EXPERIMENT MANUAL

REMOTE-CONTROL MACHINES DLX

THAMES & KOSMOS

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Safety Information

WARNING. Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long cords may become wrapped around the neck. Store the experiment material and assembled models out of the reach of small children.

WARNING. Only suitable for children over 8 years. Instructions for parents are included and have to be observed. Keep the packaging and instructions as they contain important information.

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 five AA batteries (1.5-volt, type AA / LR6) or five AA rechargeable batteries (1.2-volt, min. 2300 mAh / type AA / LR6), 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.

››› Always insert batteries in the right polarity orientation, pressing them gently into the battery compartment.

››› 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.

››› Be sure not to bring batteries into contact with coins, keys, or other metal objects.

››› Avoid deforming the batteries.

With all of the experiments that use batteries, have an adult check the experiment or model before use to make sure it is 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!

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.

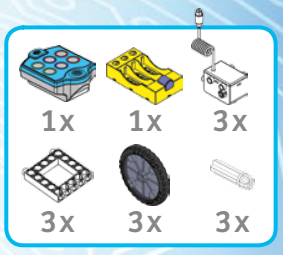
NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, maybe 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 form that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

An experiment to hit the ground running

Here are some important preparations to do before you start building the remote-control machines. Run this test to make sure that all the motors work!

Operating the motors by remote control

YOU WILL NEED

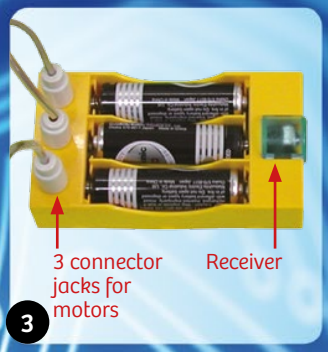


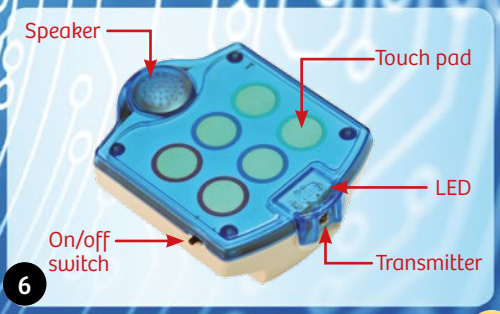
- IR remote control
- Battery box with receiver
- 3 motors with wire
- 3 square frames
- 3 wheels
- 3 motor shafts
- *5 AA batteries (1.5-volt, type AA/LR6) or 5 AA rechargeable batteries, (1.2-volt, min. 2300 mAh/type AA)*

HERE'S HOW

1. Open the battery compartment on the bottom of the IR remote by sliding the cover off.
2. Insert two batteries into the IR remote. Make sure to insert them in the proper direction. Then close the compartment again.
3. Insert three batteries into the receiver's battery compartment. Again, pay attention to the direction.
4. Insert one motor shaft into each of the wheels and then insert the shafts into the three motors. To prevent the motors from tipping over, secure each of them to one of the square frames.
5. Now connect the motor wires to the battery box by inserting them in the three jacks mounted on the battery box end opposite the receiver.
6. Switch on the IR remote. Use the touch pad to make the motors turn to the left or right.

WANT TO LEARN MORE?
Then come on into the exciting world of robots!





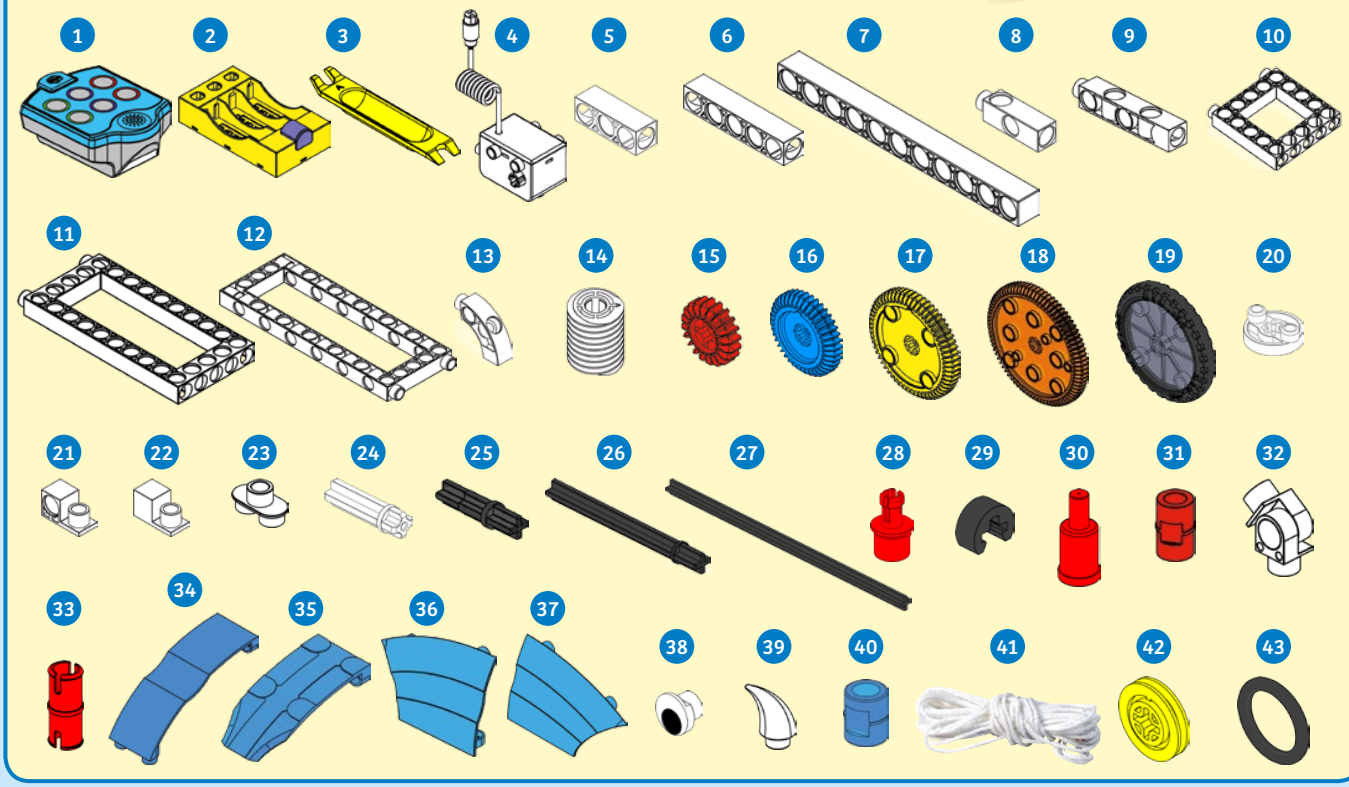
WHAT'S HAPPENING?

As soon as a link is established between the IR remote and the receiver, the little red LED on the remote will light up and you will hear a sound. Which pair of touch pad buttons is responsible for which motor is determined by the jack into which you inserted the wire. This picture shows you how they are arranged. Why not see what happens when you switch the wires around?

Although the motors are installed in different orientations in the different models, the battery box with the receiver is usually placed in such a way that it is best to stand behind the models as you drive them. The assembly pictures will show you which wire to insert into which jack. Always hold the remote with its transmitter pointed at the model.

GOOD TO KNOW ! If you are missing any parts, please contact Thames & Kosmos customer service. Any materials not included in the kit are indicated in *italic script* under the "You will need" heading.

The parts in your kit:



Checklist: Find – Inspect – Check off

✔	No.	Description	Count	Item No.
❍	1	IR remote control	1	715 040
❍	2	Battery box with receiver	1	715 041
❍	3	Part separator tool	1	702 590
❍	4	Motor with wire	3	710 419
❍	5	3-hole rod	3	715 042
❍	6	5-hole rod	6	714 179
❍	7	11-hole rod	8	714 282
❍	8	3-hole dual rod	4	714 283
❍	9	5-hole dual rod	6	714 126
❍	10	Square frame	4	714 284
❍	11	Short frame	3	715 044
❍	12	Long dual frame	3	715 045
❍	13	Curved rod	2	714 285
❍	14	Worm screw	3	715 046
❍	15	Small gear, red	4	710 062
❍	16	Medium gear, blue	2	710 061
❍	17	Large gear, yellow	2	715 047
❍	18	Extra-large gear, orange	1	715 048
❍	19	Wheel and tire	4	715 049
❍	20	Rod connector	2	715 050
❍	21	90-degree converter - X	4	715 051
❍	22	90-degree converter - Z	2	714 128
❍	23	Two-to-one converter	6	714 286
❍	24	Motor shaft axle	4	702 801
❍	25	Short axle (3 cm)	2	703 236
❍	26	Medium-long axle (7 cm)	3	713 490

✔	No.	Description	Count	Item No.
❍	27	Extra-long axle (15 cm)	1	703 518
❍	28	Axle pin	2	702 525
❍	29	Axle lock	2	702 813
❍	30	Shaft pin	2	702 526
❍	31	Anchor pin (red)	28	702 527
❍	32	Hinge	2	715 052
❍	33	Joint pin	10	702 524
❍	34	Large body plate	1	714 013
❍	35	Small body plate	2	715 280
❍	36	Body plate 3	1	714 276
❍	37	Body plate 4	1	714 277
❍	38	Eye	2	715 053
❍	39	Horn	2	715 054
❍	40	Short anchor pin (blue)	8	714 129
❍	41	String	1	715 055
❍	42	Small pulley	1	707 011
❍	43	Small rubber o-ring	1	703 205

You will also need:

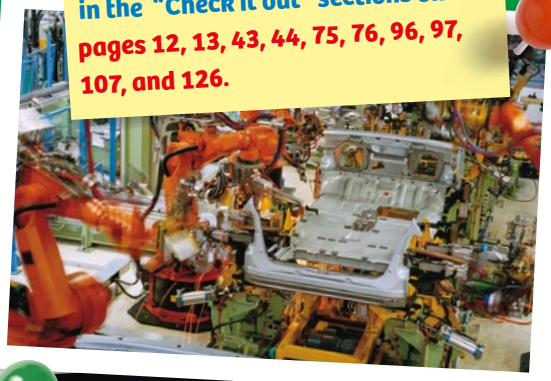
No matter what: 5 AA batteries (1.5-volt, type AA/LR6) or 5 AA rechargeable batteries, (1.2-volt, min. 2300 mAh/type AA)

You will need the following items in order to perform the experiments: Experiment kit packaging, coin, masking tape, stop watch, screw top from a water bottle, water, dish cloth, scissors, felt-tip pen, large marble, measuring tape, note pad, pen, small paper cup, paper clip, pin, fine sand, trowel and hand broom, toy figure, books, calculator, balloon, ruler, table tennis ball

Also: Material for making boxes and pallets (see pages 127-128): colored card stock or heavy construction paper, glue, tracing paper or wax paper

››› TABLE OF CONTENTS

TIP!
You will find additional information in the "Check it out" sections on pages 12, 13, 43, 44, 75, 76, 96, 97, 107, and 126.



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

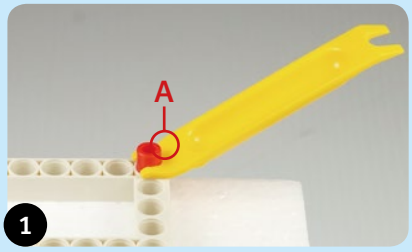
››› It shows you the difficulty level for the model's assembly:

Here are a few tips for assembling the models. Read through them carefully first and you will find the assembly process to be much easier.

The part separator tool

In the box, you will find a little yellow tool called the part separator tool.

1. End A of the part separator tool makes it easy to remove anchor pins from the frames.



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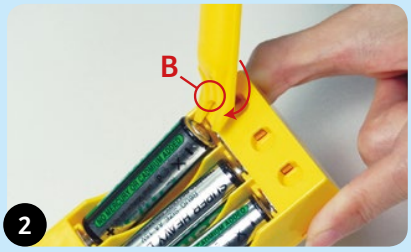

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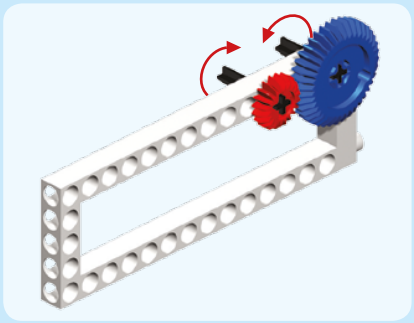
2. End B of the tool is used for removing batteries from the battery compartment.

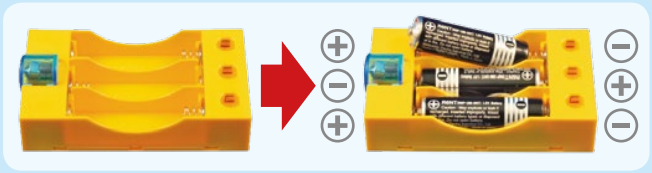
Gear wheels



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.

You have probably also discovered the worm screw by now. It looks a little like the thread of a screw. It will also have to mesh tightly into the installed gear wheels. See page 20 to learn more.

Battery box



Insert the batteries in accordance with their indicated plus-minus polarity. Push them down with gentle pressure until they click into place between the spring and the metal contact plate.

IR remote control

1. To open the battery compartment on the bottom of the IR remote, slide the cover forward at the grooved location.
2. Insert two batteries, paying attention to the polarity indicated in the compartment and on the batteries.
3. Close the compartment again.


1


2

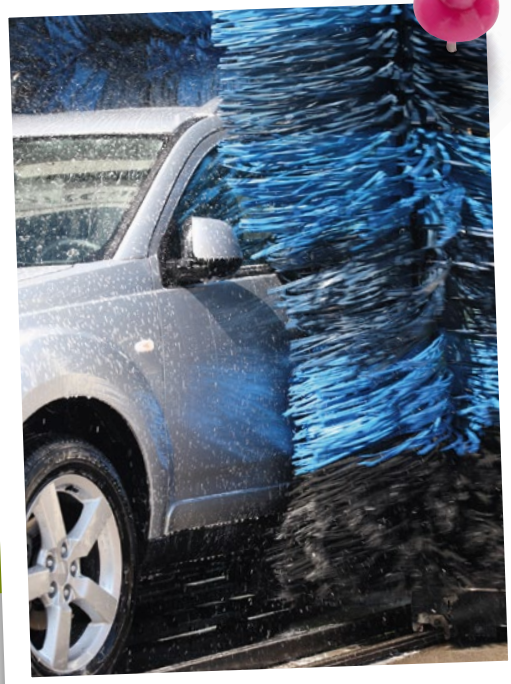
TIP!

Once a certain amount of time has passed without activation of the IR remote control, the contact between the remote and the receiver will be broken. If that should happen, simply switch the remote off and then back on again.

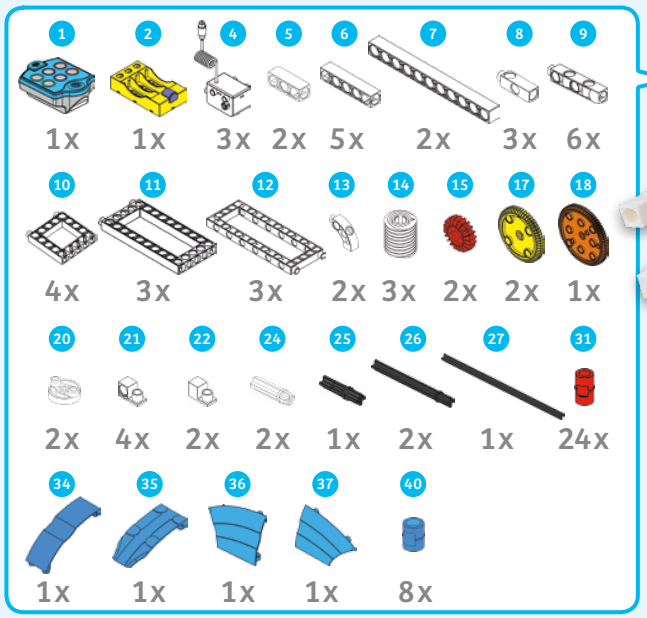
The Robotic Arm: Technology of the Future at Your Fingertips

Robots have been in existence for a long time. And there are a lot of things that they can do. One of their most important tasks is to support us in our work. In fact, the name "robot" comes from the Czech word "*robota*," which can be translated as "work."

The 20 models in this kit will give you a fascinating look into the world of robots. Let's start with a classic — the robotic arm.



ROBOTIC ARM


1 1x
2 1x
4 3x
5 2x
6 5x
7 2x
8 3x
9 6x
10 4x
11 3x
12 3x
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14 3x
15 2x
17 2x
18 1x
20 2x
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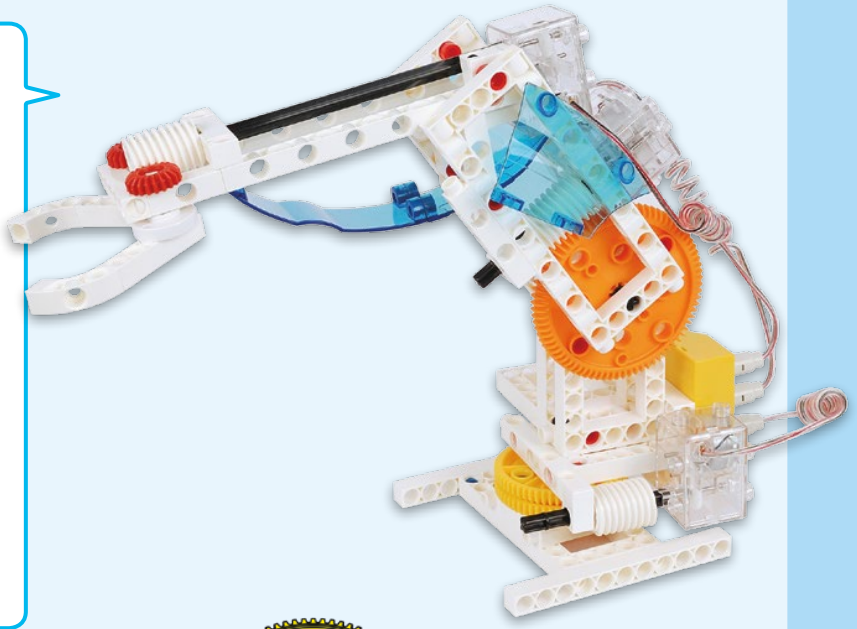
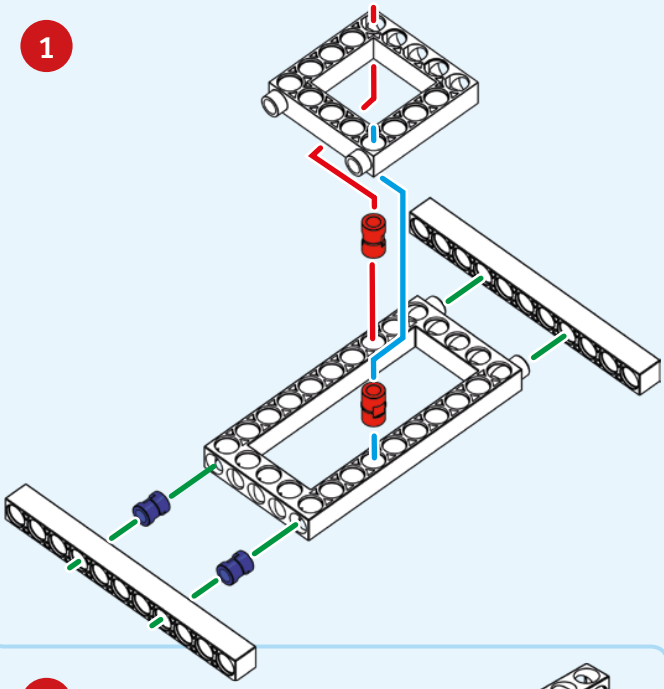
31 24x
34 1x
35 1x
36 1x
37 1x
40 8x

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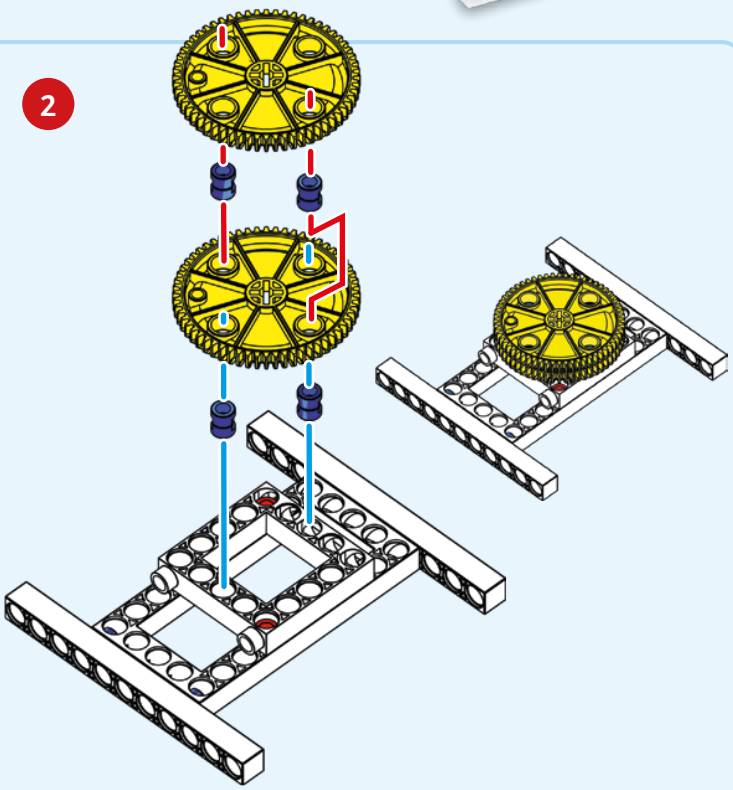
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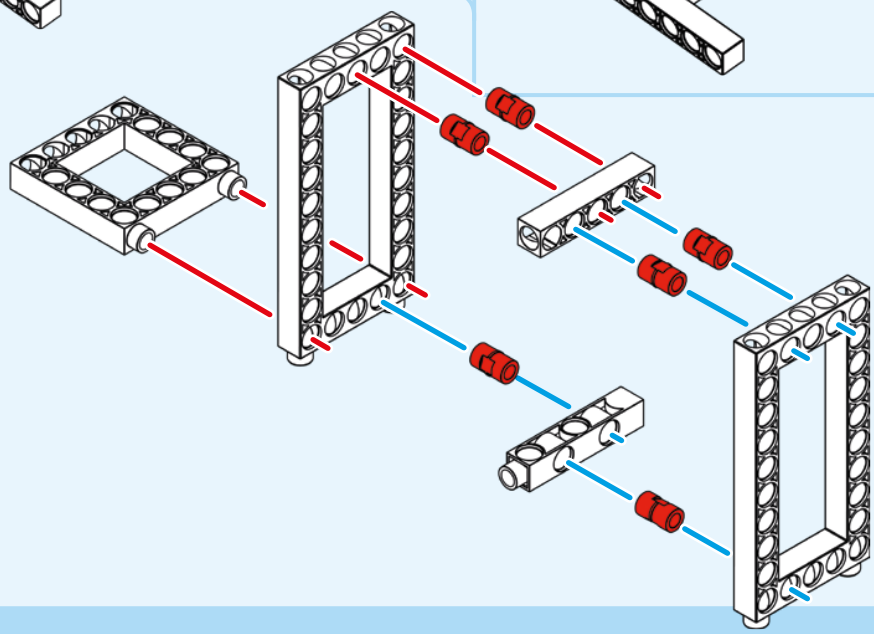
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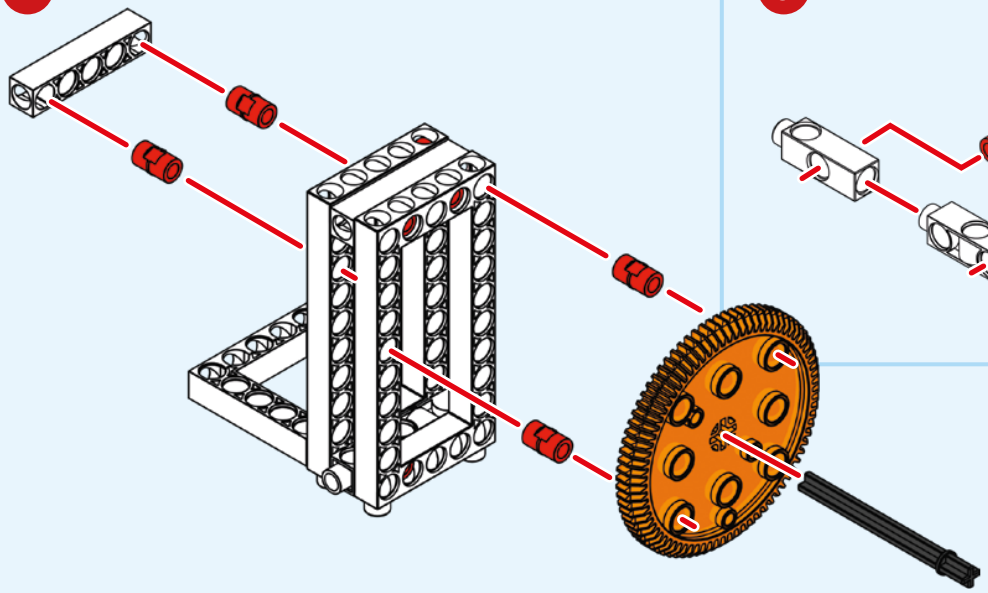

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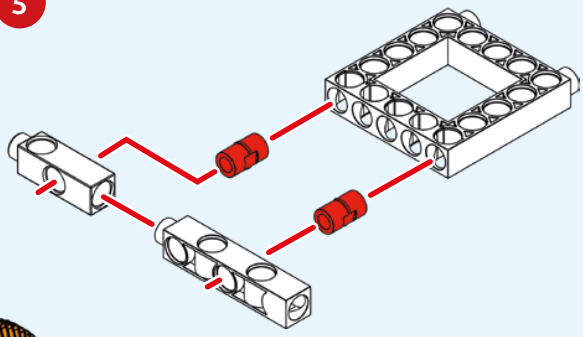

