DARPA). It is supposed to complete outboard tasks during space flights or on space stations such as the ISS. That way, astronauts will no longer have to leave the space ship or space station.

There are already several models of this robot series. Some are equipped with various means of movement, such as a Segway platform on four wheels. These ground-based Robonauts will be developed for missions on planetary surfaces. Robonauts can be controlled remotely.

**Robonaut 2**, developed jointly by NASA and General Motors, was sent to the ISS in February 2011. His human-like hands were designed to allow him to use the same tools as the station's human crew.

Robonaut 2 is modularly constructed, so the arms, "head," or torso can be switched out. He also has cameras. He can evaluate the pictures it takes and decide all by himself what actions to carry out in response. For example, Robonaut 2 is capable of entering text into a cell phone, recognizing and operating switches, and picking up and using tools. So Robonaut 2 can perform self-directed tasks, including outside the space station. If all works as planned, he should in fact be able to be used to relieve the human astronauts of duties like that.



## A 3D PRINTER FOR THE MOON

Another future project sounds even more like science fiction: **Living on distant planets** or other heavenly bodies. **Living on the moon** has long seemed impossible. How could all the building materials for a space station be transported there?

Now, researchers want to approach the problem in a different way. Using the latest technical advances in 3D printing, NASA plans to convert the **six-legged robot ATHLETE** into a 3D printer. ATHLETE, which looks a little like a giant spider, was originally designed to explore the moon's surface.

In the future, this robot is supposed to be used to **create a moon base using a 3D printing process**. As its building materials, instead of relying on the usual raw materials, this 3D spider printer will be using **moon dust**, employing microwaves and laser technology to melt the moon dust particles.

The first ATHLETES have already been converted for this purpose. The initial prototypes are already being tested as 3D printers at one of the NASA centers.

For several years, NASA has been working together with a private company on a 3D printer for the ISS. In the future, this 3D space printer should enable astronauts to manufacture their own tools and other devices. The first tests of the 3D printers in zero gravity have been successful.

So you see: The future of space travel has already begun.





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