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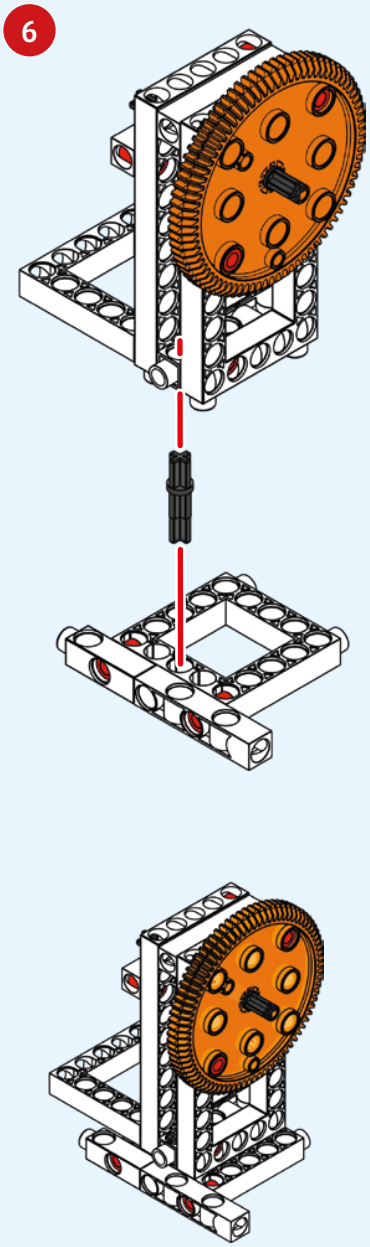

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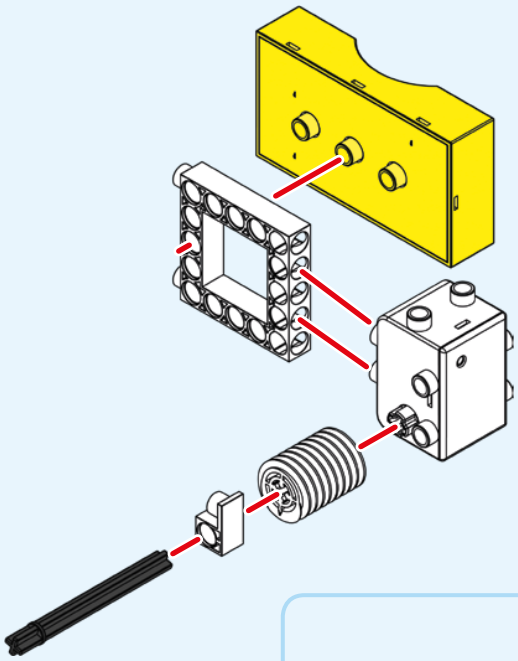

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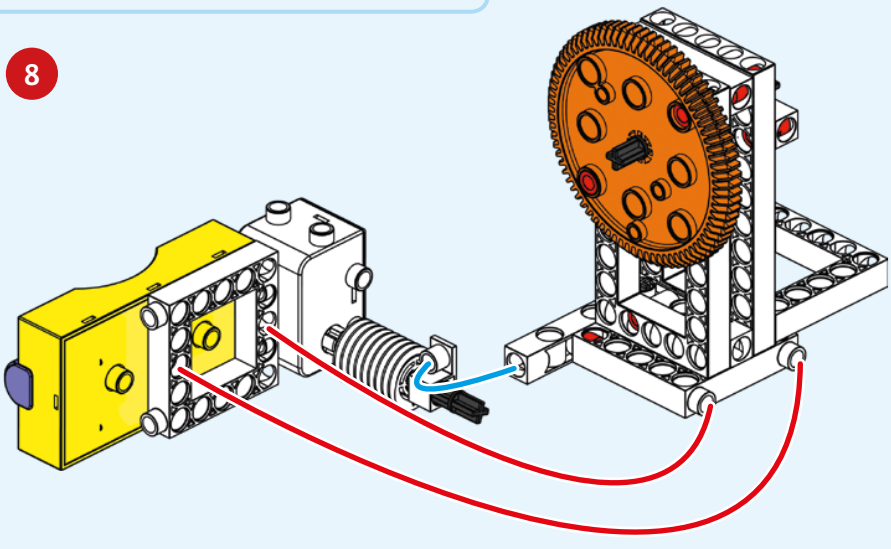

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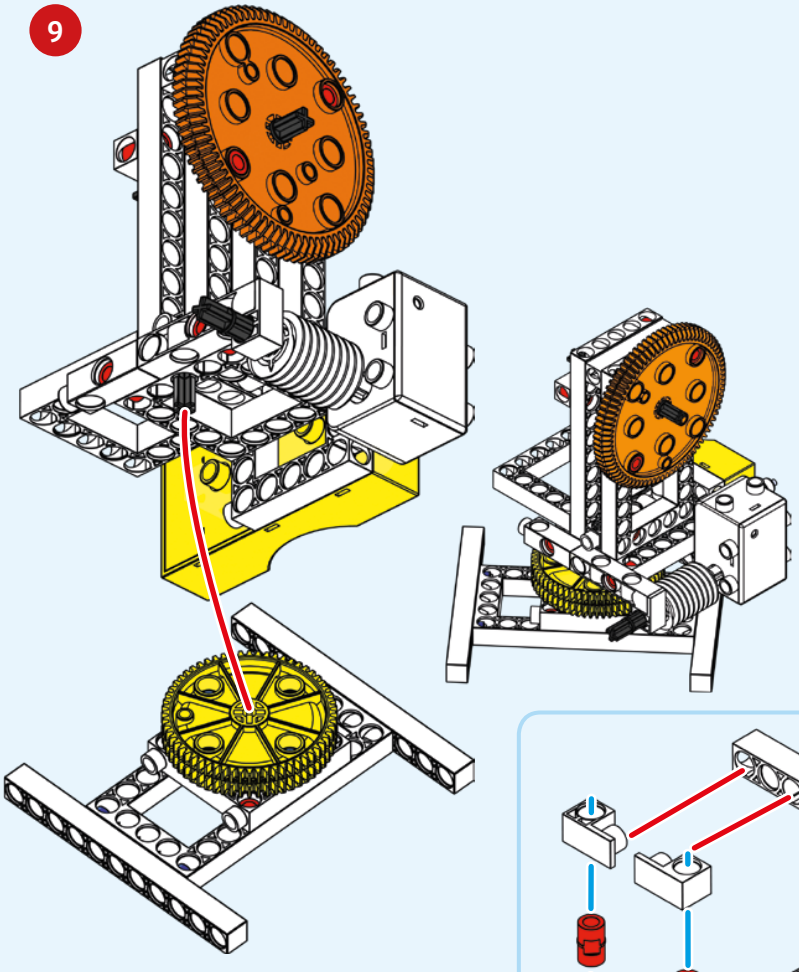

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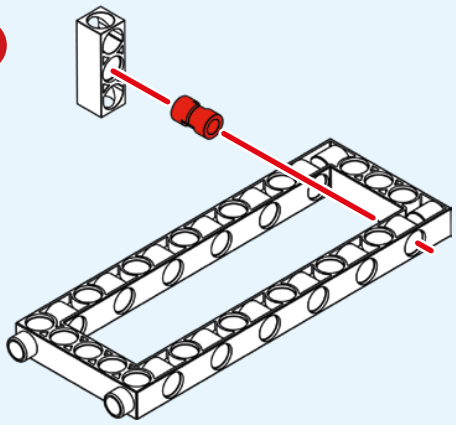

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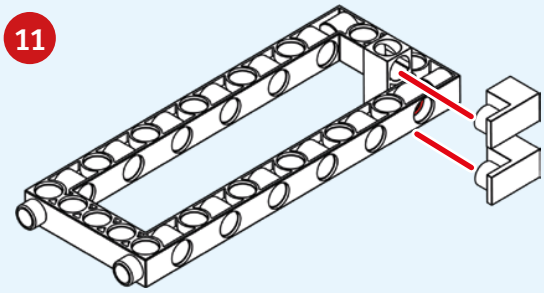

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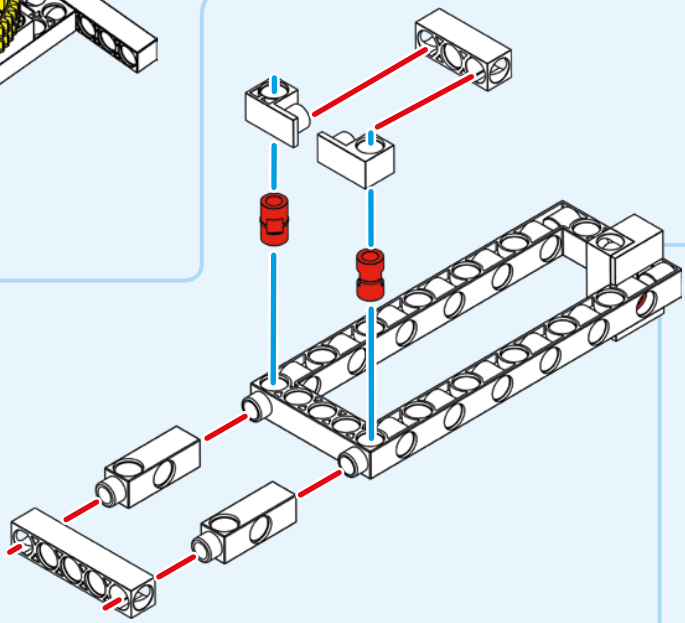

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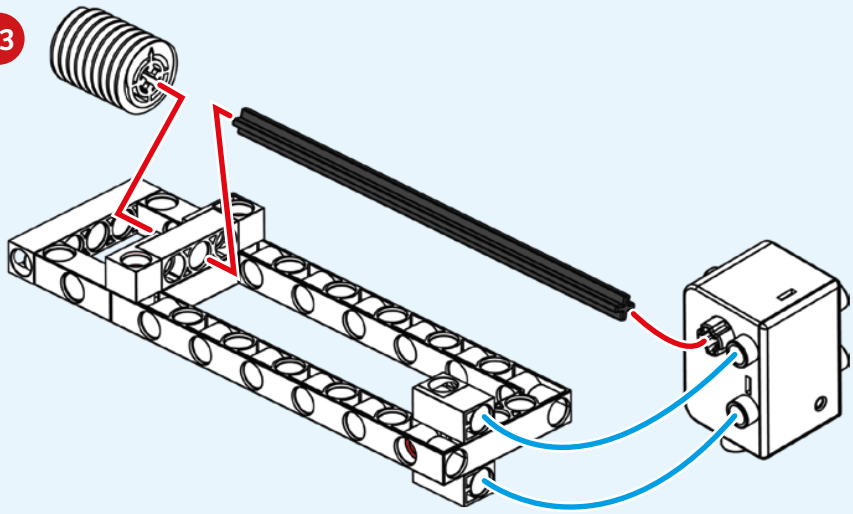

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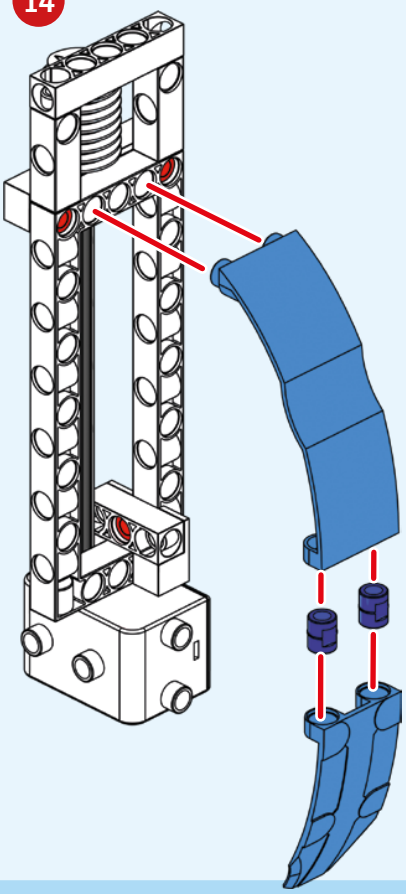

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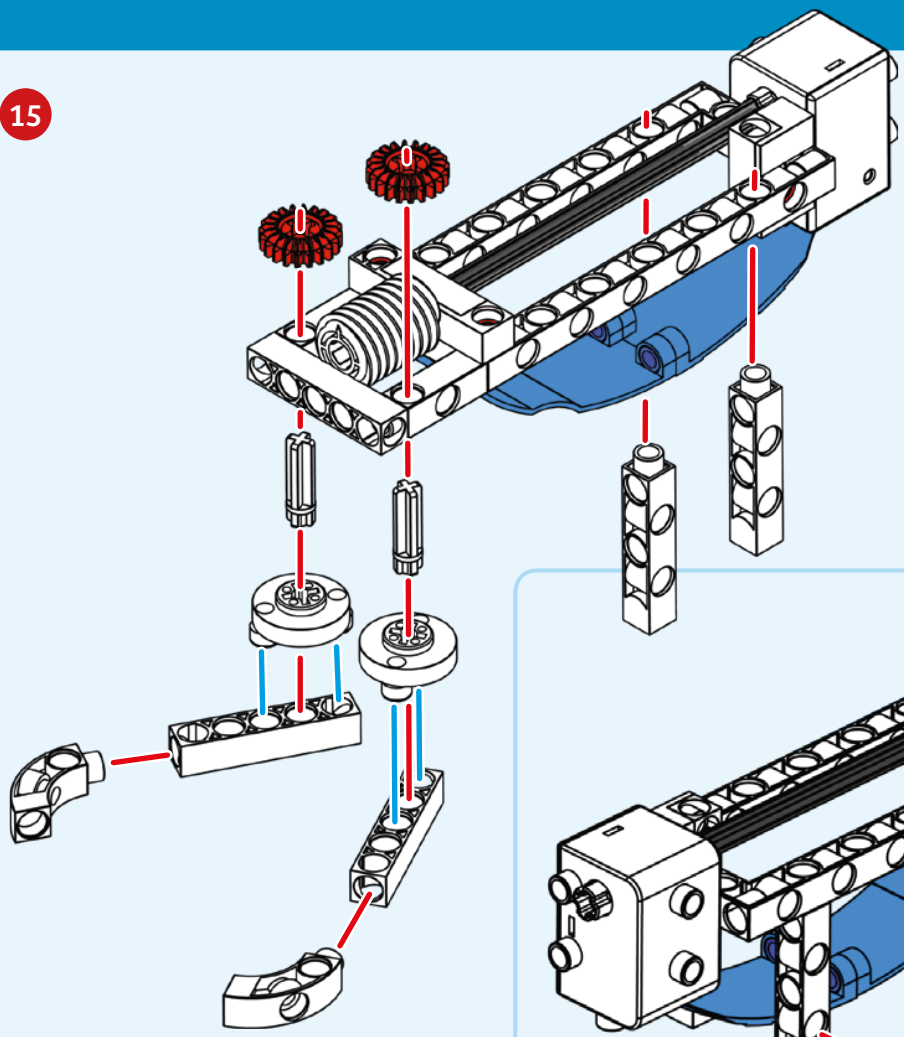

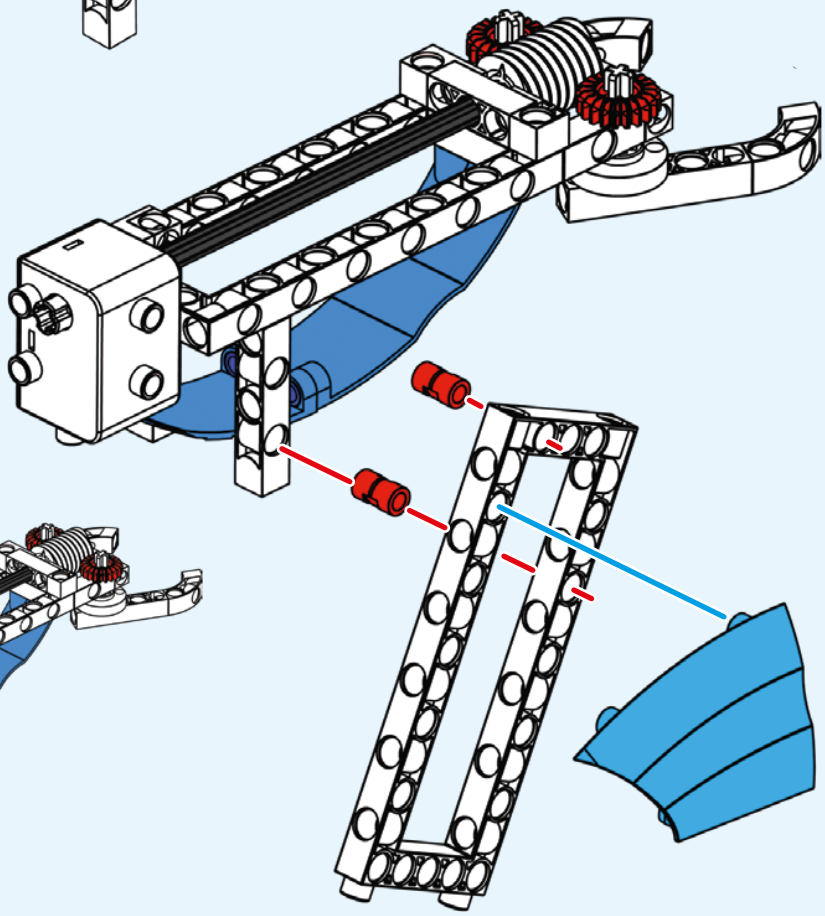

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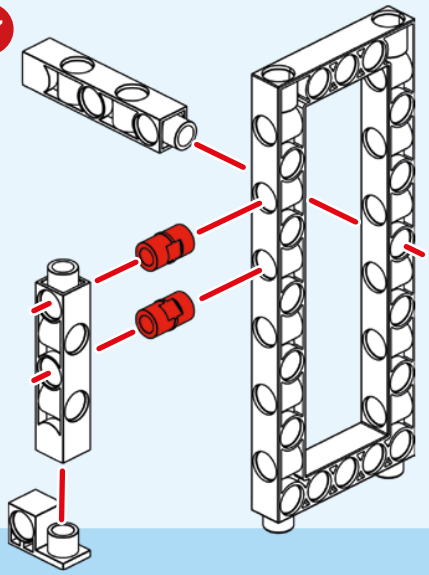

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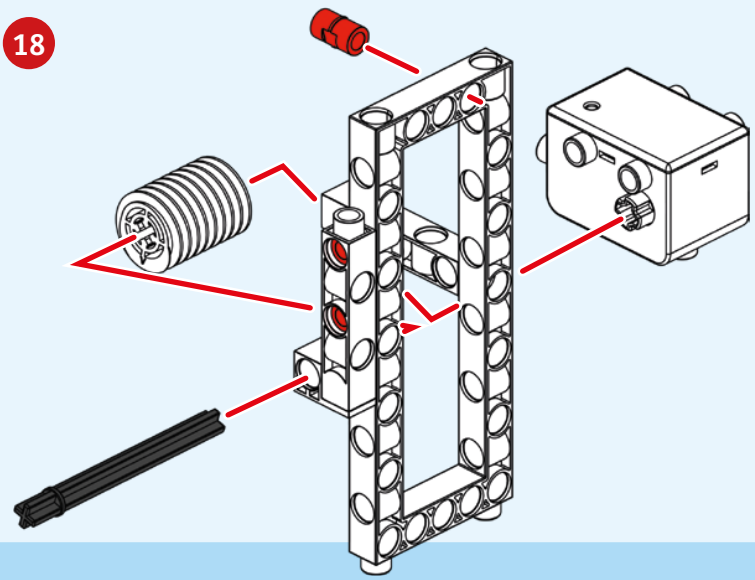

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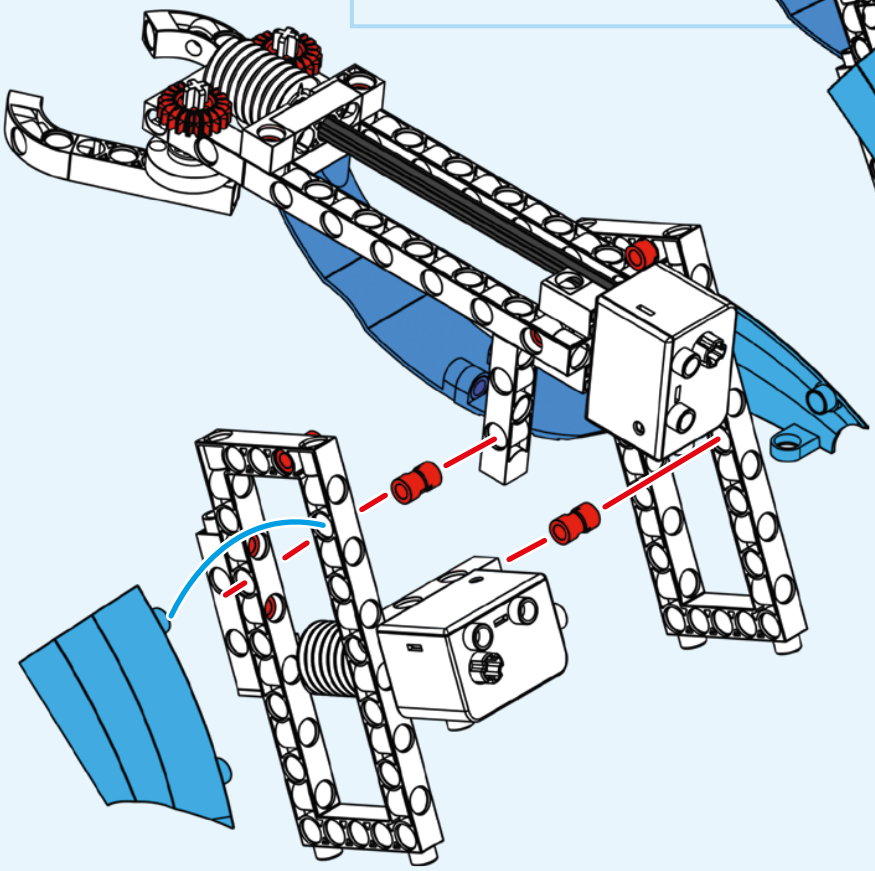

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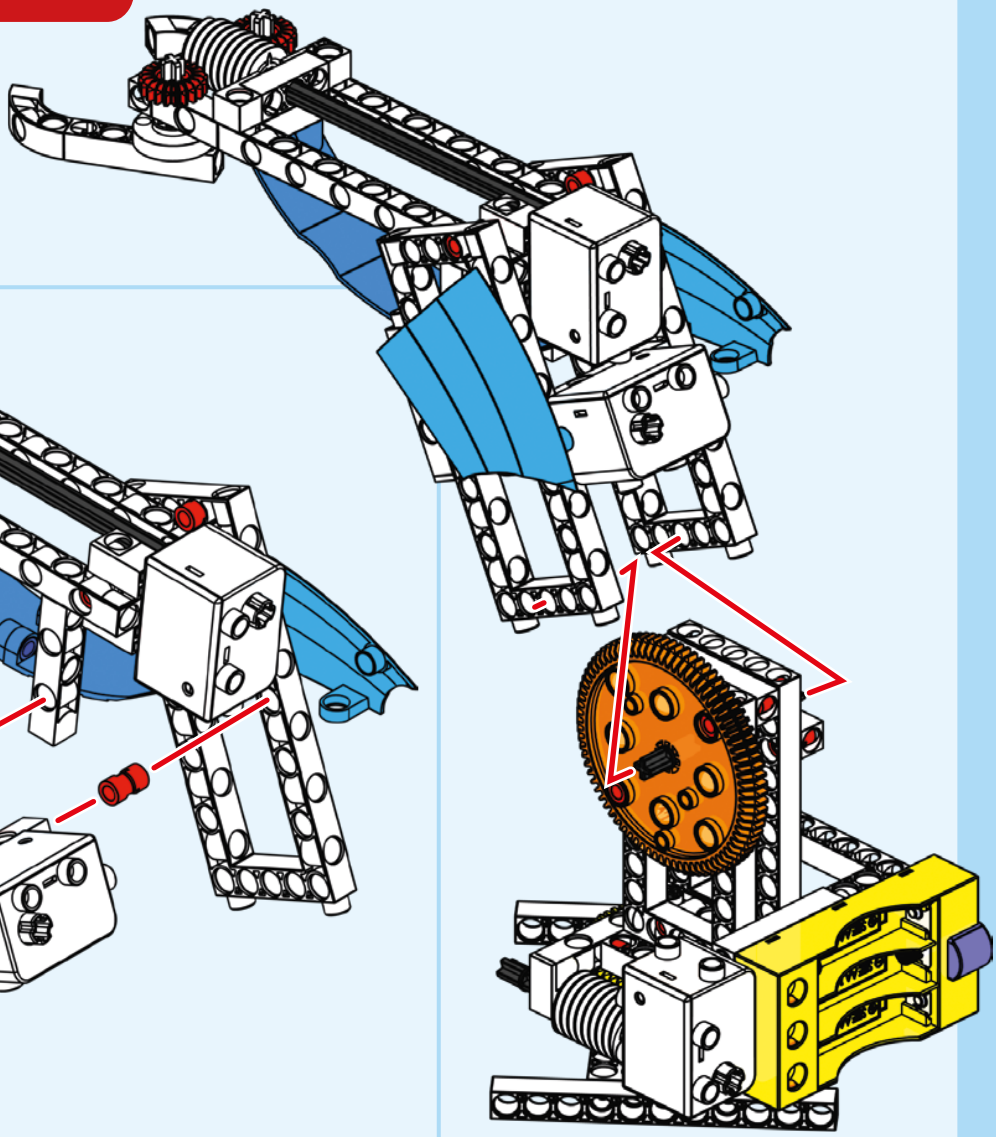
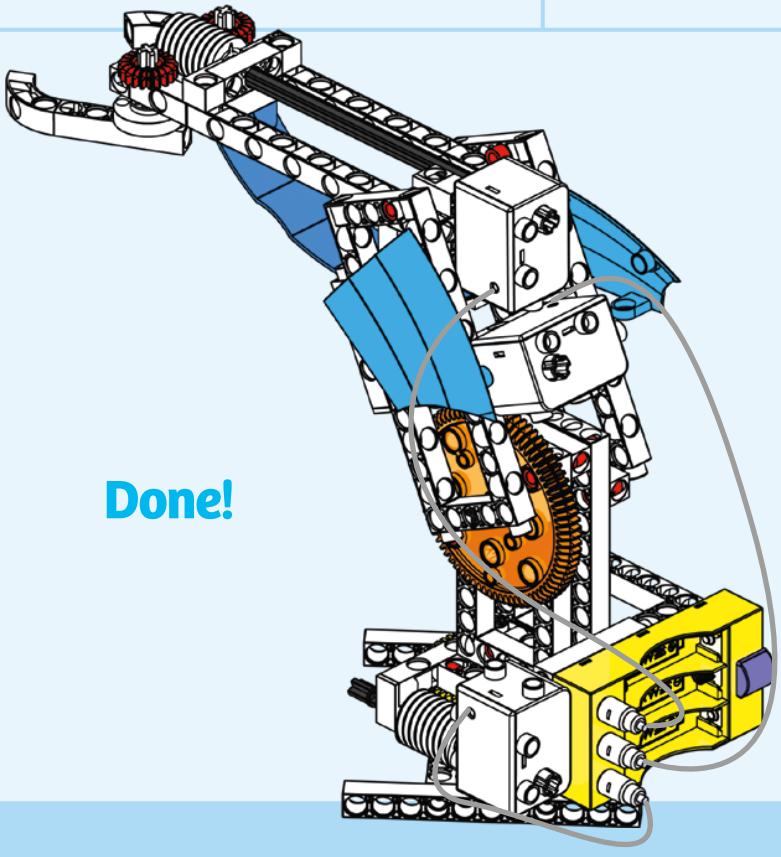
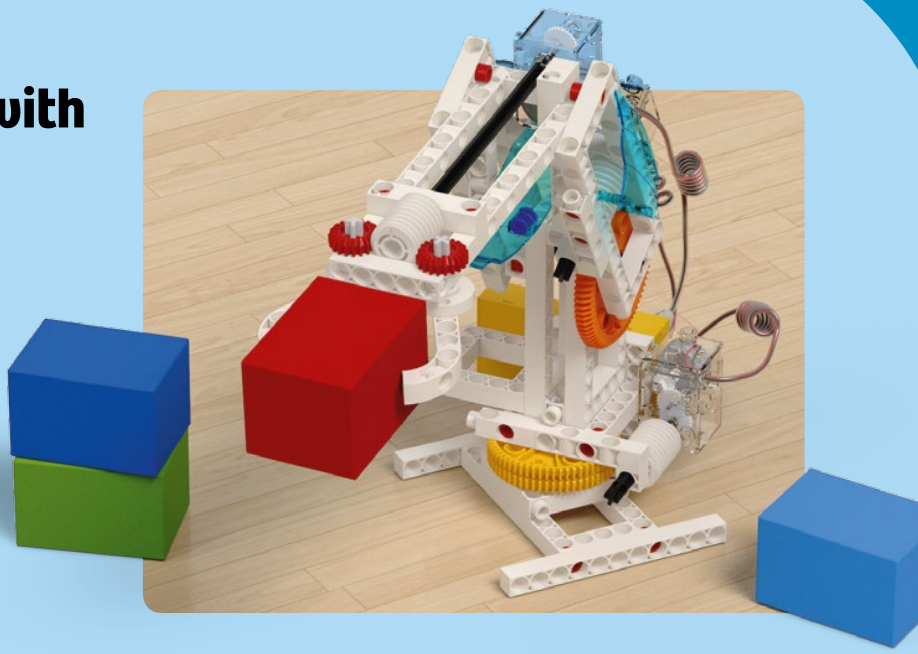




Done!

EXPERIMENT 1

Moving delicate cargo with the robotic arm



YOU WILL NEED

- **The assembled robotic arm**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *4 or more boxes (see page 127)*
- *Experiment kit packaging*
- *Coin*

HERE'S HOW

1. Set the robotic arm someplace where it will have enough room to move. Perform a test run to familiarize yourself with its controls and to be sure you know which touch pad buttons you use to steer it.
2. Are you ready to start? Pile up a stack of four (or more) boxes within easy reach of the arm.
3. Steer the robotic arm so that it grabs the top box. Lift up the box and rotate the robotic arm 180 degrees, or a half-circle.
4. Carefully set down the box and release it. Lift the arm straight up so it doesn't knock over the box as it moves away.
5. Move the arm back to the original stack, grab the next box, and move it to the new stack. Keep going until you have brought the entire stack to the new location.
6. Or, you can try transporting all of the boxes at once. Or try using a support platform for your cargo, such as the experiment kit box.
7. And now for the ultimate challenge: Set a coin on its edge, grab it with the robotic arm, and set it back down on its edge again!

WHAT'S HAPPENING?

The touch pad works more or less the same as the touch pad of a tablet computer or a smart phone. When you touch a button with your finger, it triggers the remote control's electronics to make the motor turn. See how much pressure you have to apply and for how long in order to get the motor to turn a desired amount.

If you want, you can control all three motors at the same time, and in any combination. In other words, you can make them all move in the same direction or make one move in a different direction from the others. Sudden changes from left to right or vice versa are also possible.

WANT MORE?

Organize a little competition: Who can load the cargo the fastest? Try to save time by operating the motors simultaneously rather than in sequence.

A Brief Guide to Robotics

What exactly is a robot? A simple definition could be something like: A robot is a machine that does work that humans would otherwise do.

The most important components of a robot are as follows:

- the sensors that collect data about the surroundings and about the position of the robot's own components
- the actuators, or movable components such as motors that change the shape, position, and orientation of the robot
- the robot's controls
- the mechanical framework
- the robot's drive mechanism

The science that deals with robots is known as robotics. Robotics experts distinguish autonomous robots from robots that are controlled remotely — like the ones in this kit. Likewise, robots can work either in one fixed place or as mobile units.

In short, there are a lot of different types of robots. Some of the most important ones are presented here on these two pages.

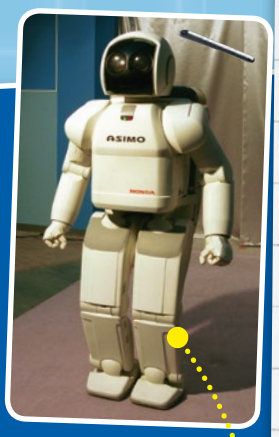
AUTONOMOUS MOBILE ROBOTS

These robots move all by themselves and perform their tasks without any human assistance. Typical functions include following a line on the ground or a source of light, or avoiding obstacles. There is also a sport called robot-sumo, in which mobile robotic sumo wrestlers fight each other.

DOMESTIC ROBOTS

There are already domestic robots performing chores in people's households today. Some well-known examples are: vacuum-cleaner robots, lawnmower robots, and window-cleaning robots. The Care-O-bot II can even handle and fetch everyday household objects. You will find more on this topic in the "Check it out" section on page 43.

HUMANOID ROBOTS



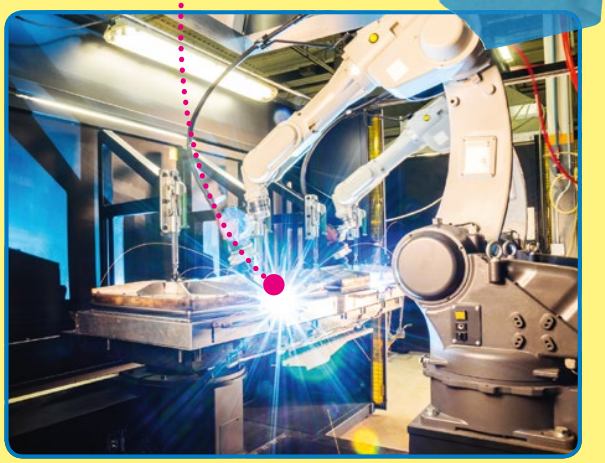
"Humanoid" is a term meaning human-like. For a long time, humanoid robots only existed in the fantasy worlds of science fiction books and movies. One reason for that is that designing something to move on two legs is not as simple as you might think. But the basic problem has been solved for a few years. That means that robots such as Honda's ASIMO are able to move around all by themselves and perform chores with their artificial arms and hands.

ROBOTIC EXPLORERS

The most famous robotic explorers have been ones that have actually done their work in outer space — the Mars rovers Sojourner, Curiosity, and Opportunity. The ten-kilogram Sojourner rover, for example, was able to move freely on the Martian surface, perform rock and soil analyses, and transmit its findings back to Earth.

INDUSTRIAL ROBOTS

Industrial robots are usually the least impressive to look at. That's because they are often constructed specifically to perform just one task over and over. For example, a tool such as a claw might be permanently installed on a robotic arm. Industrial robots are used in the automobile industry for such things as welding.



ROBOTIC TRANSPORTERS

These "workhorses" are already being used for many tasks. For example, they can pick up boxes all by themselves, transport them, and put them down again (see the "Check it out" section starting on page 75).

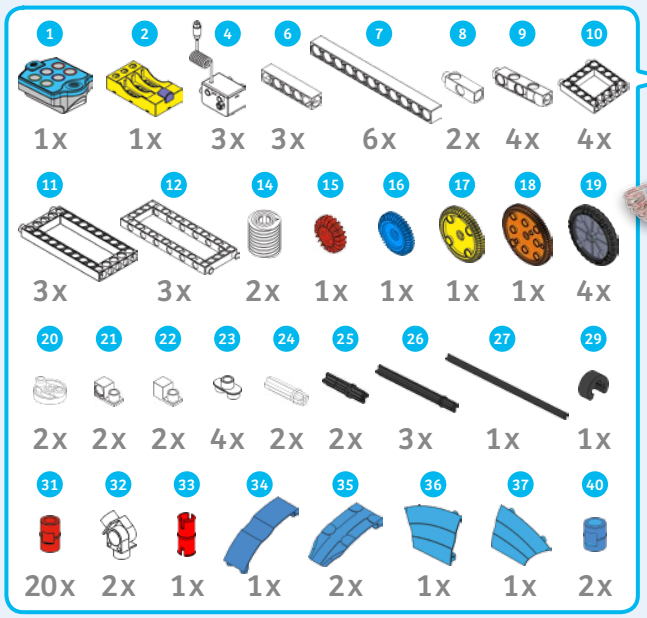
LEGGED ROBOTS

Legged robots are able to move with the help of legs. Usually, they have four or six legs so they don't tip over so easily.

Can Robots Push and Crawl?

There's one field of application that is becoming more and more important for robots — working in rescue operations following events like serious accidents, fires, or earthquakes. In these applications, robots have to be able to do tricky things like crawl across difficult terrain or push aside rubble, to name just two. Robots still have a hard time with demanding tasks like these. But who knows? They may soon be performing even more rescue operations and taking more injured victims out of harm's way.

BULLDOZER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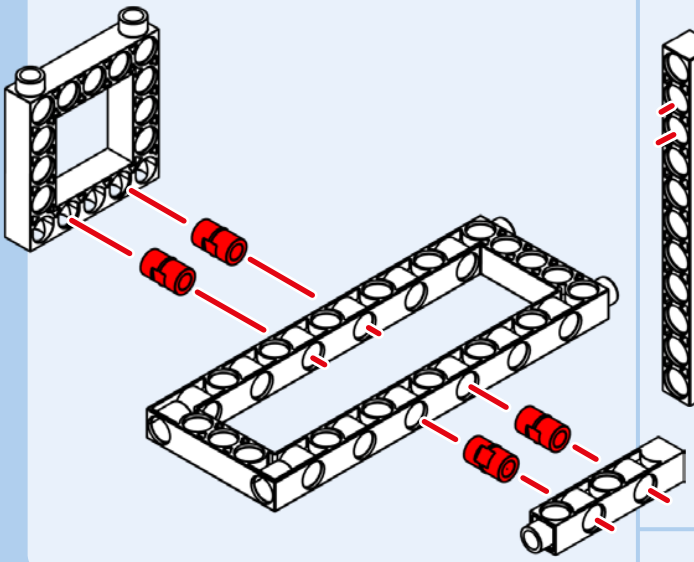
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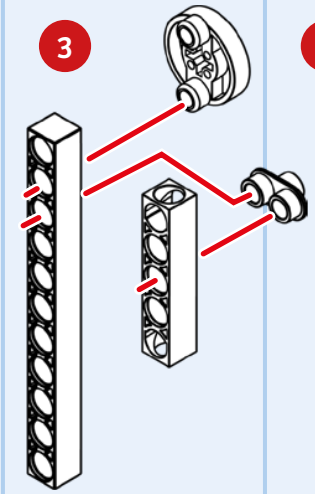
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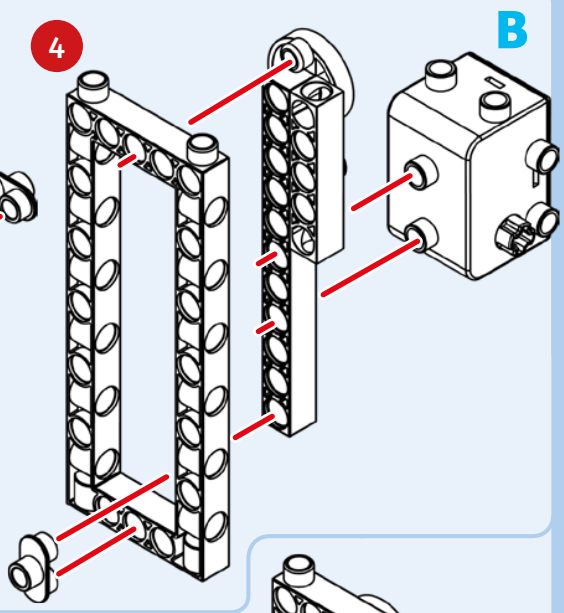
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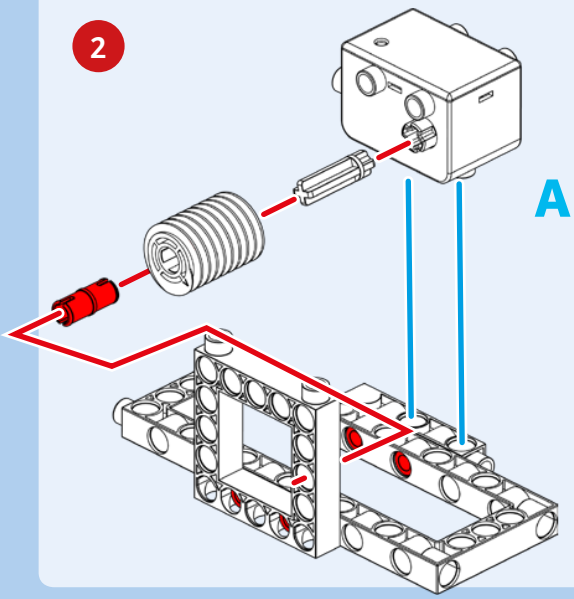
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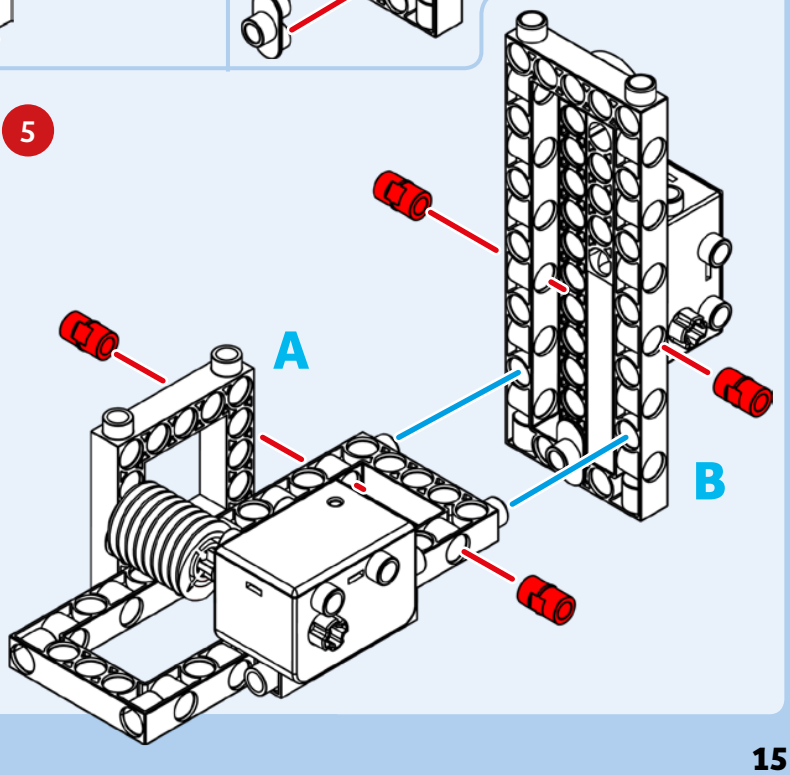
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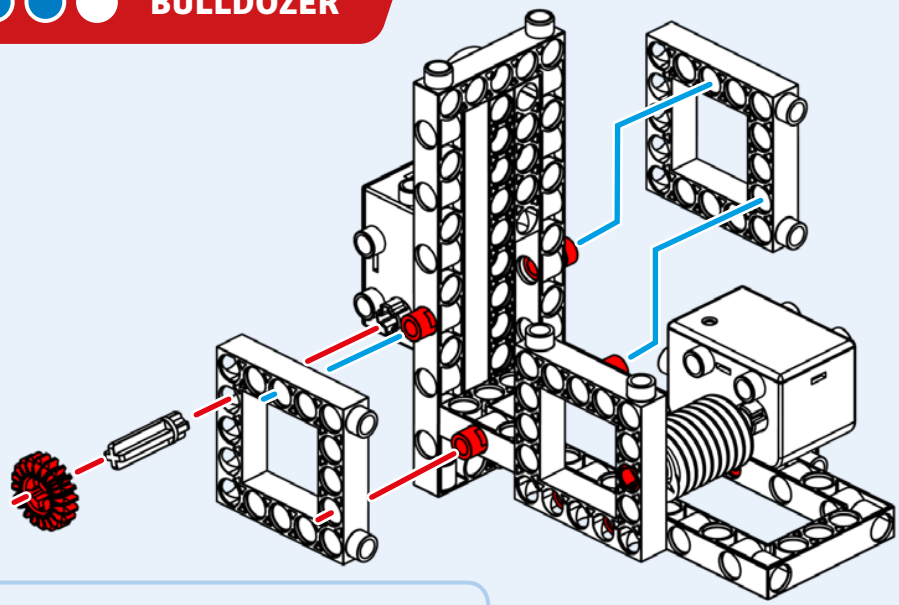

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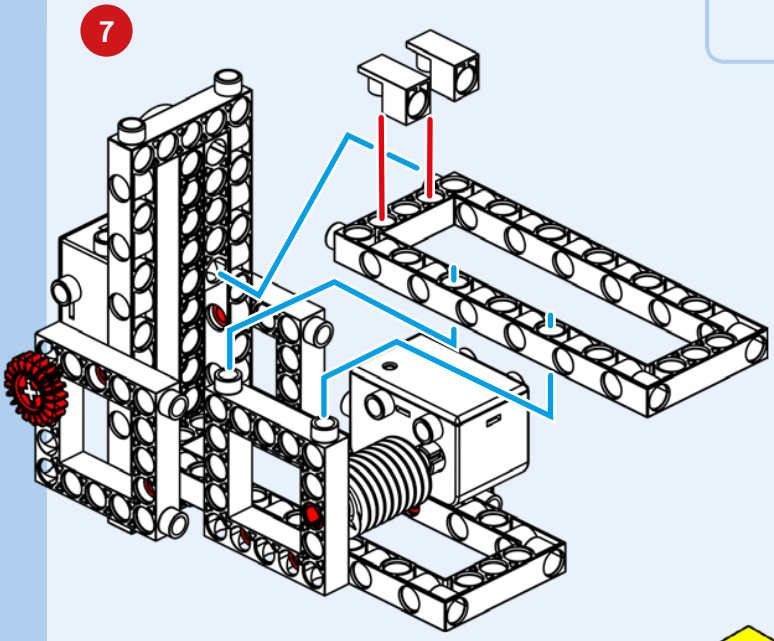

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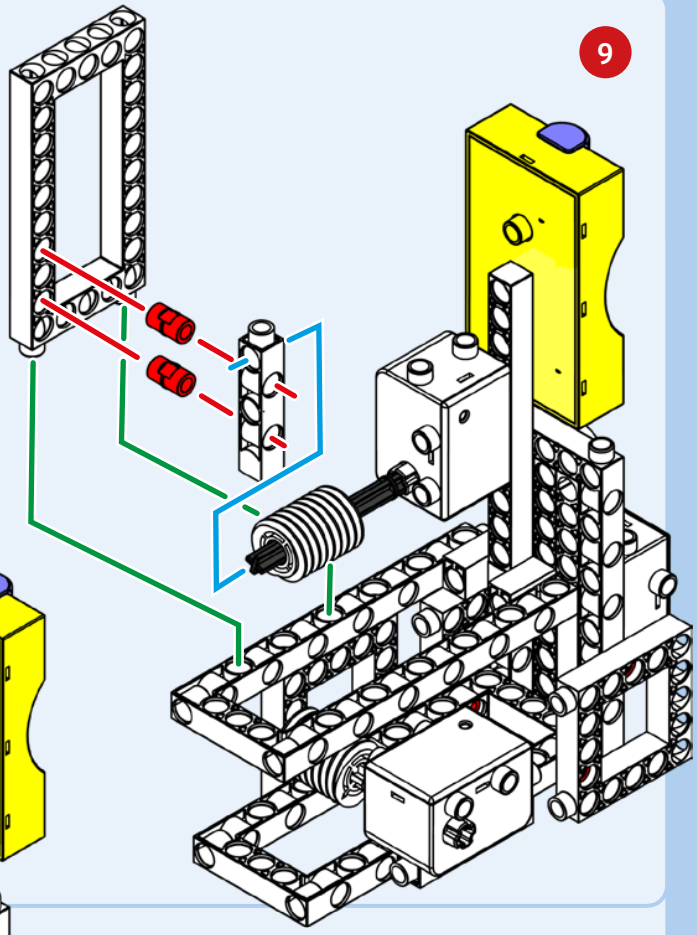

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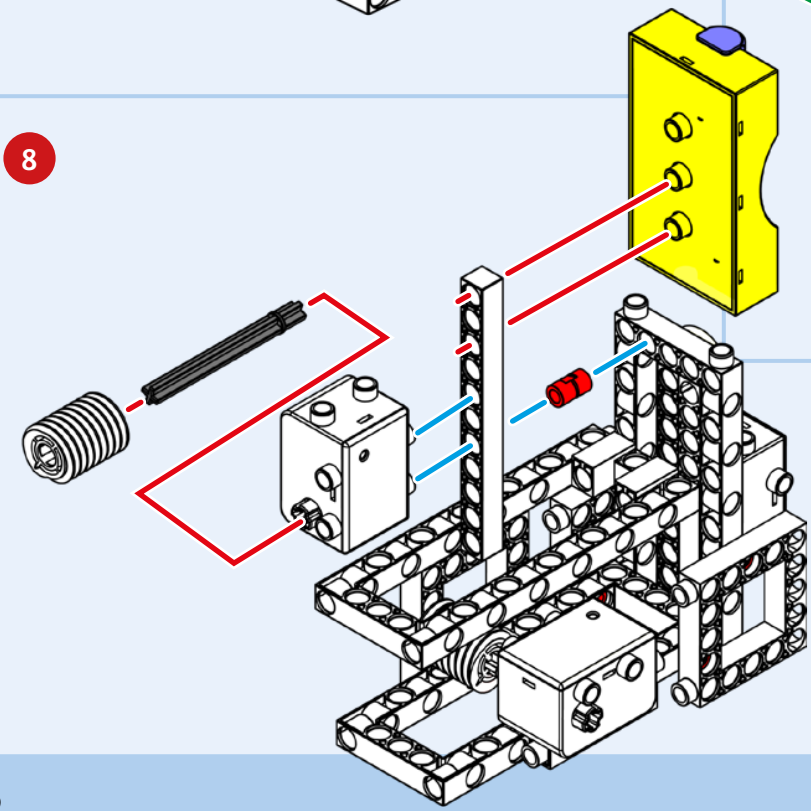

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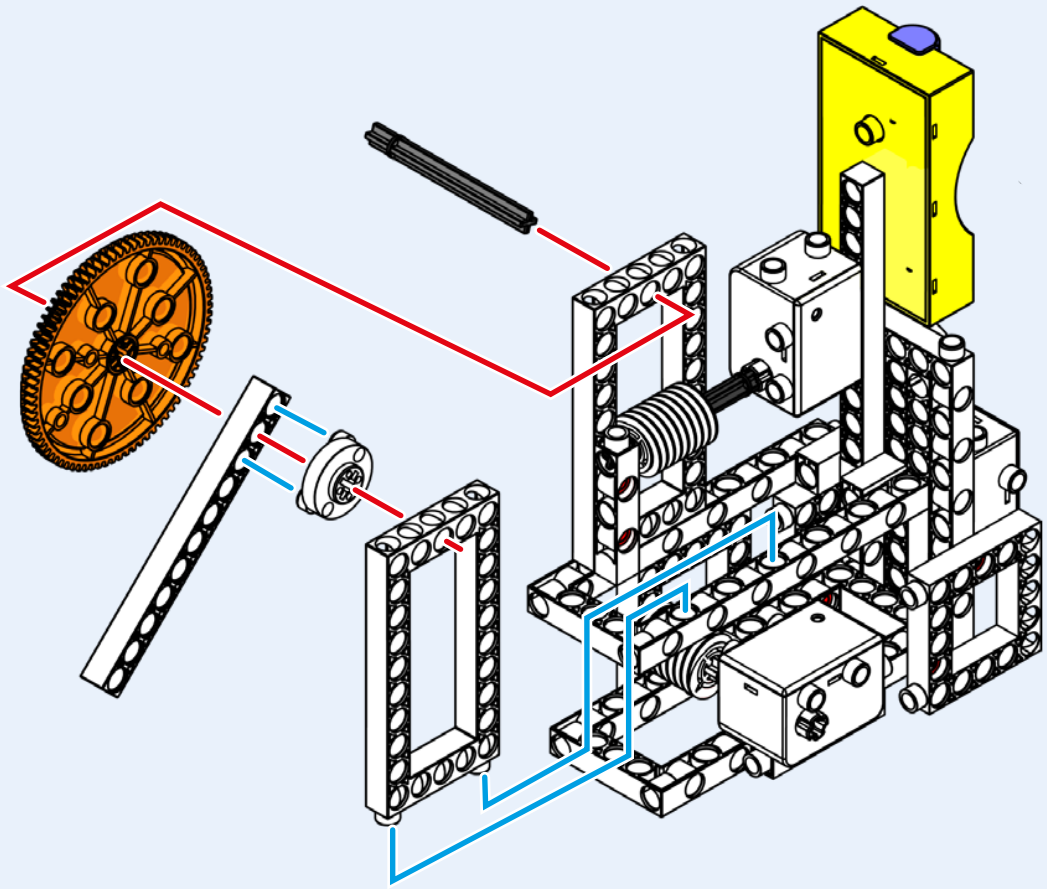

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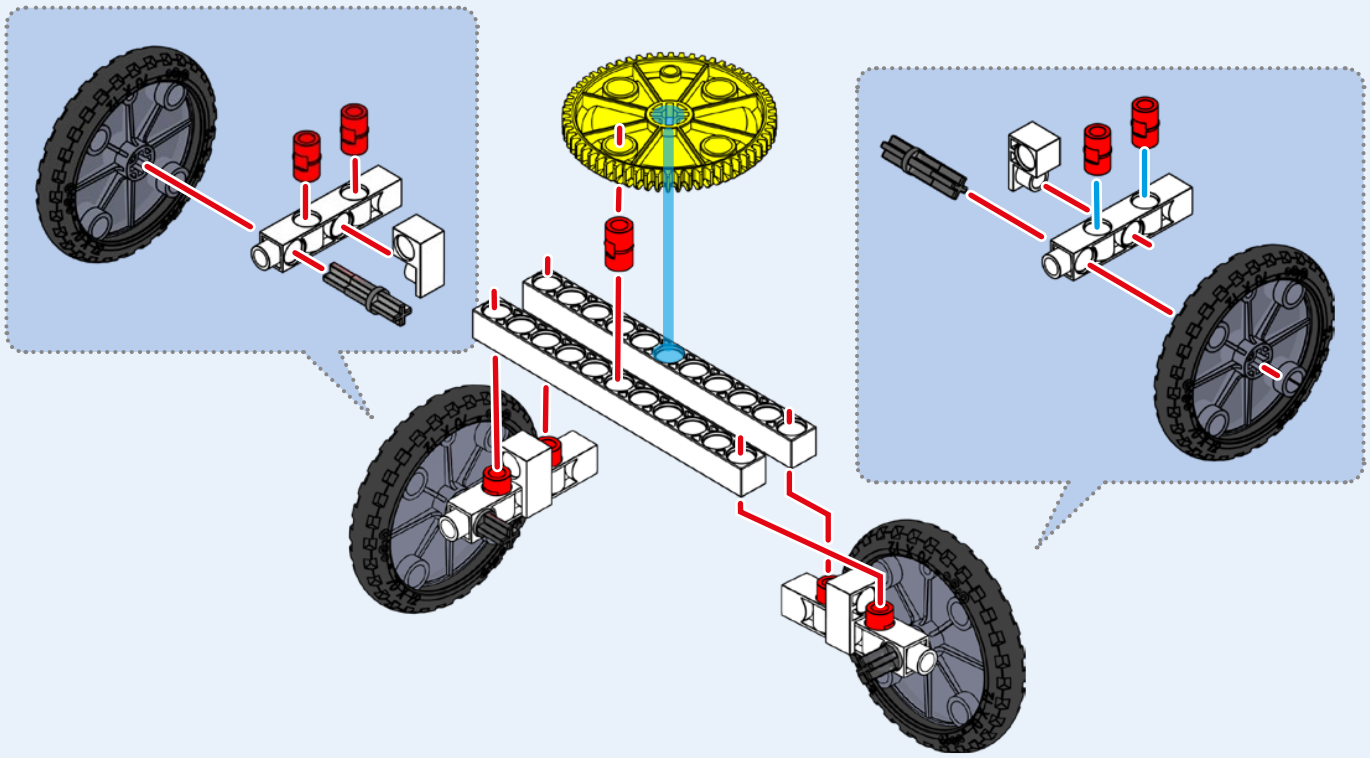

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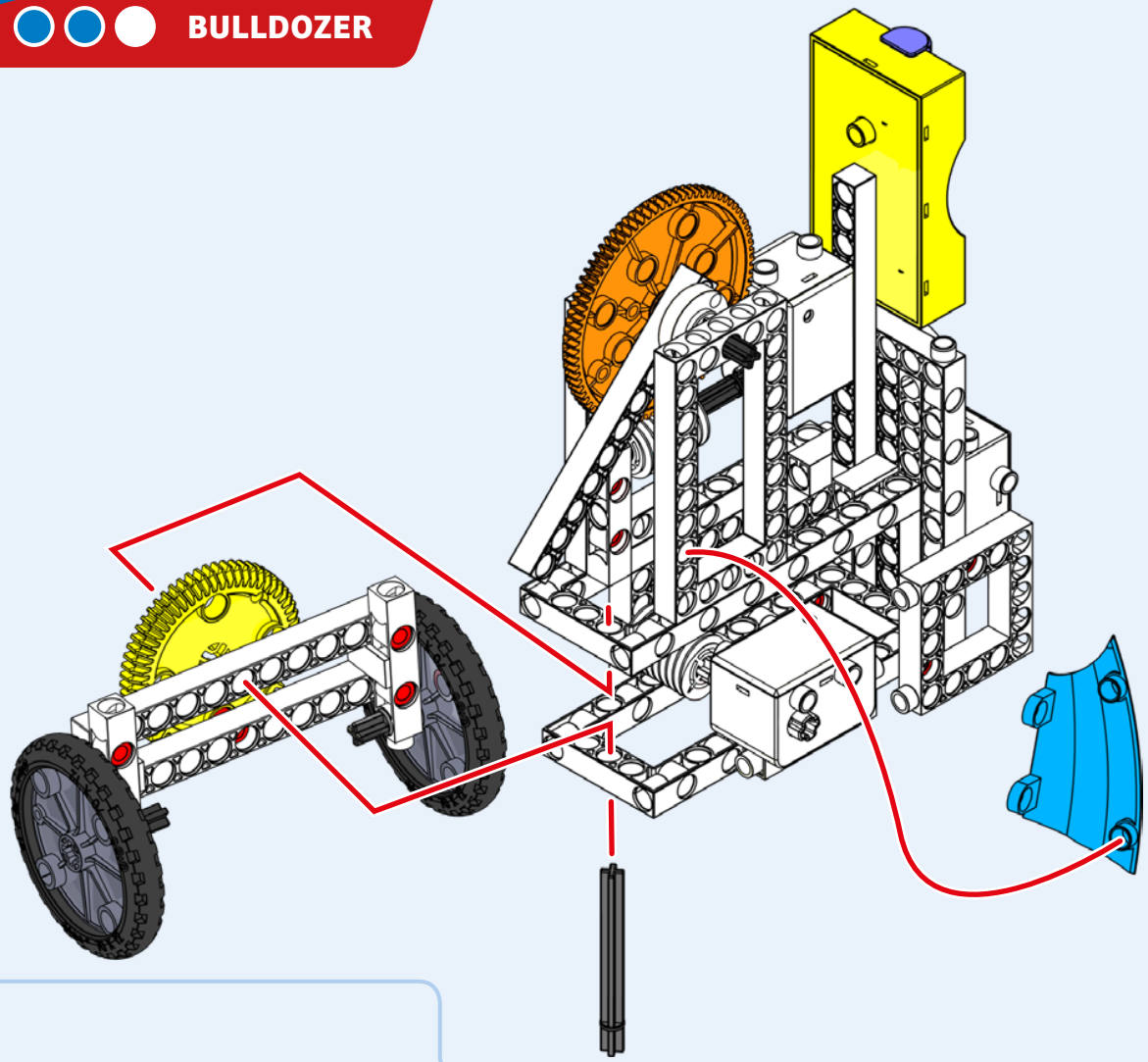

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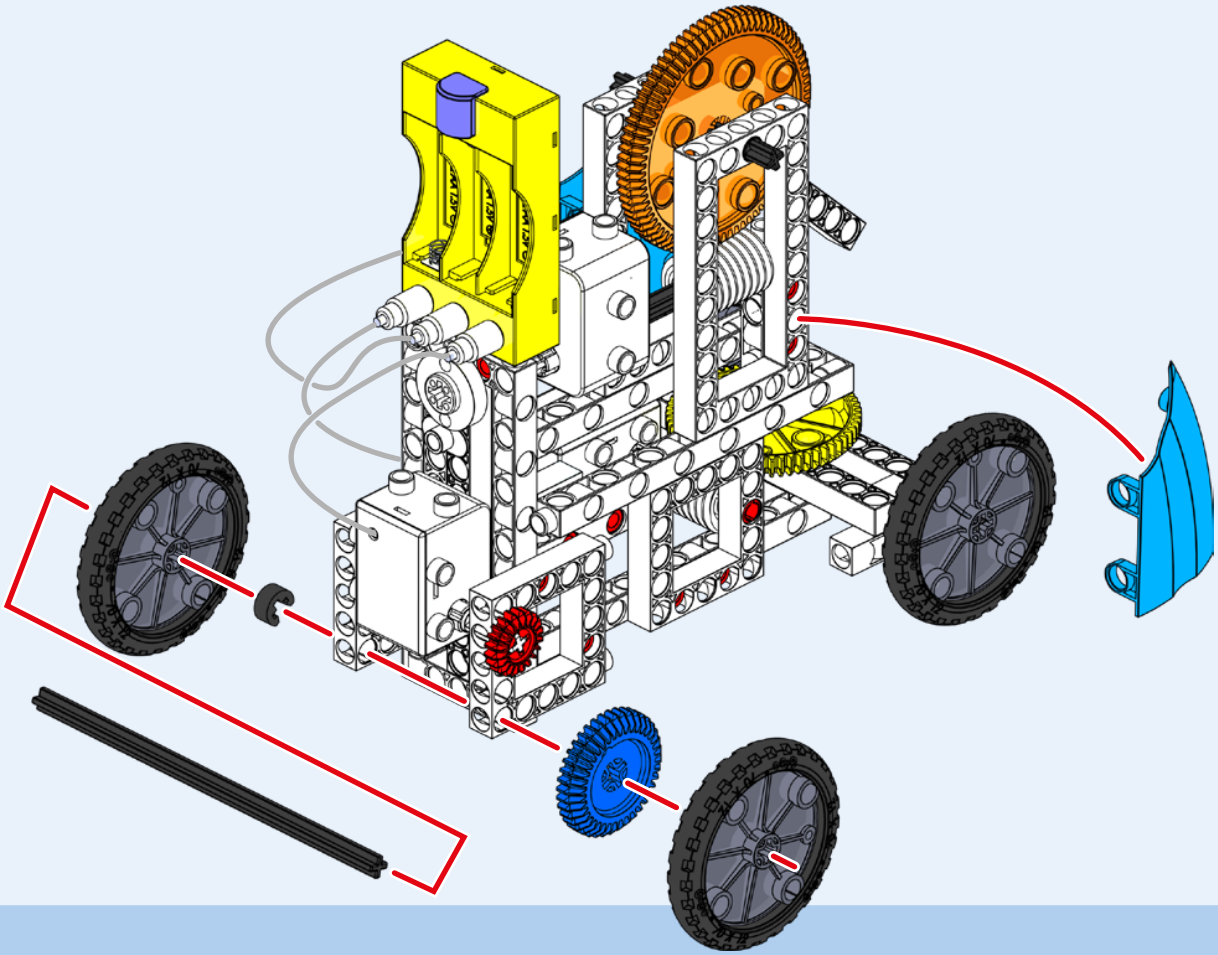

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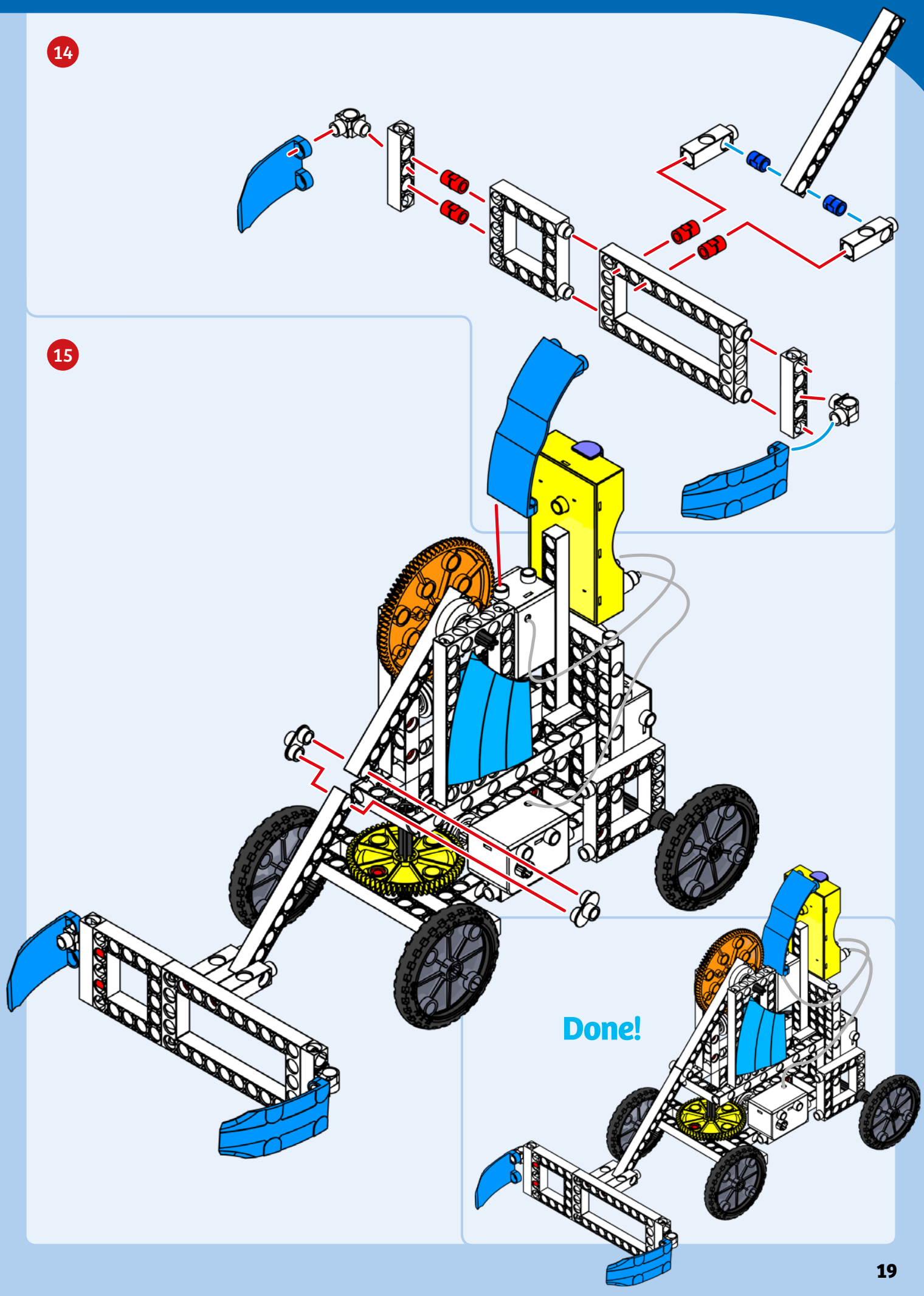


EXPERIMENT 2

Cleaning up with the bulldozer

YOU WILL NEED

› The assembled bulldozer
› IR remote control
› 5 AA batteries or 5 AA rechargeable batteries
› Boxes (see page 127) or building pieces, etc.
› Masking tape
› Stop watch, note pad, and pen

HERE'S HOW

1. Scatter several boxes or other small objects out across the floor of the room. These are the things you will be using the bulldozer to clean up. Just be sure that nobody slips on them.
2. Mark an area on the floor where all the scattered objects are to be moved. You could use masking tape, for example. This way, you will have a clearly identified target zone.
3. Familiarize yourself with the bulldozer's controls. Which touch pad buttons control which motor and which function?
4. Time to start! Push each one of the scattered objects in turn into the identified target zone.
5. How about having a bulldozer competition with one of your friends? To make it fair, each contestant should start with the same objects arranged in the same positions. You can use snippets of masking tape to mark each spot, and write a note on each piece of tape indicating which object should be placed there.
6. As soon as you have arranged all the bits of masking tape, place the bulldozer on its marked starting position.
7. On your marks, get set, go! Use the stop watch to measure the amount of time each contestant takes to finish.

WHAT'S HAPPENING?

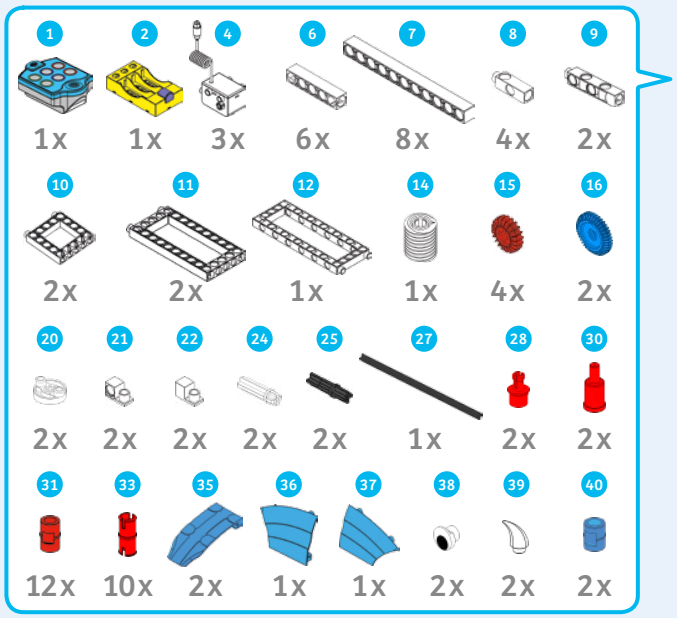
You have probably noticed how the transmission for the turning movement and for lifting the shovel acts by way of gear wheels.

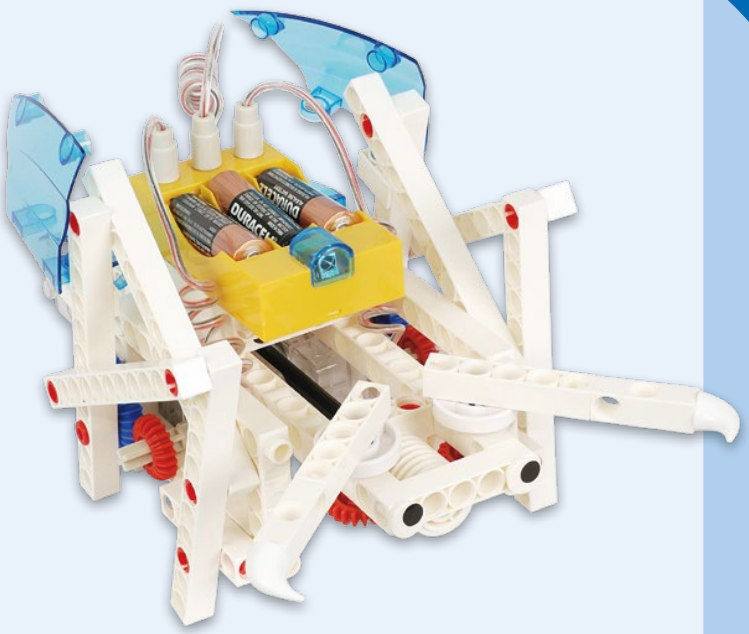
This kind of transmission system is known as a worm drive. It consists of a worm gear (the "normal" gear wheel) and the worm screw, the thing that looks a little like the thread of a screw. A worm drive is often used when shafts and axles cross, i.e. when they run at right angles to each other.

In other words: You can use a worm drive to transfer a turning movement to a different axis. With the shovel's lifting mechanism, the motor shaft runs in the lengthwise direction of the bulldozer. The worm drive, however, lets the large gear wheel's axle run at a right angle to the lengthwise direction of the bulldozer.

Another feature of the worm drive is its relatively large transmission ratio (see Experiment 8).

ROBO-BEETLE





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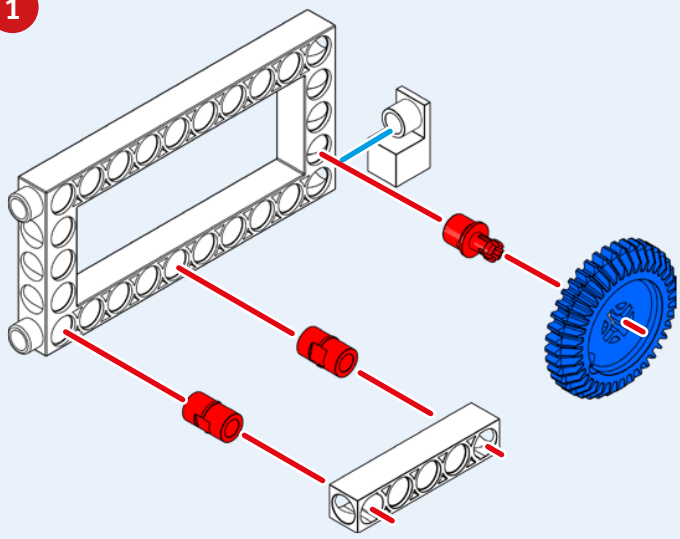

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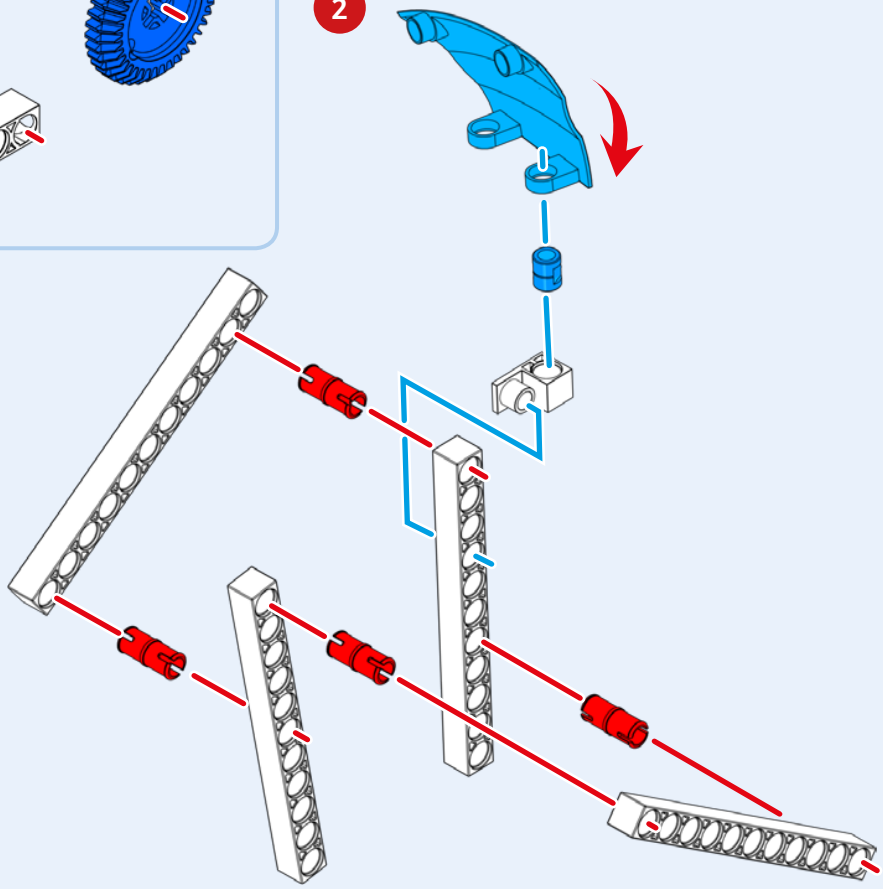

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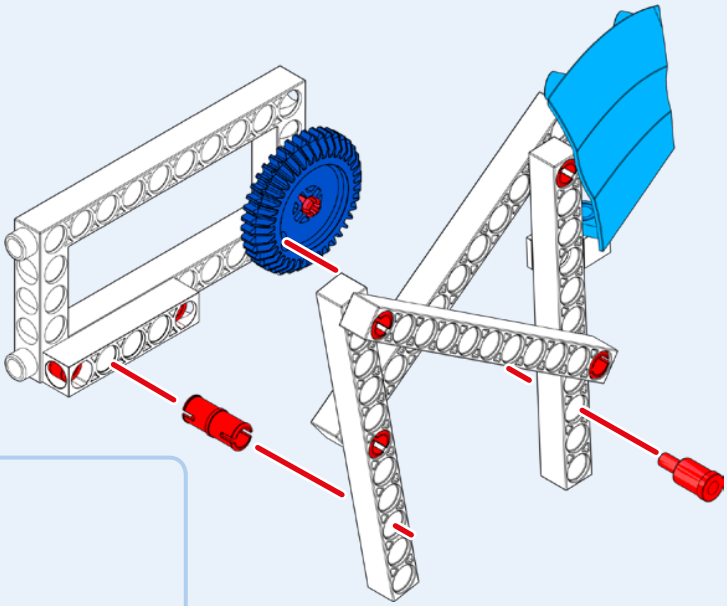

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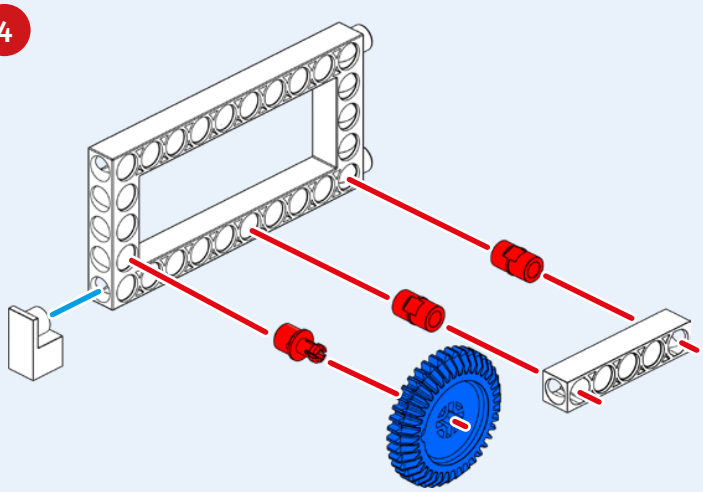

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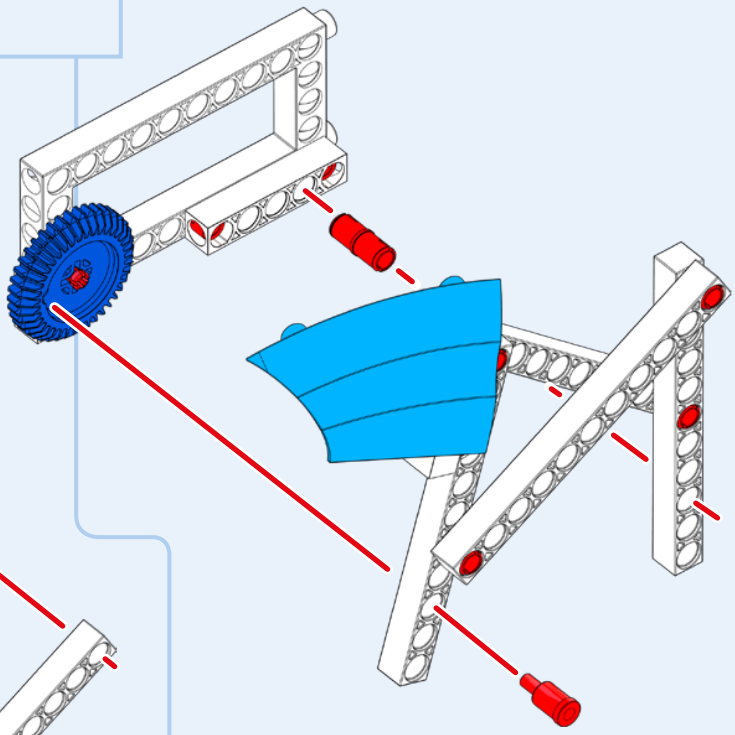

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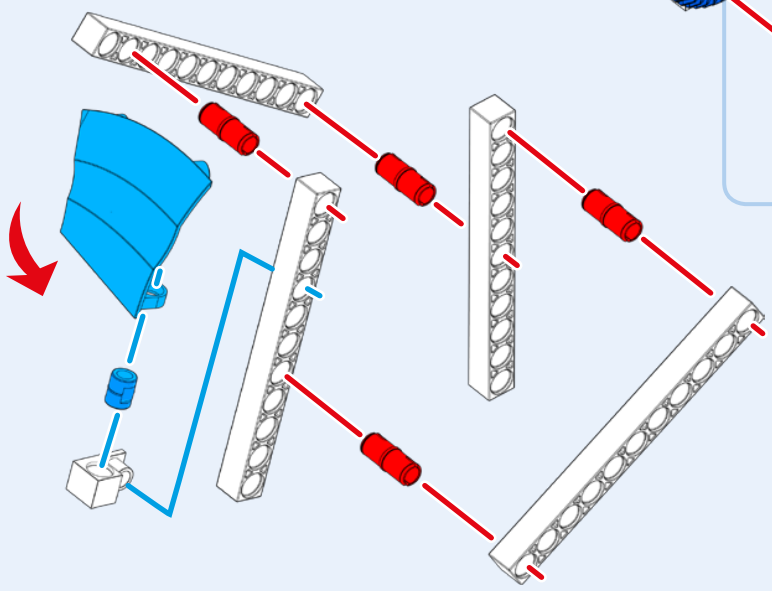

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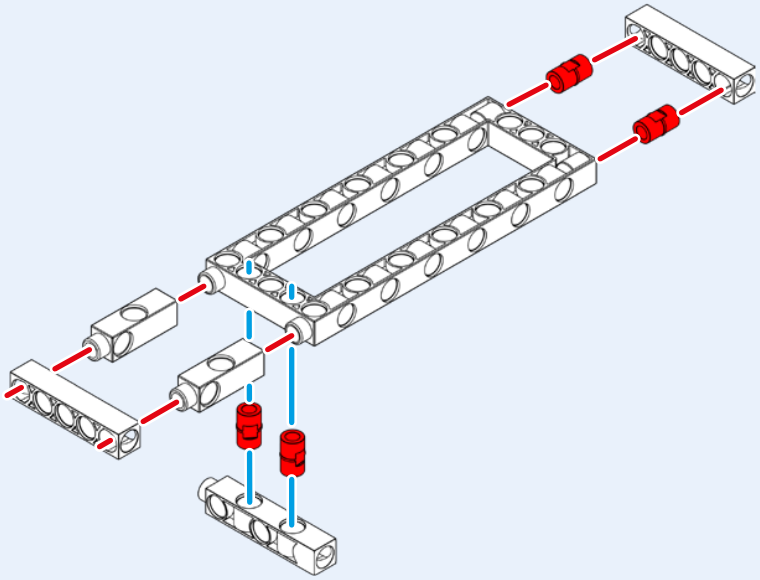

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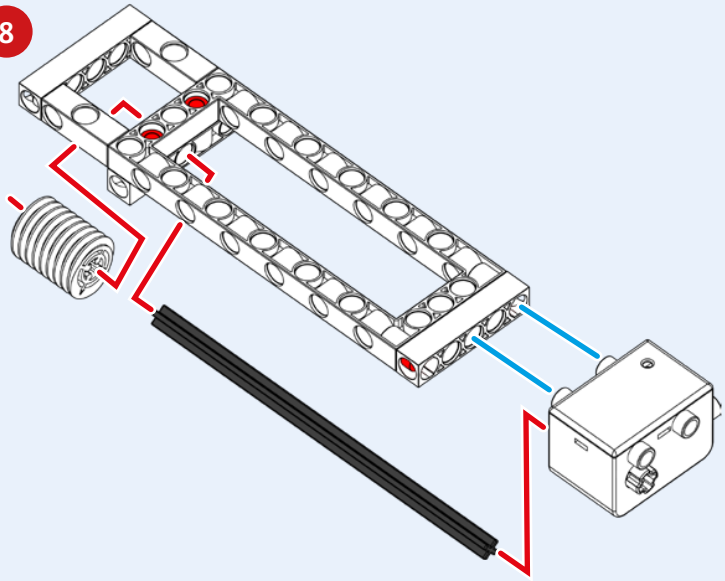

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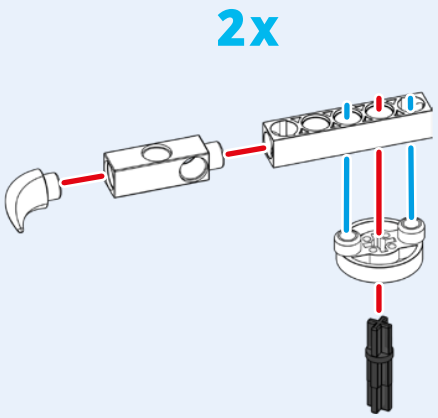

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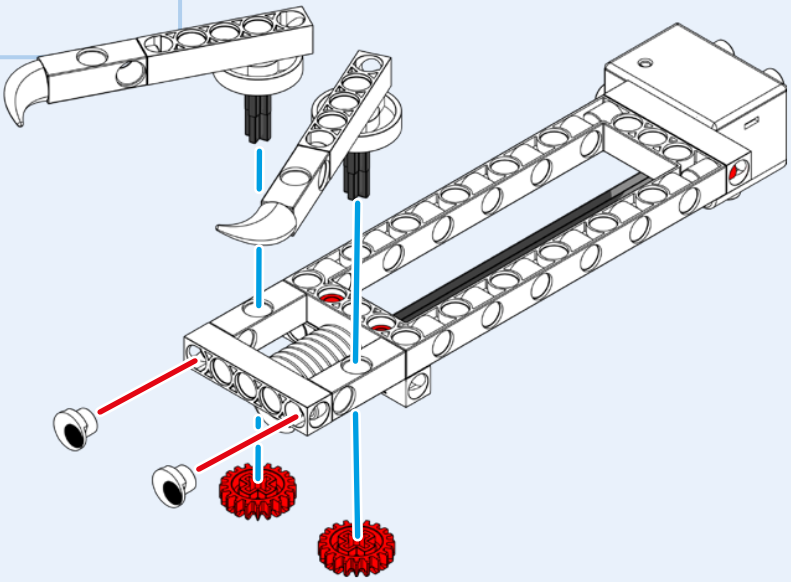

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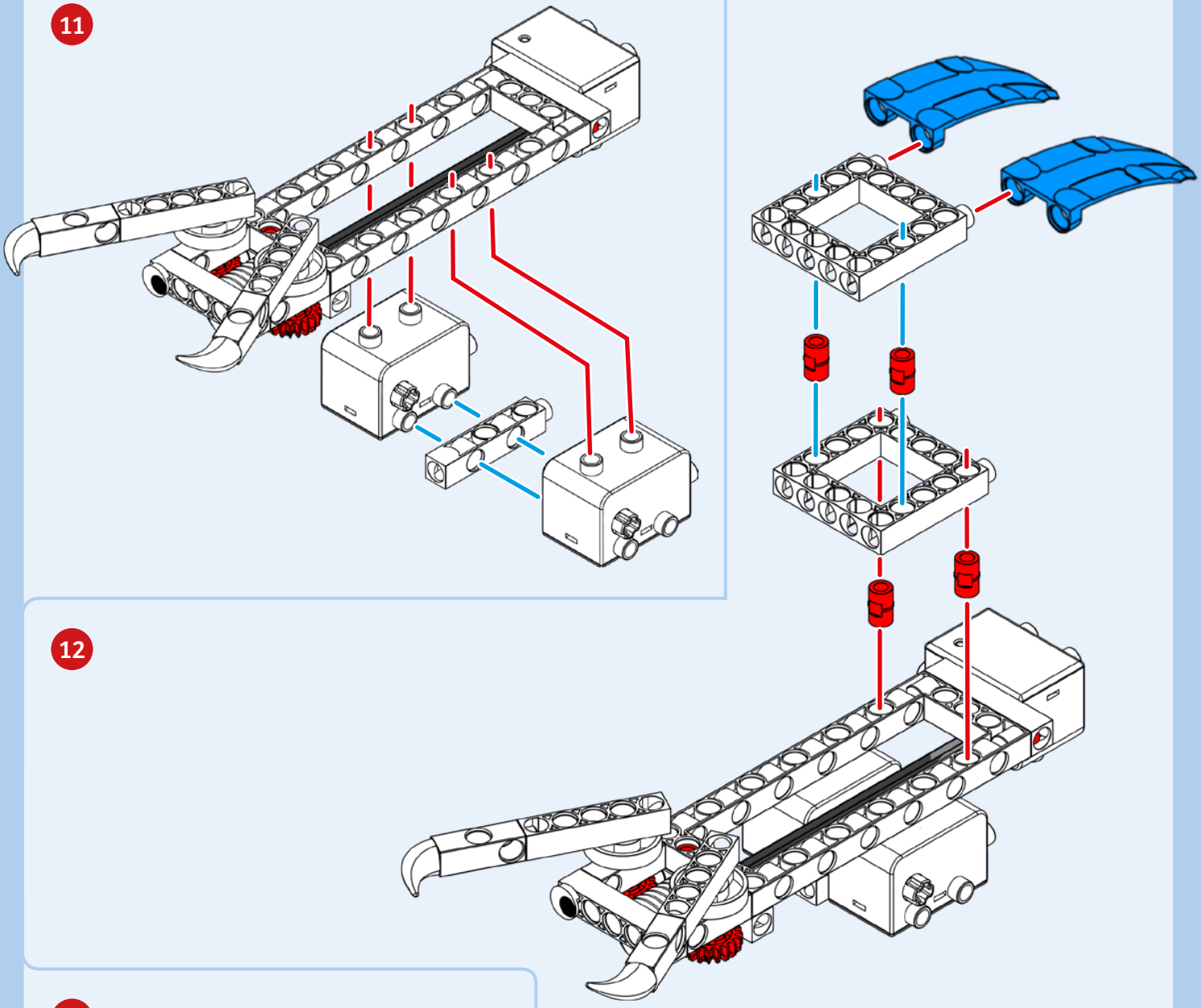

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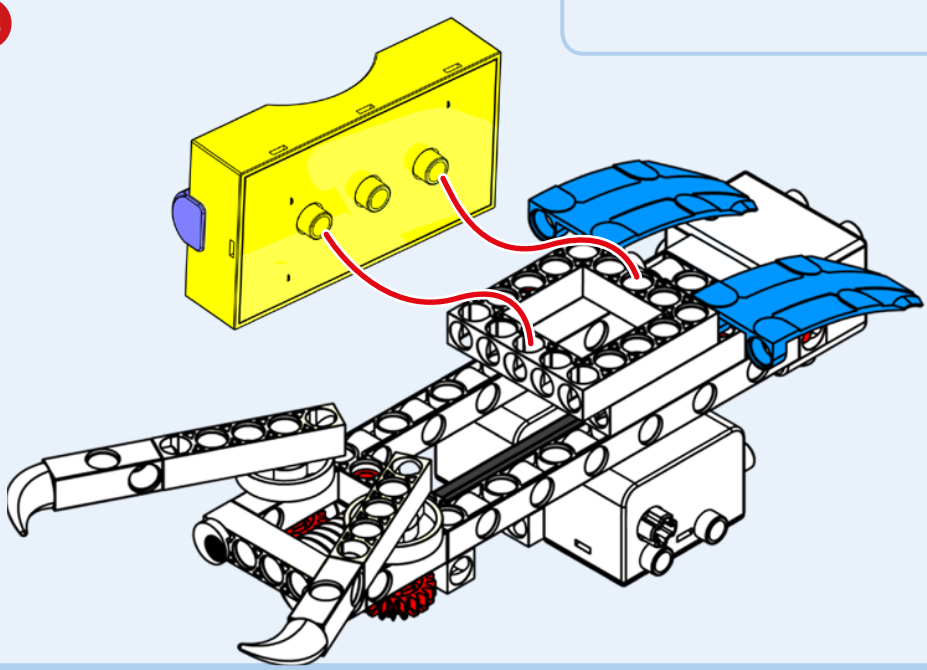

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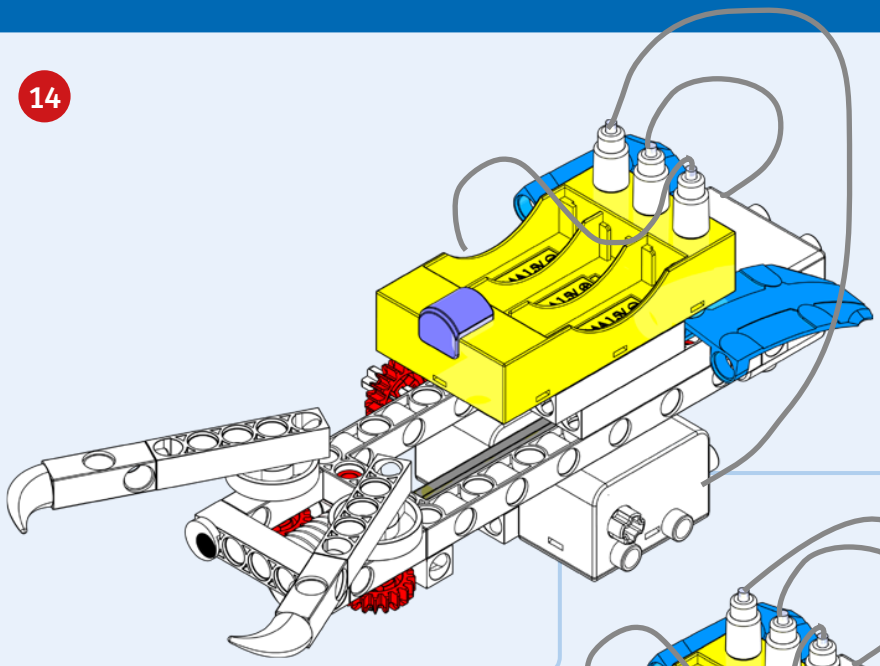

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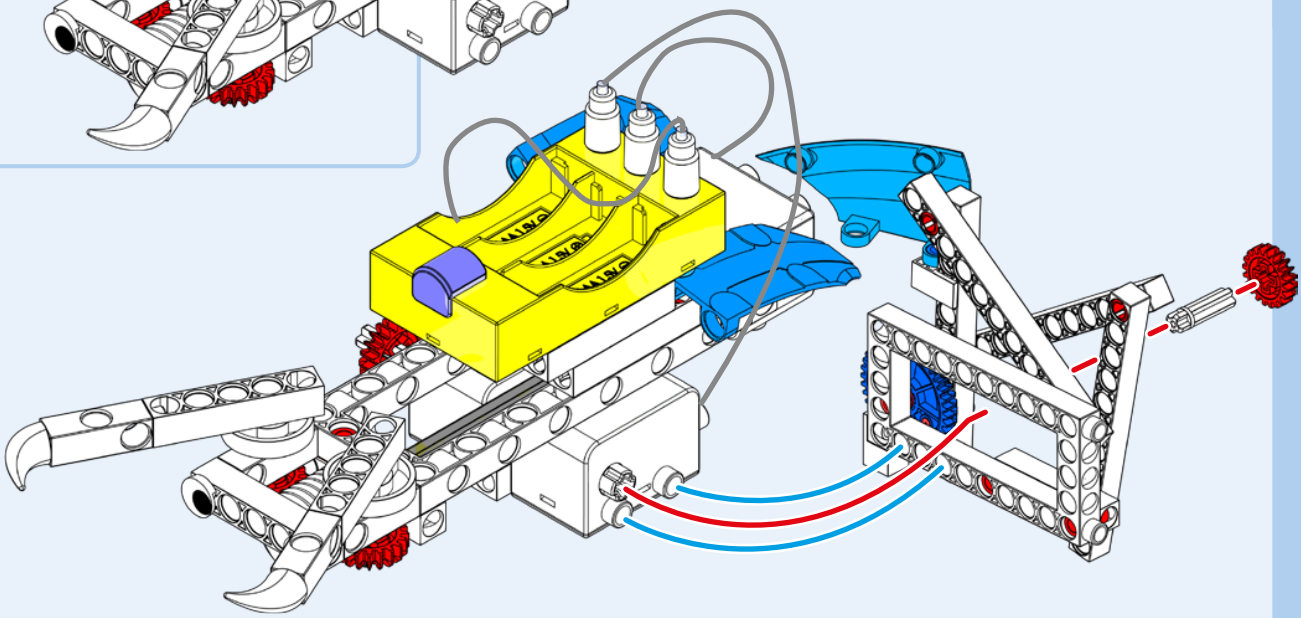

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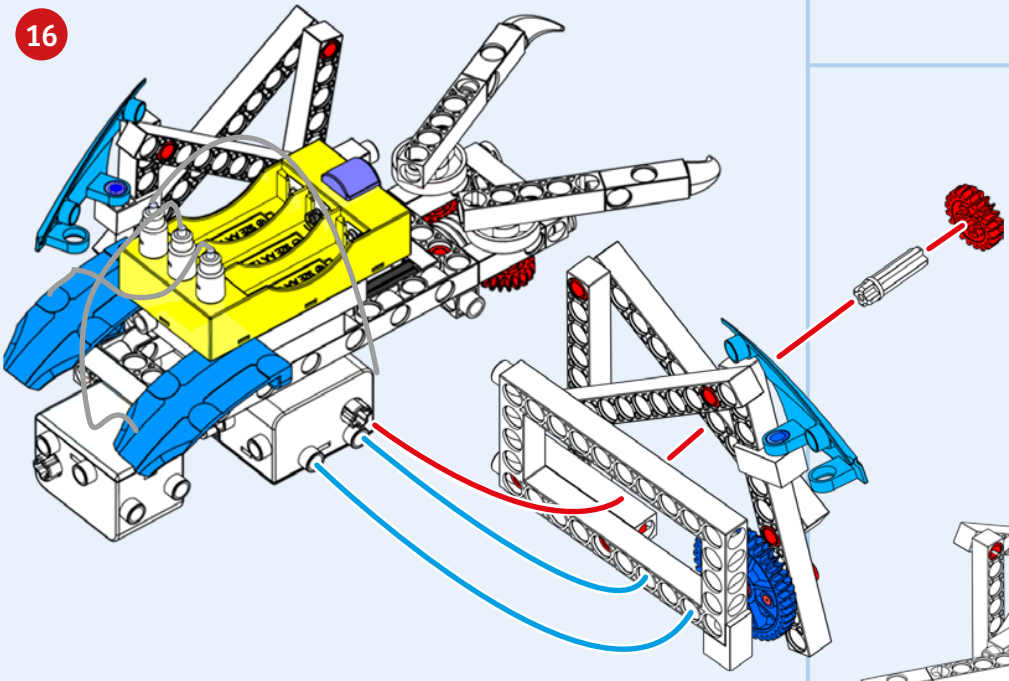

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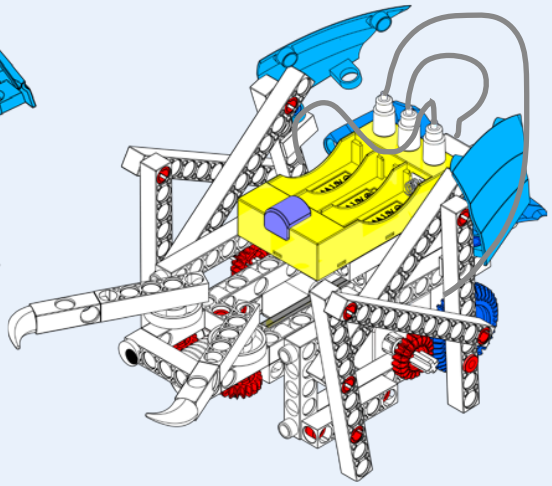


EXPERIMENT 3

Using the robo-beetle to balance a container of water

YOU WILL NEED

- **The assembled robo-beetle**
- **IR remote control**
- **2 square frames**
- **2 red anchor pins**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Box (see page 127)*
- *Screw-on cap from a water bottle*
- *Some water*
- *Dish cloth*

HERE'S HOW

1. Familiarize yourself with the robo-beetle's controls. Can you make it go forward and backward? And in a circle? Then you're ready to start!
2. Place a square frame somewhere on the floor of your room far away from the beetle.
3. Set a box on its narrow edge on top of another square frame placed on the floor in front of the robo-beetle. Have the beetle approach the box and grab it.
4. Turn the beetle a little and carry the box to the other square frame.
5. Now it's time to raise the level of difficulty. First, though, you will have to take your robo-beetle outside or to a room that can handle a little spilled water. The bathroom would be best for that.
6. Stick the two square frames together with two red anchor pins and lay them flat on the floor. Then set the box on top of the frames.
7. Fill the screw-on cap almost to the brim with water, and set it on the box. Now, have the beetle move toward the screw-on cap and grab it.
8. Turn the beetle a little and carry the screw-on cap to another location in the room that you have selected as your goal. If you manage to get there without spilling any water, you are the champion!

WHAT'S HAPPENING?

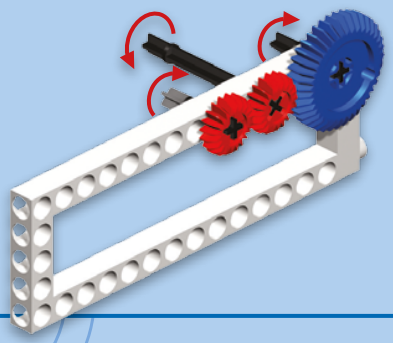
If you take a look at one of the long sides of the beetle, you will see how the red gear wheel meshes with the blue one. The two together form a gear drive.

This kind of transmission has three main tasks:

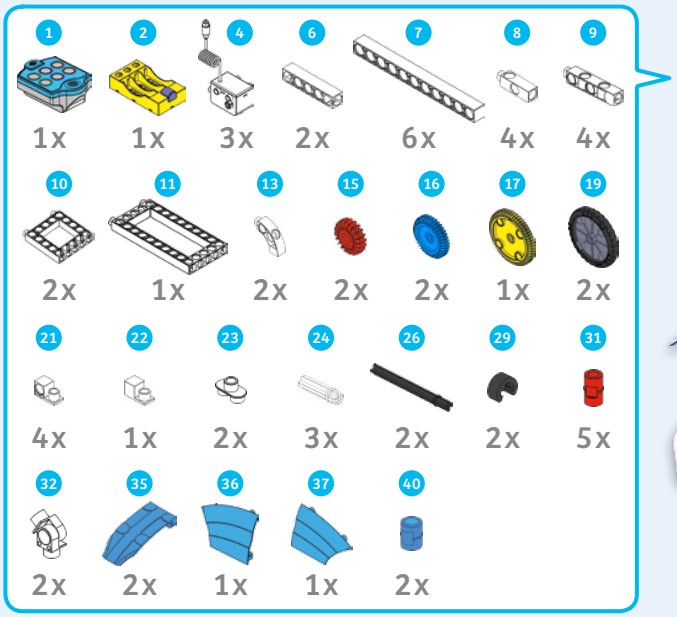
1. To transfer force to a different axis: In the case of our robot, the force is transferred from the motor shaft with the red gear wheel to the blue gear wheel for the legs.
2. To change the speed of rotation: You can change the speed at which two gears turn by using gears with different numbers of teeth (see Experiment 8).
3. To change the direction of rotation: When the red gear wheel turns to the left, the blue one turns to the right, and vice versa.

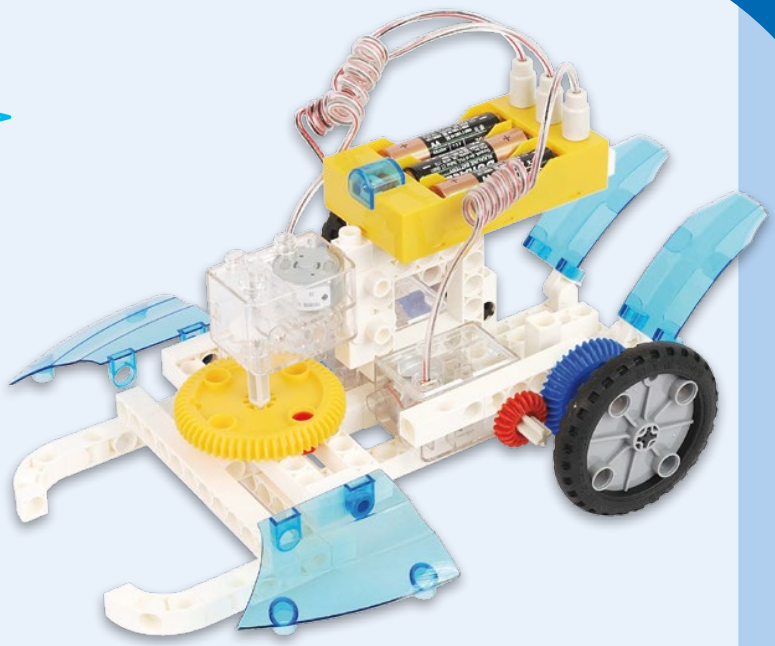
DID YOU KNOW?

How can you transfer force without changing direction? It's simple: Just insert a third gear wheel between the other two. Try it yourself.



BALL MACHINE





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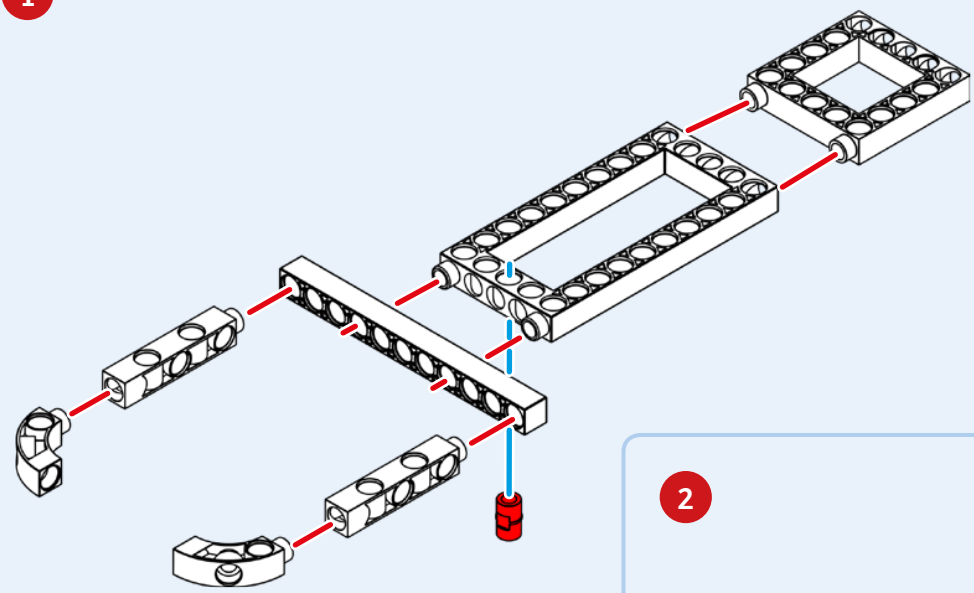

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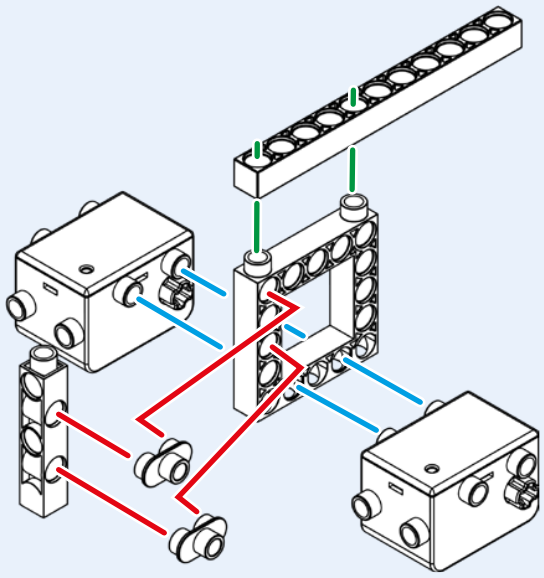

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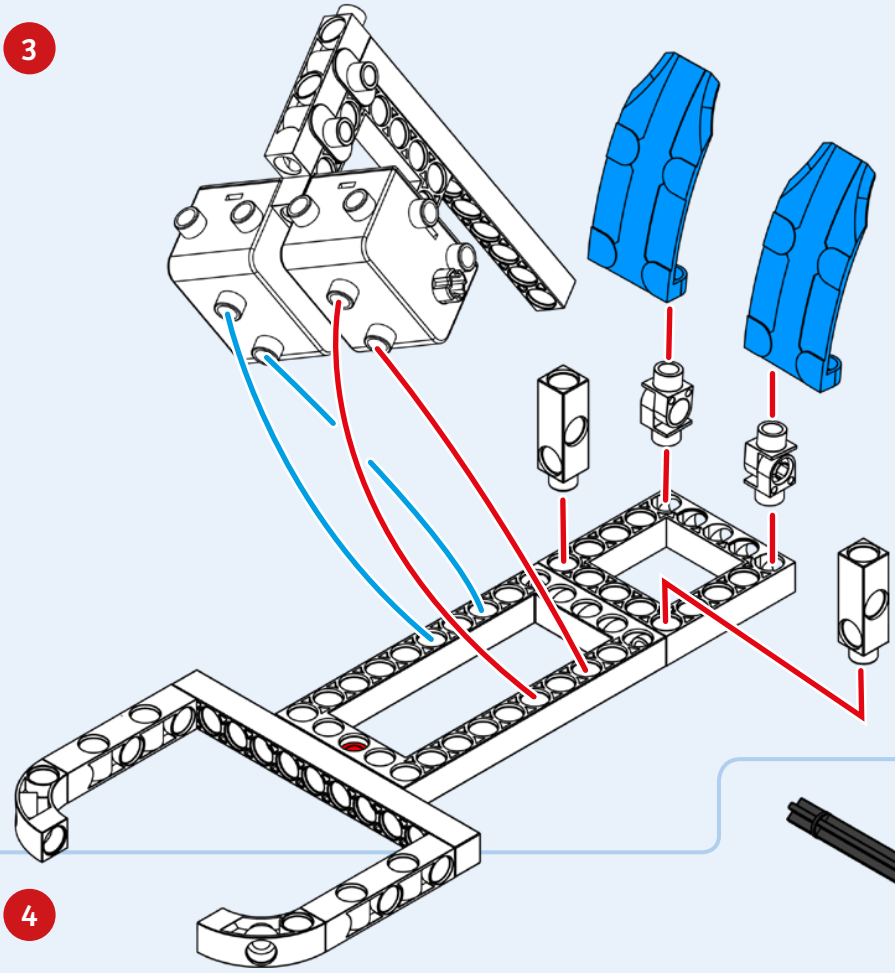

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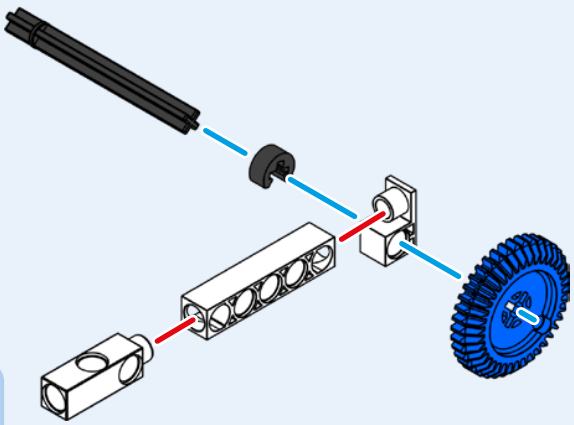

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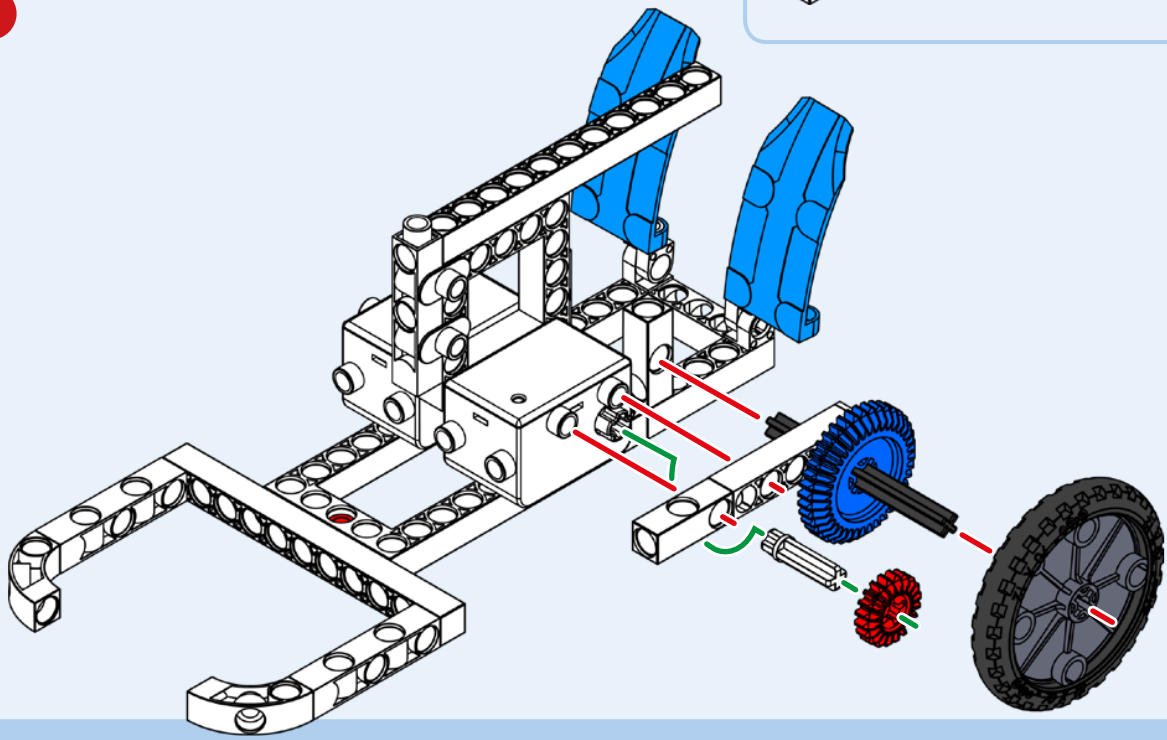

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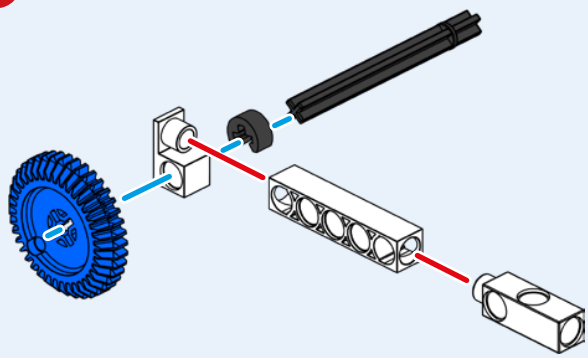

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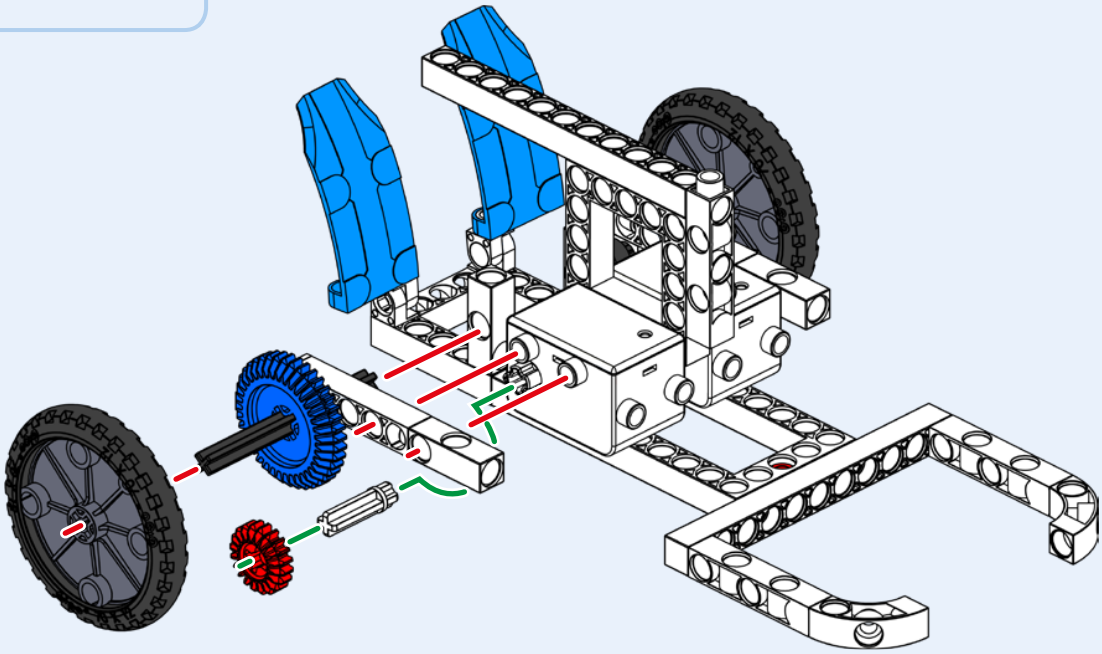

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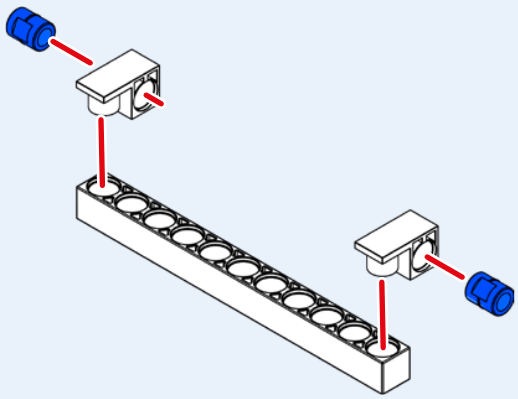

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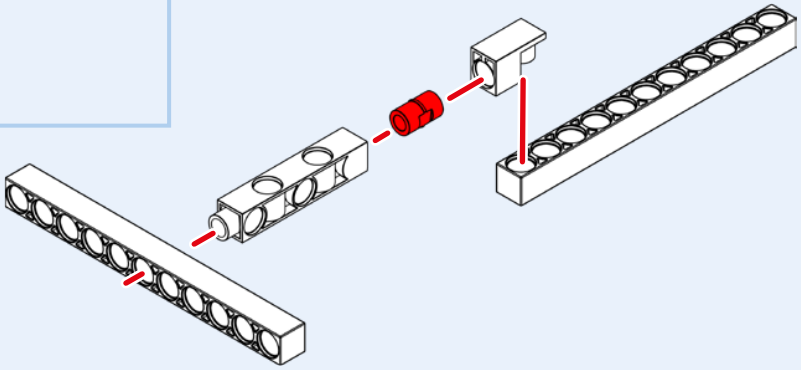

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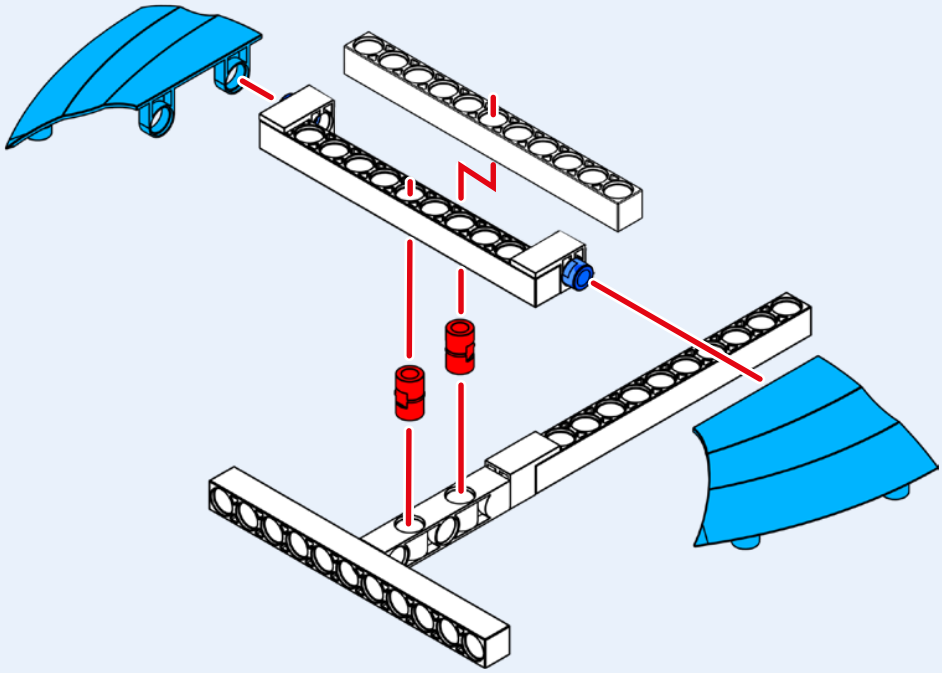

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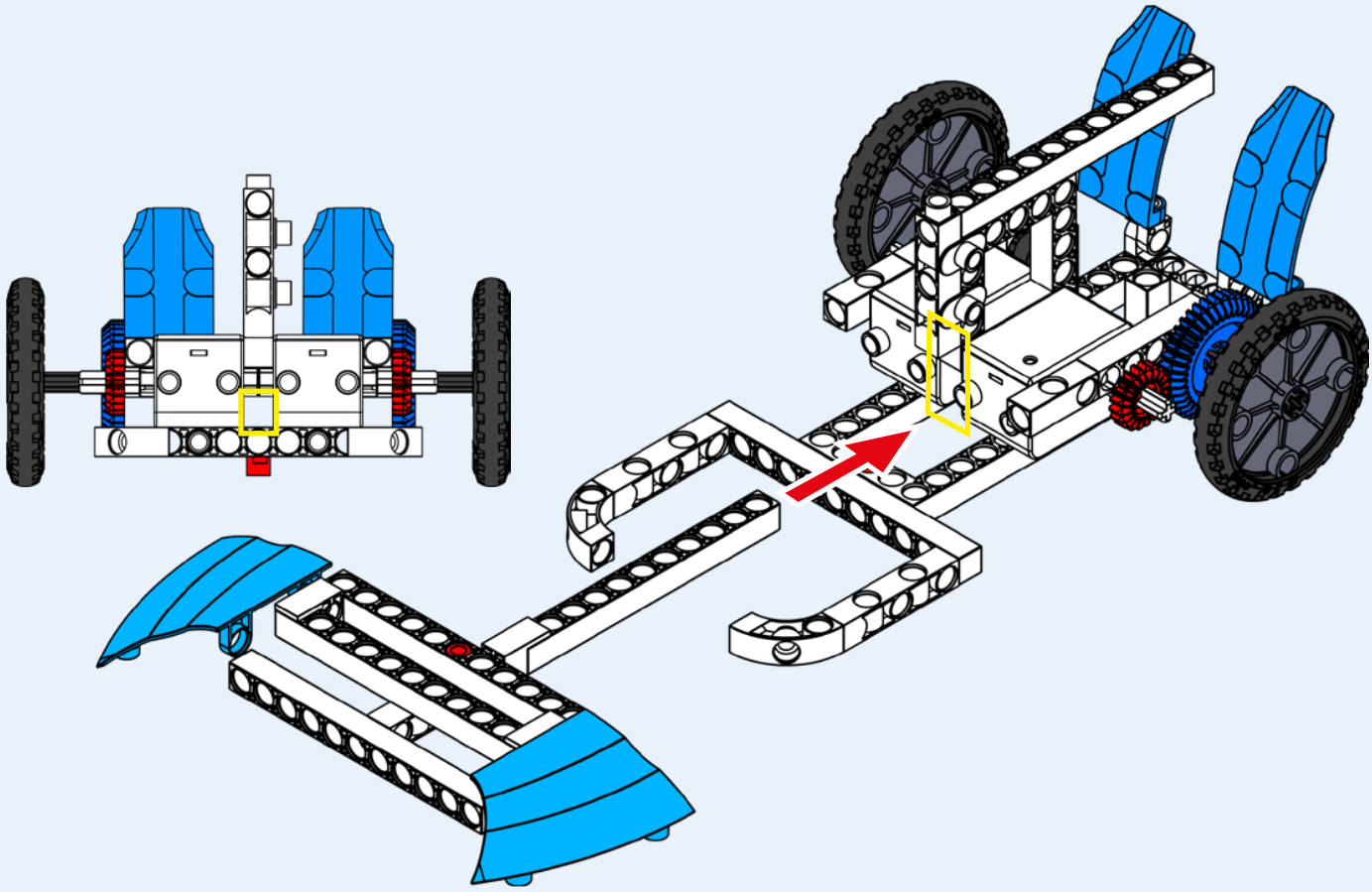

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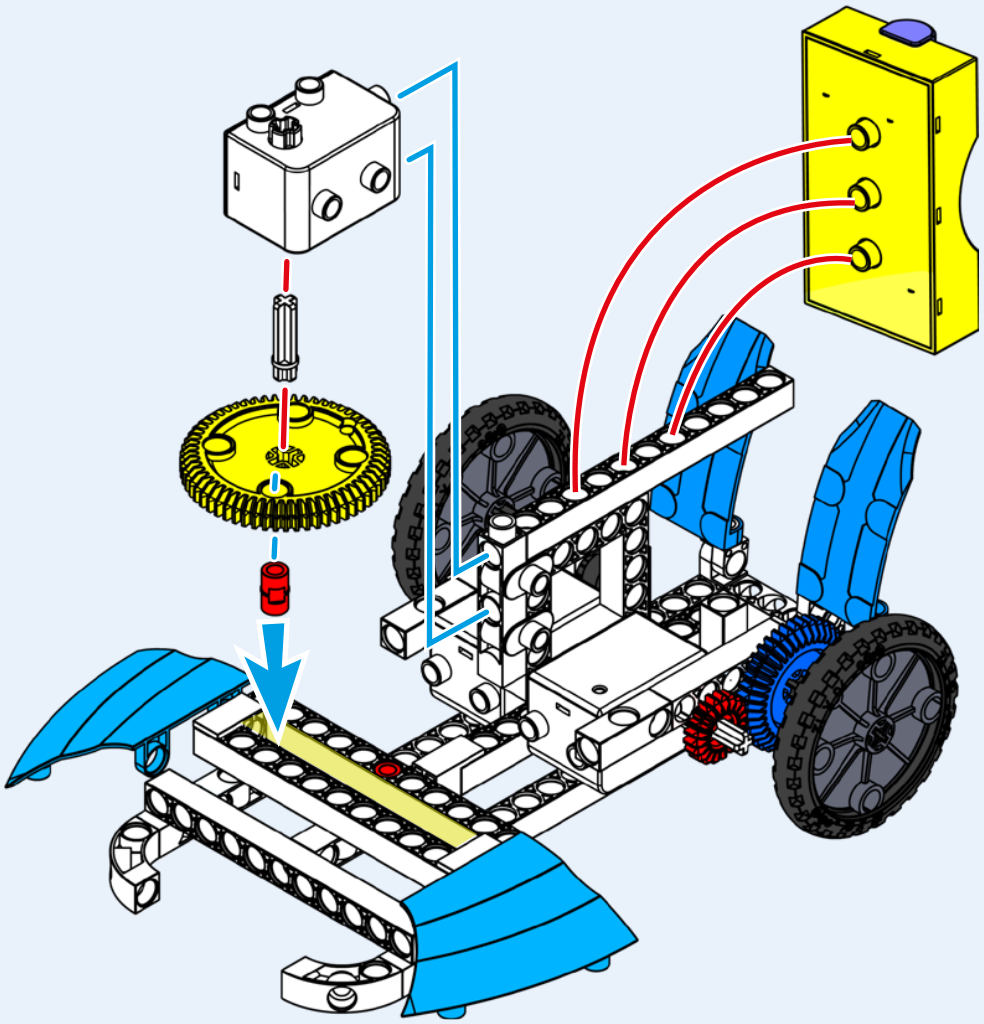

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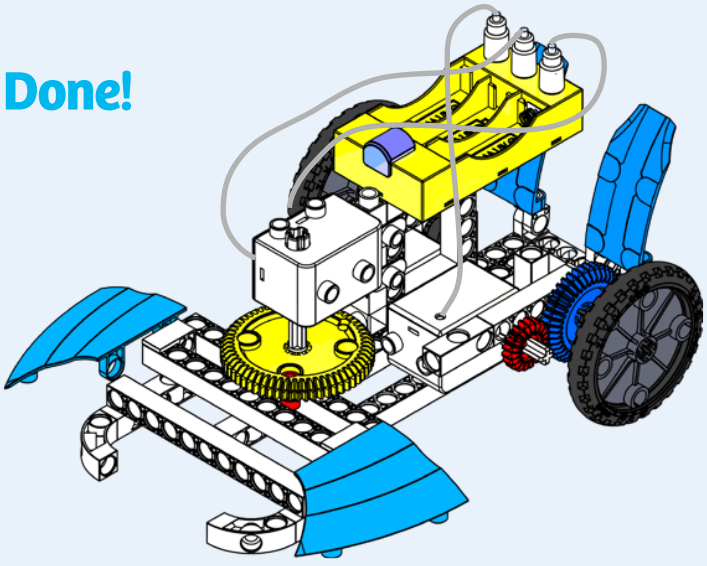


EXPERIMENT 4

"Golfing" with the ball machine

YOU WILL NEED

- **The assembled ball machine**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Masking tape*
- *Scissors*
- *Felt-tip pen*
- *Large marble (small ball)*
- *Stop watch, note pad, and pen*

HERE'S HOW

1. Familiarize yourself with the ball machine's controls.
2. Cut 10 equal-sized squares from the roll of masking tape and distribute them evenly and not too close to each other across the floor.
3. Mark one square with "Start" and number the others from 1 to 9. Those will be the 9 "holes" of your golf course. Place the ball at the starting square.
4. Now, your task is to use the ball machine to pass the ball to each hole in turn. You only get a point if you hit the hole on the first try.
5. As soon as you've gotten a little practice hitting the holes, you can try playing against the clock — and against an opponent too, of course. Use the stop watch to keep time. Here are the rules: If you don't hit a hole on the first try, there's a 5-second penalty. This will be added to the total time measured with the stop watch.

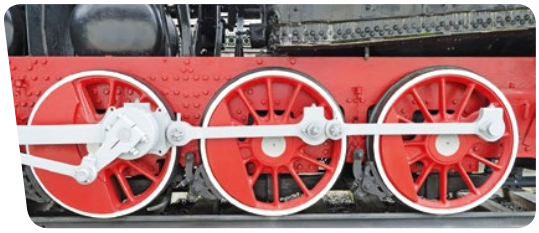
KEYWORD: REPRODUCIBILITY

To ensure that a contest is fair, you have to be sure that each player encounters the same conditions. In this experiment, you achieve this by constructing an "experimental setup" that can always be reproduced the exact same way as in the first test run. This **reproducibility** is also an important requirement in science, by the way. An experiment must always be able to be performed by other scientists anywhere in the world in the exact same way that it was performed the first time.

WHAT'S HAPPENING?

Your ball machine is equipped with a pushing element. You can move it back and forth, although for this you also need a rotating motor with the element mounted off-center.

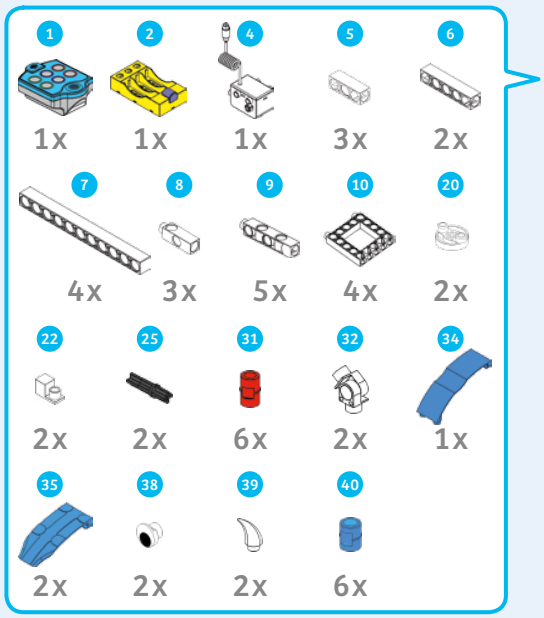
This kind of mechanism, sometimes known as an **eccentric**, consists of a drive pulley (the yellow gear wheel) whose center (the red anchor pin) lies outside the shaft axis. An eccentric can be used to convert rotational into lengthwise movements and vice versa (see also Experiments 6 and 13). Steam locomotive wheels are also equipped with eccentrics.



DID YOU KNOW?

Actual ball machines really are used at golf courses. Instead of being used for hitting, though, they are used to collect the golf balls that players have hit on the driving range for practice.

BAT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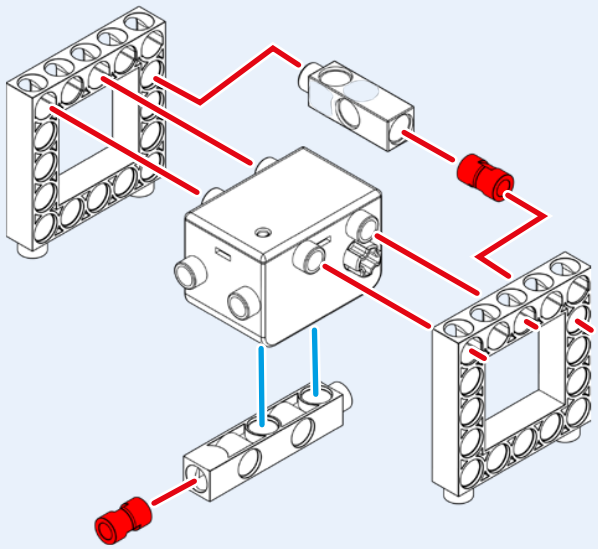

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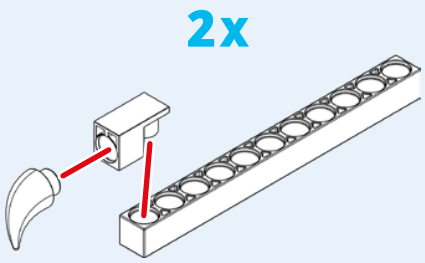
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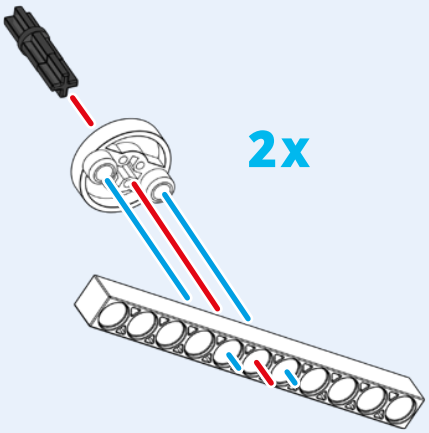
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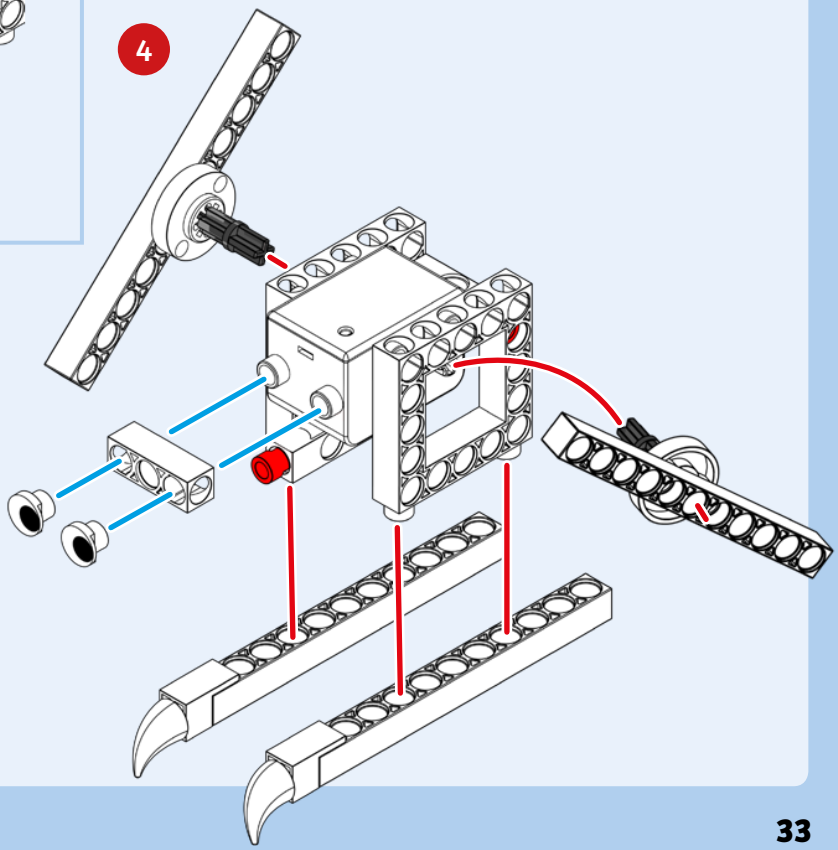

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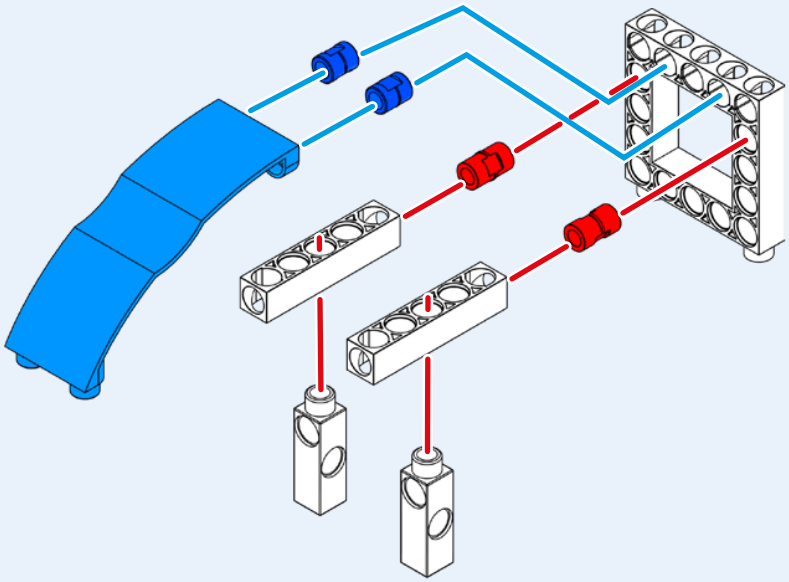

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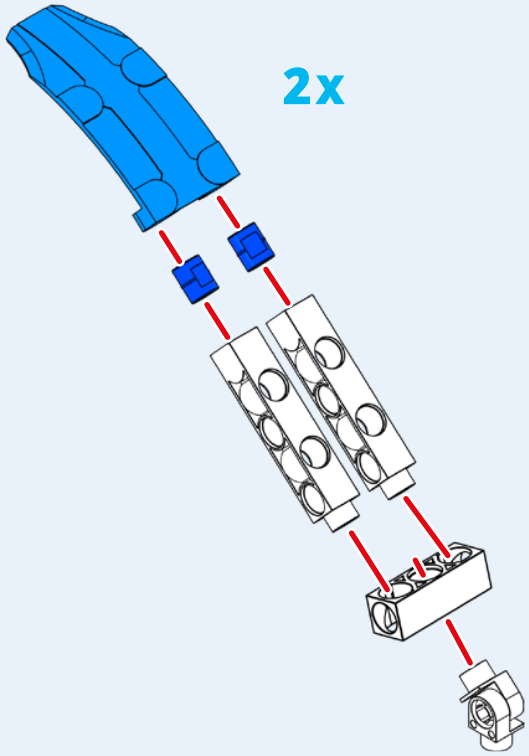

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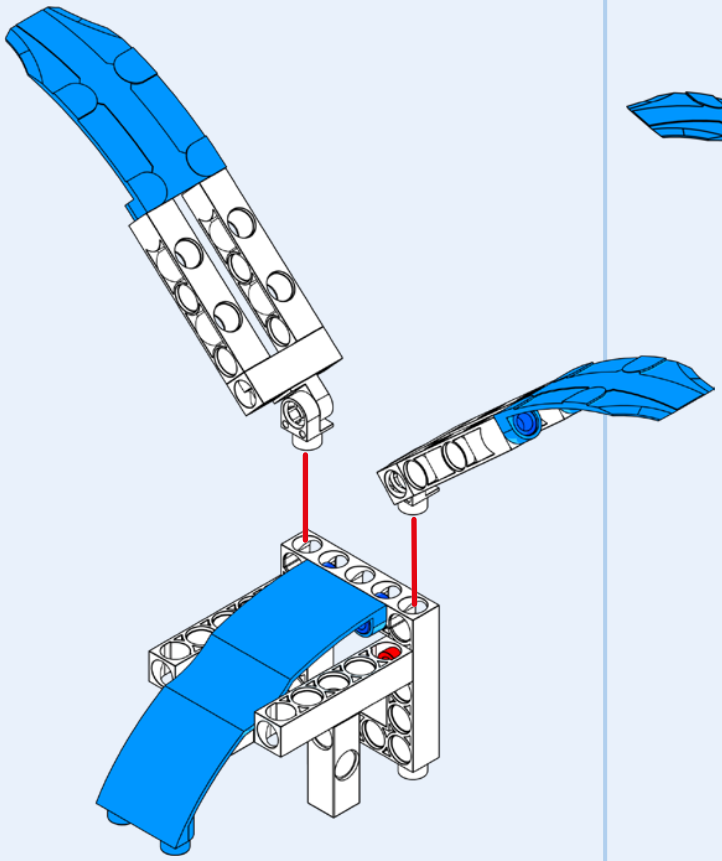

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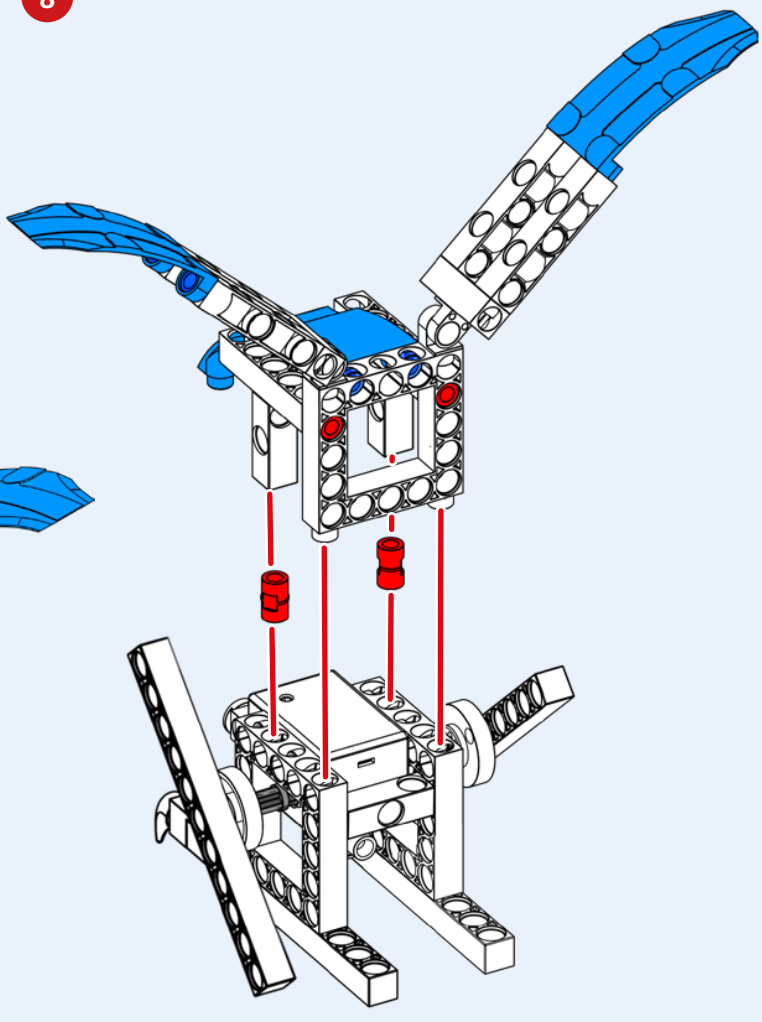

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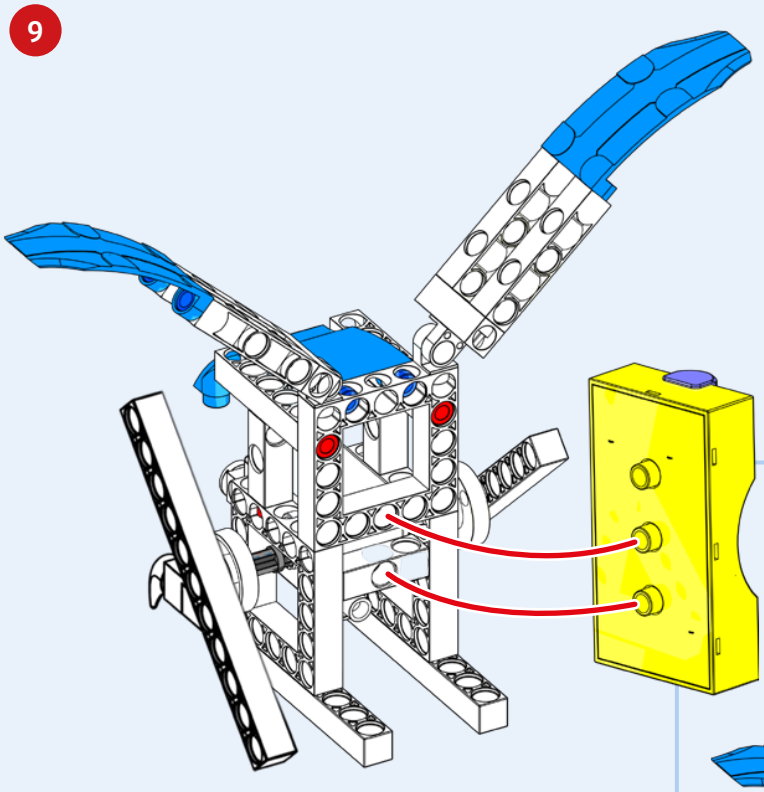

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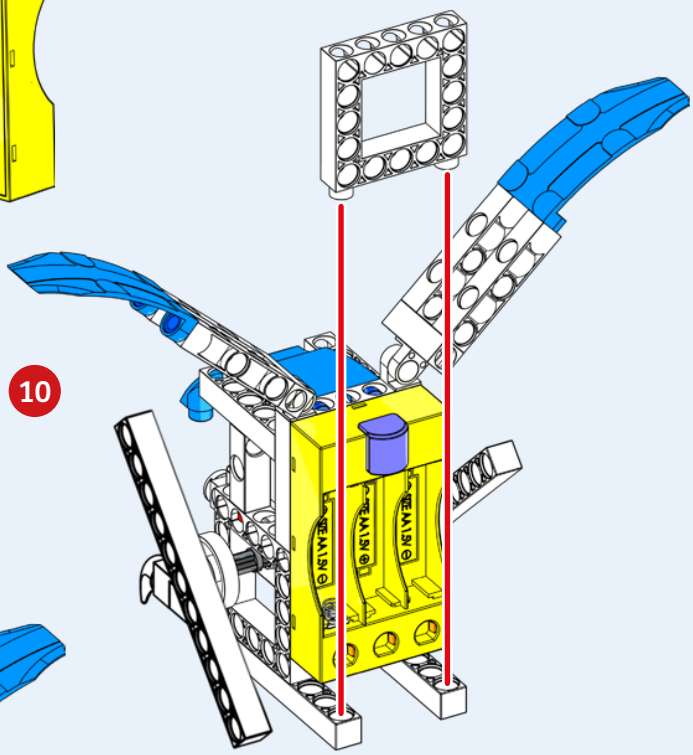

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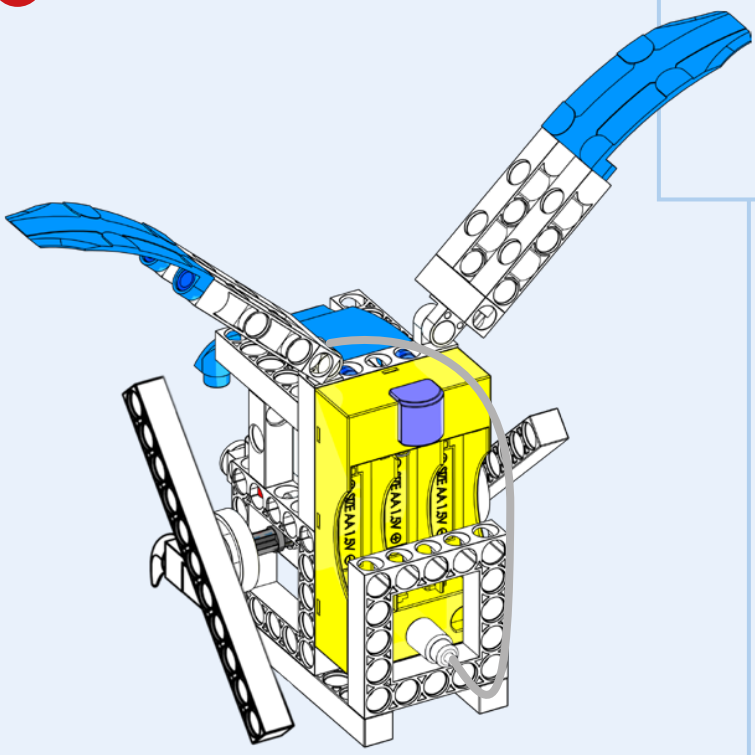

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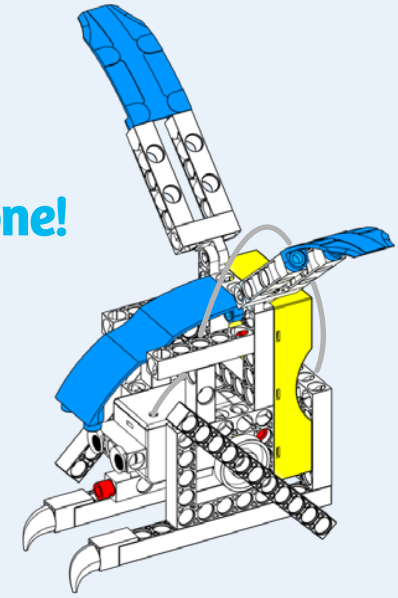


EXPERIMENT 5

Bat race

YOU WILL NEED

- **The assembled bat**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Masking tape*
- *Measuring tape*
- *1 teammate*
- *Stop watch, note pad, and pen*

HERE'S HOW

1. Use the masking tape to mark a starting line.
2. Take the measuring tape and place a second piece of masking tape a meter away, for example, and mark that one as your finish line.
3. Warm up by familiarizing yourself with the controls and movements of your bat.
4. Now get your bat into the race: Set it on the starting line facing the finish line.
5. Ideally, have a teammate give the starting instructions (for example: "On your marks, get set, go!") and measure the time with the stop watch.
6. Write down the time and let the next player take a turn. Who will win the race?

WHAT'S HAPPENING?

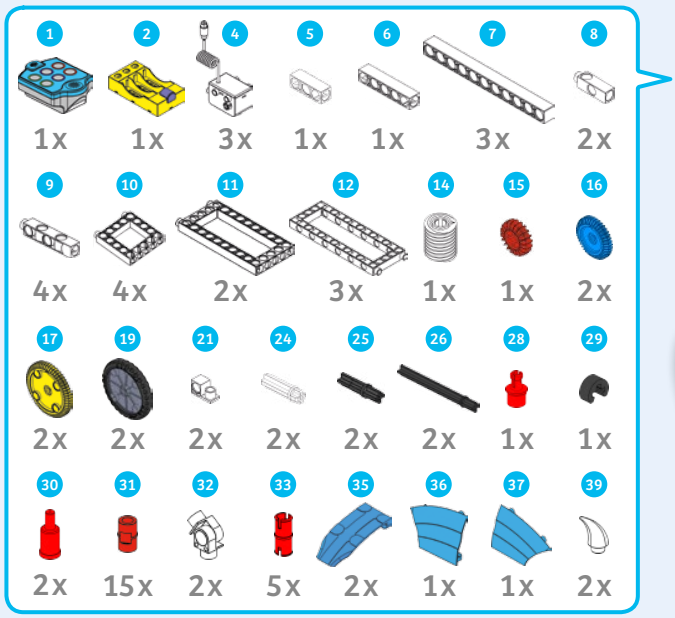
The bat moves differently from your other mobile robots — not on wheels, but on legs. You have probably already noticed that two legs don't usually offer a very reliable way to move. That's why robot engineers tend to rely on more than two legs. Six-legged constructions are an ideal foundation for legged robots that can move securely and stably, even across uneven terrain.

KEYWORD: BIONICS

In robotics, engineers often try to borrow abilities and techniques from nature. The science of doing this is called **bionics**, coined from the Greek word for "life."

Bats have a lot of useful abilities to offer bionics, particularly their ultrasound echolocation system. Bats emit ultrasound waves that bounce back off of objects located in their surroundings, which the bat can use to interpret the objects' locations. Robots also take advantage of systems like this. For example, they use echolocation systems to find out how far away obstacles are.

STAG BEETLE



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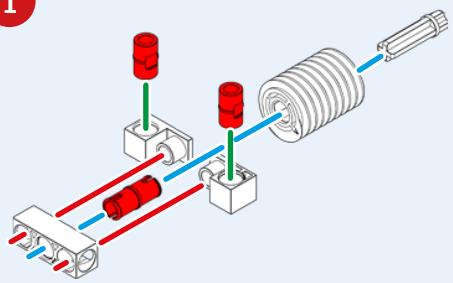

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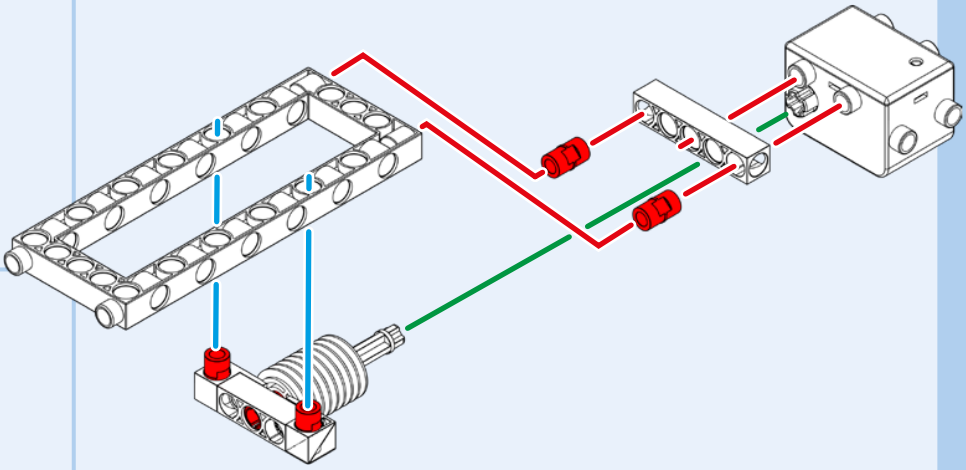

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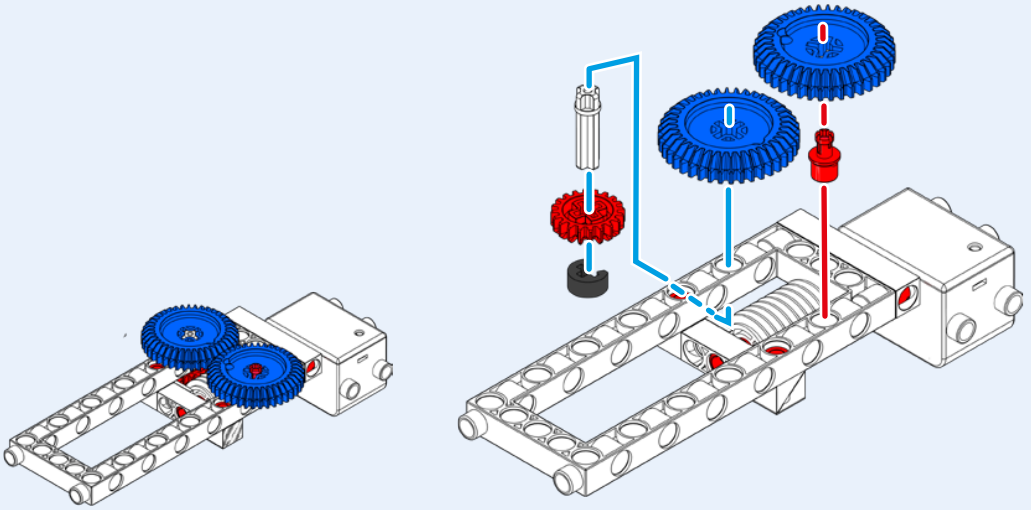

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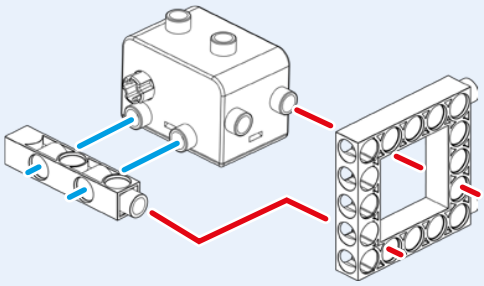

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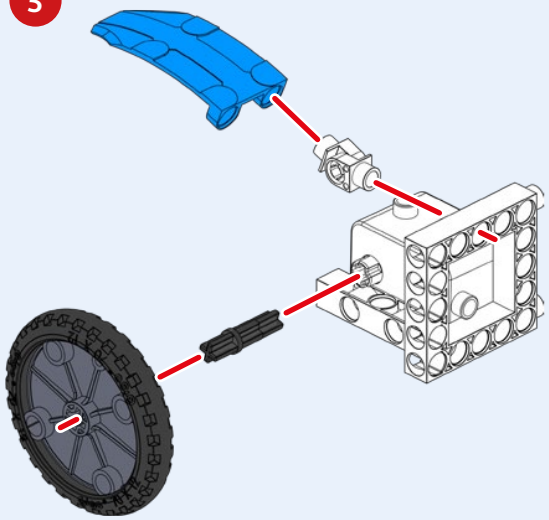

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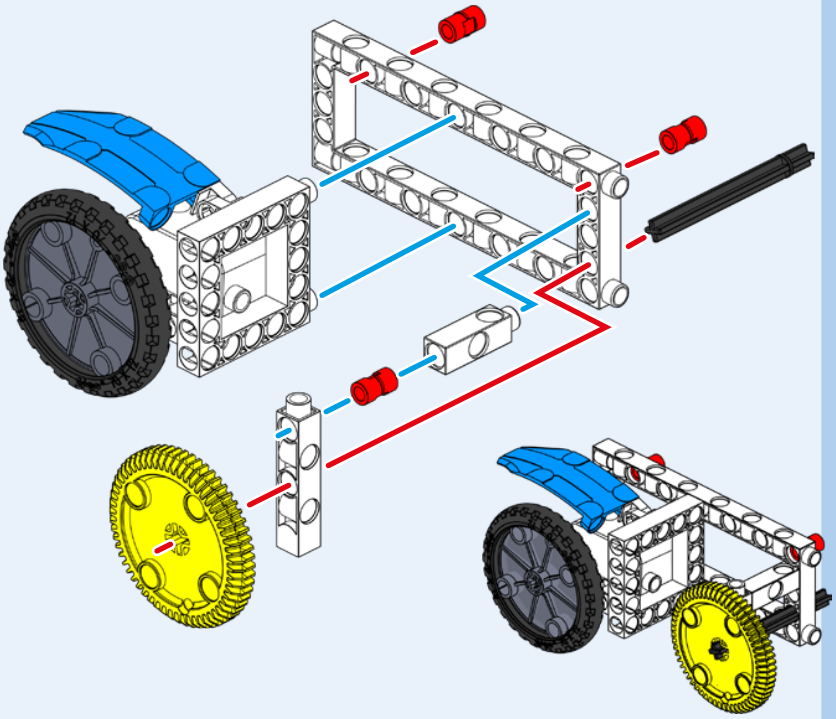

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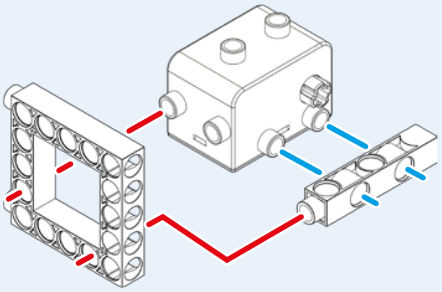

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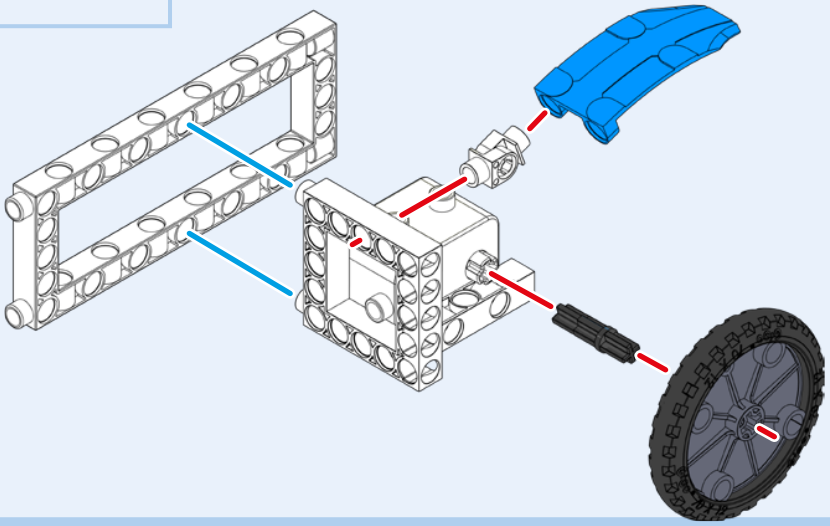

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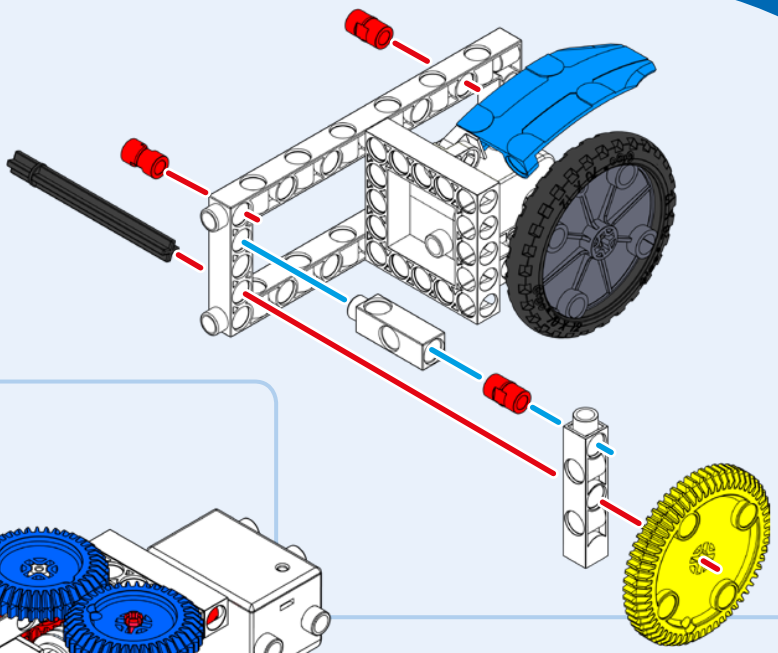

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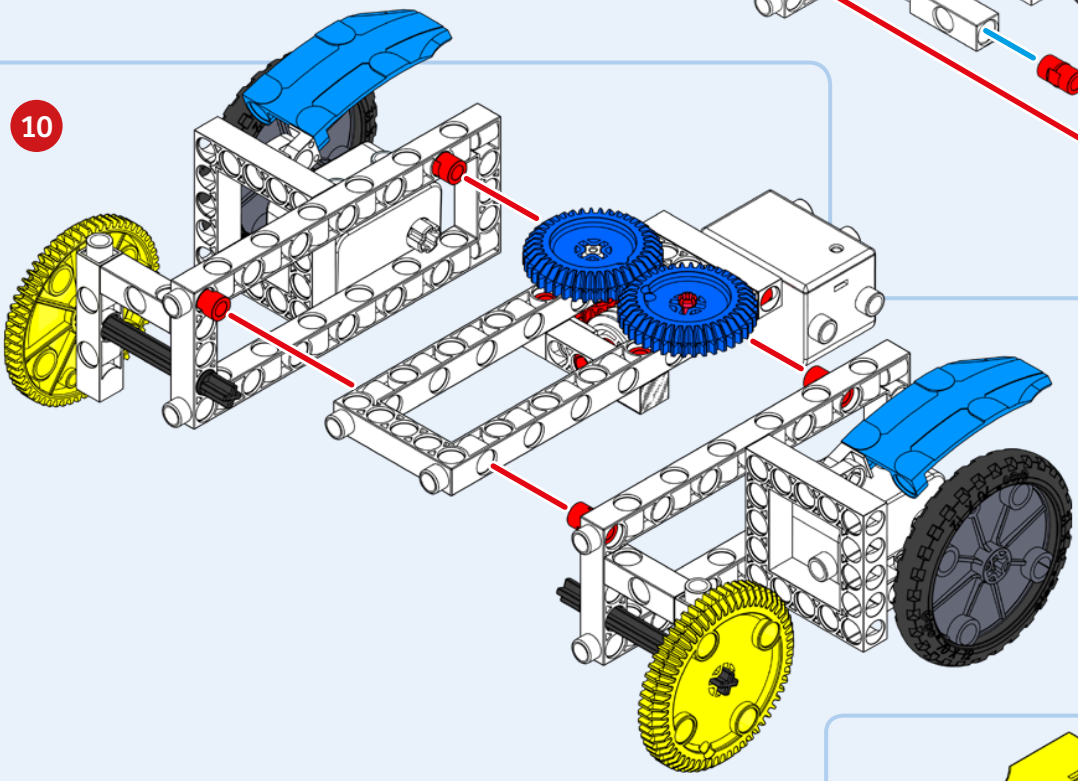

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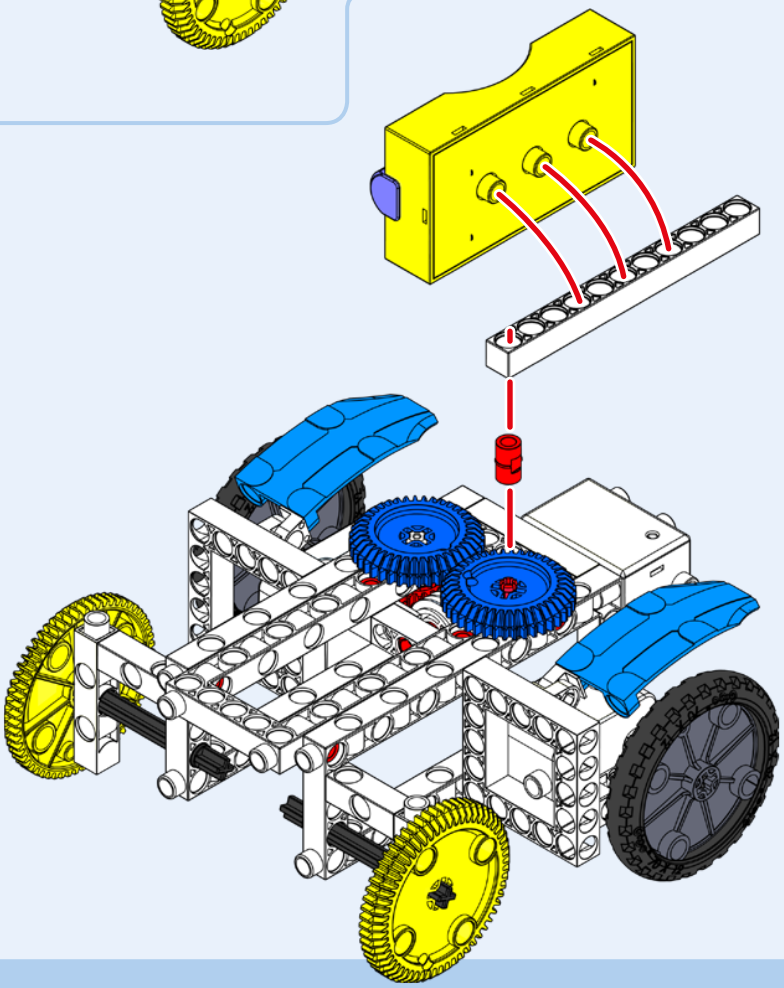

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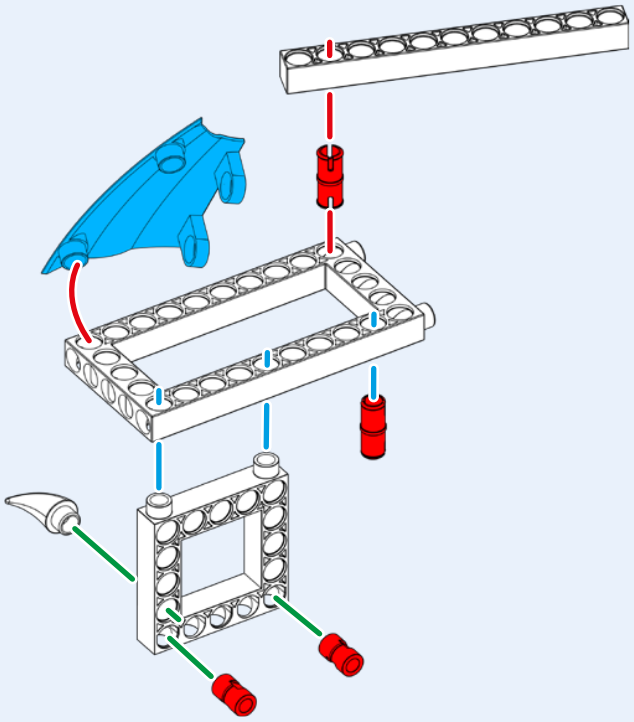

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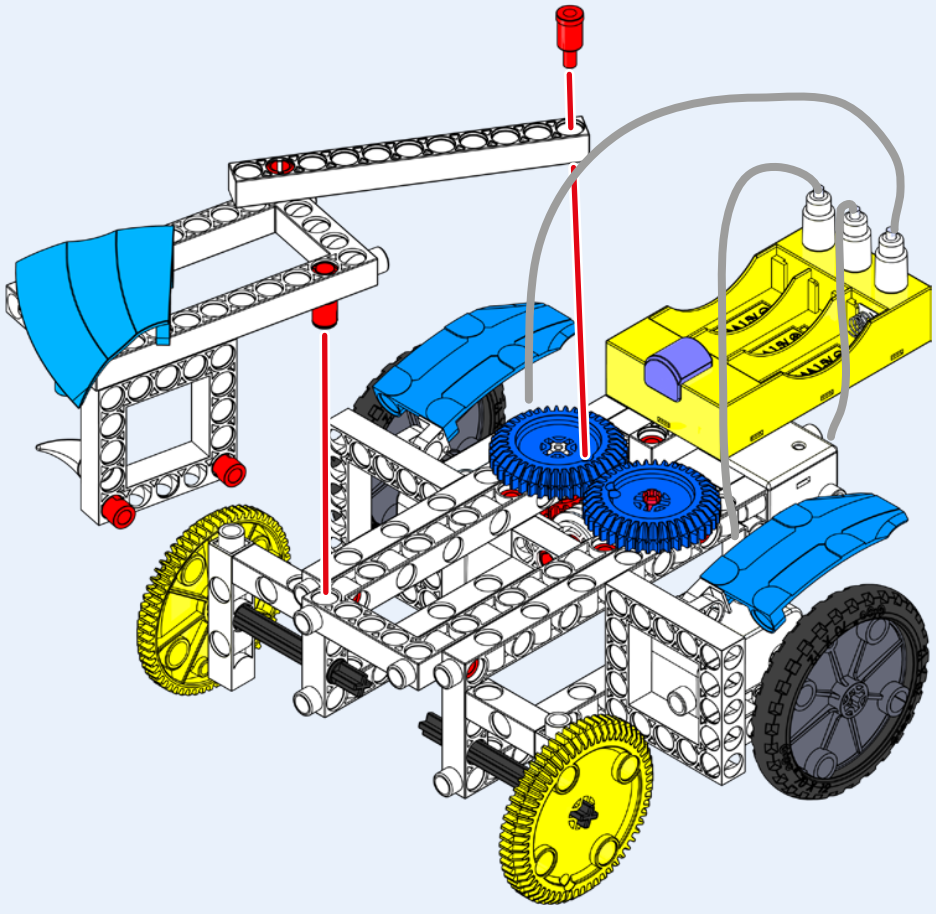

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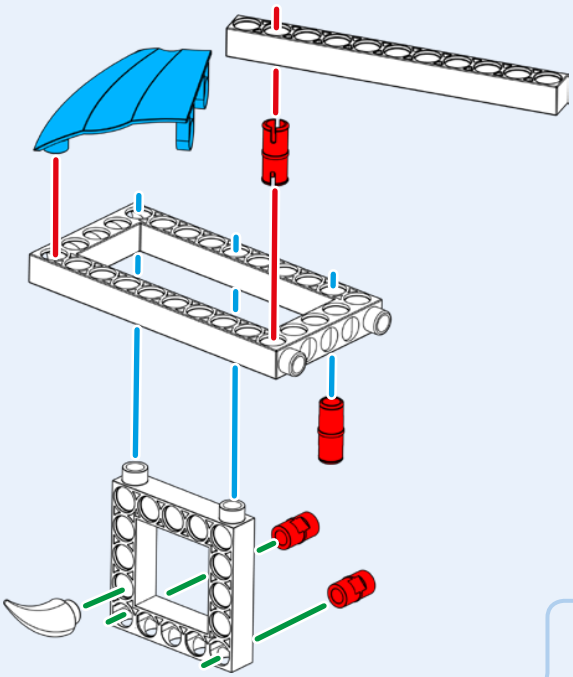

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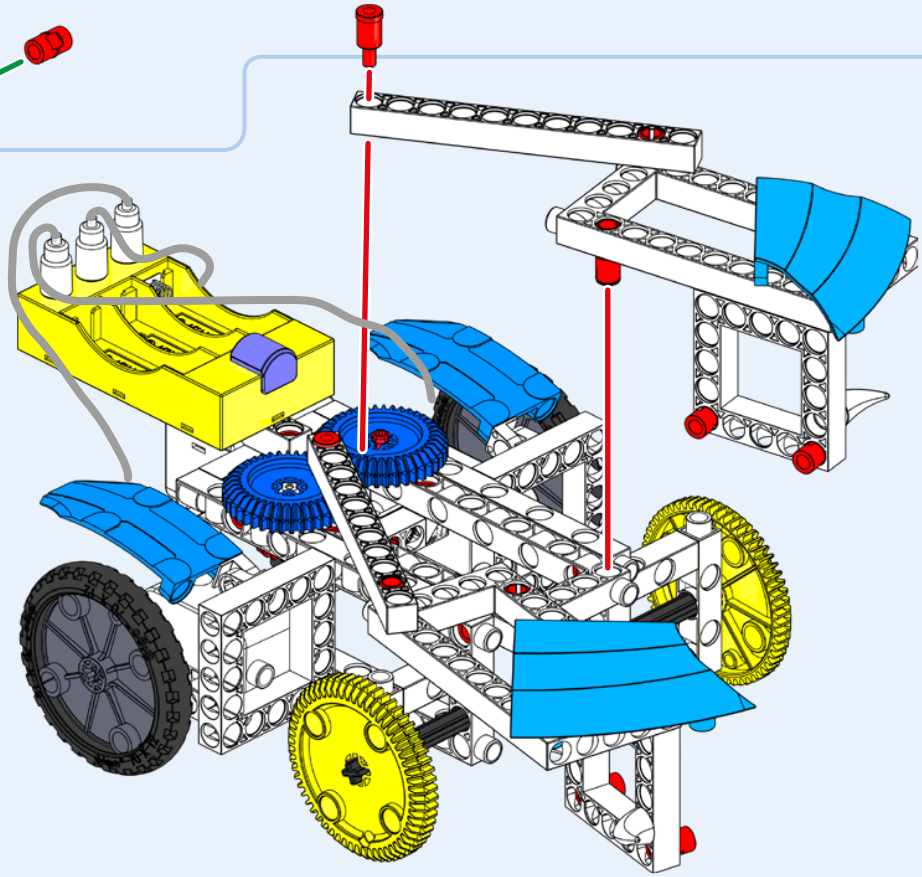
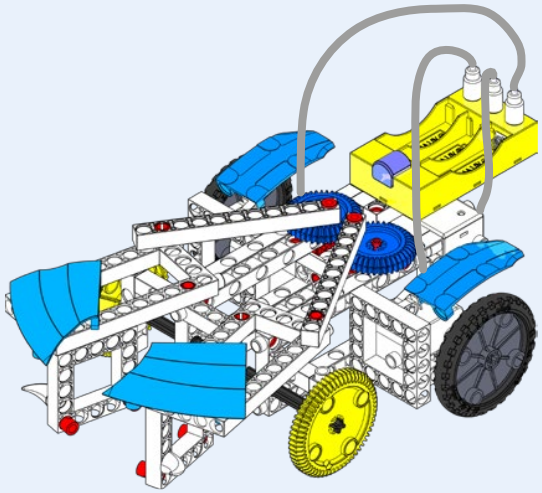
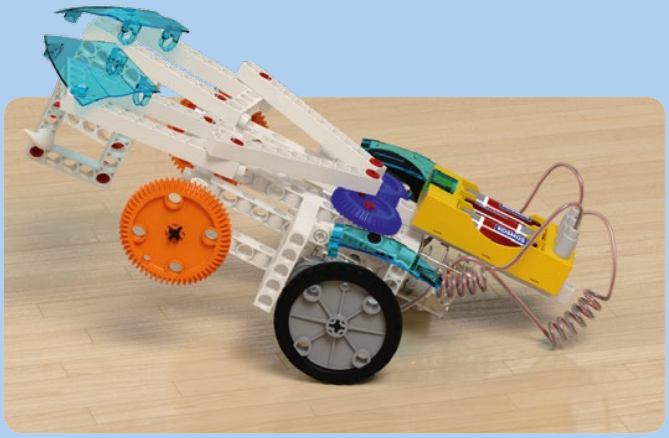




Done!

EXPERIMENT 6

Doing wheelies with the stag beetle



YOU WILL NEED

- **The assembled stag beetle**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Measuring tape*
- *Stop watch, note pad, and pen*

HERE'S HOW

1. Familiarize yourself with the controls of the stag beetle. Which touch pad buttons control which motor? You will see that your beetle is capable of some impressive acceleration, and acceleration is what this experiment is all about.
2. You will need a surface with a lot of "grip," not a smooth one. Try experimenting with a variety of floor surfaces.
3. The goal is to pop a wheelie. That means you'll have to accelerate both rear wheels as much as possible in the shortest time. This will make the front of the stag beetle lift up as it rides on its back wheels. You can also do it by driving the stag beetle quickly in reverse and then abruptly switching to forward.
4. Decide where you want the starting point to be and mark it with a strip of masking tape. Try seeing how long a wheelie you can do along the strip of tape.
5. You can also have a competition with other contestants, of course. Keep track of the time each person takes to cover the specified stretch of ground.
6. Or, you can just time how long each contestant can keep the stag beetle driving on its rear wheels. Who can do it the longest?

WHAT'S HAPPENING?

If you drive a multi-axle vehicle, such as a motorcycle, car, or your "stag beetle," on just its rear axle, that's known as a wheelie.

Two important points:

››› The center of the vehicle's gravity is of crucial importance. The higher it is, the less force you need to pop the wheelie. That's why your stag beetle has the motor and battery box mounted up high.

››› The vehicle needs enough power at the drive axle to get a fast start and lift the weight of the front part.

DID YOU KNOW?

Expert motorcyclists are capable of maintaining wheelies over a distance of thousands of meters.

WANT MORE?

You can add some extra weight, such as one of the 5-hole rods, onto the rear of the stag beetle. That will shift the center of gravity farther to the back and upward, making it easier to pop a wheelie. Try it!

CHECK IT OUT

Almost Olympic:
Robot Octathlon

Researchers, engineers, and inventors are always trying to improve robots. But what's the best way to do that? Some researchers have come up with the idea of having an octathlon for service robots, something like a decathlon at the Olympics.

The idea behind it is that competitions provide an incentive to do better. And when you specify all the things that the robots should be able to do, it helps people understand how to improve them.

For rescue robots, which are a special type of service robot, this offers a way to test them on the accidents and catastrophes they might have to respond to in the future. The experts came up with a list of eight tasks that robots will have to be able to handle in order to be fit for emergencies.

These are the eight challenges of the robot octathlon:

1. Drive a vehicle over various obstacles
2. Drive across difficult, uneven terrain
3. Climb up a ladder with seven rungs
4. Clear away light objects
5. Open doors
6. Drill through a light construction wall with a precision drill
7. Close valves such as water taps
8. Unroll a water hose from a hose reel

It may sound easy, but robots have to be able to master all of these things in emergency situations. It's still a little beyond the abilities of today's robots.

And this is how one contestant looks. This is **Atlas,** an American robot weighing 150 kilograms with a rotating cylindrical laser scanner in his face (see "Check it out," page 76), which he uses to orient himself in open terrain. In his first octathlon attempts, however, he was anything but sure-footed. He wobbled, took slow and tiny steps, and proved to be quite unsure of himself.

Another contestant did better. **Schaft,** a Japanese robot, even managed to back down a stairway without a handrail. But even he could only do that very slowly.

Rescue robots in the air

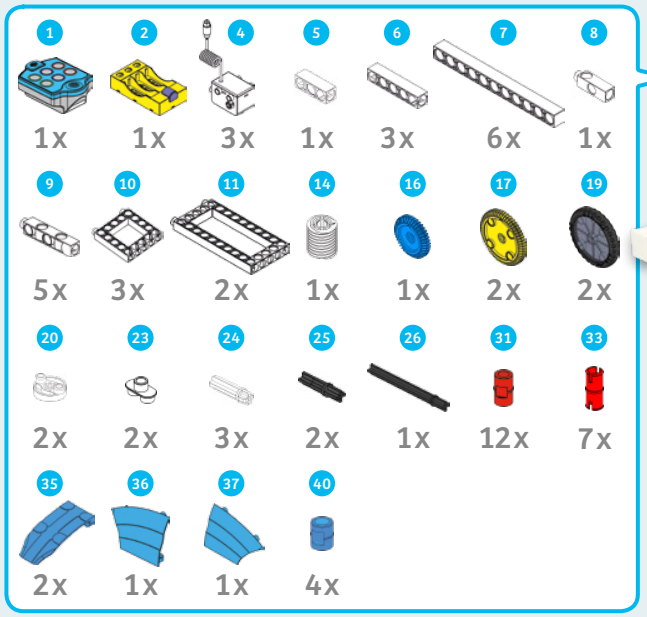
Another project under development for emergencies is taking things a step further — into the air. These rescue assistants are specialized kinds of **drones.** Since they are often as small as a shoebox, they are light enough to hover in the air. They can fly about 15 meters up, allowing them to use their built-in cameras and infrared systems to scout out the surroundings to determine where the fire is or where injured people might be.

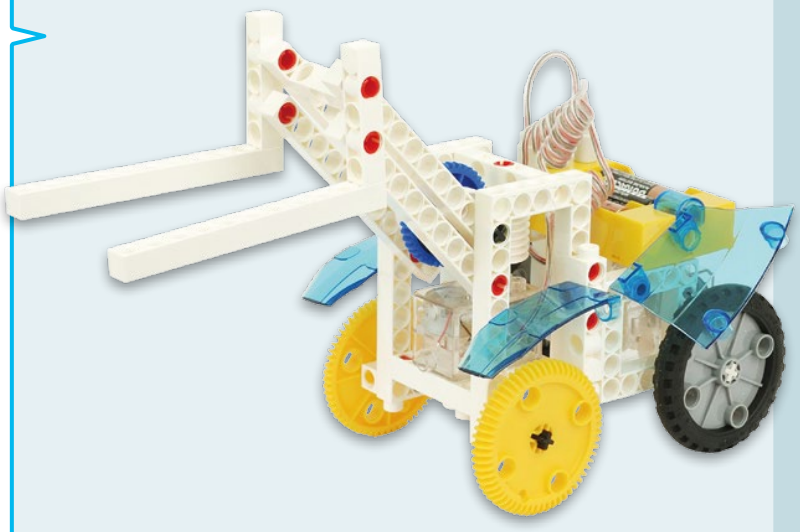
Drones like this are helpful because they can do things like transmit images of a burning house directly to the fire department. That lets the emergency personnel get an overview of the situation without having to send people into harm's way.

Robots for Transport

Carrying packages or crates from point A to point B is one of the strengths of robots. They are already pretty good at that today. What is it that they have to be able to do? They have to pick up the cargo precisely, deliver it accurately to the specified spot, and set it down there carefully. It sounds easy. But the next experiments will show you that robots don't have an easy task here.

FORKLIFT





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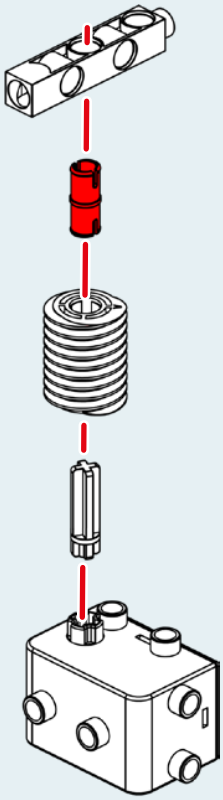

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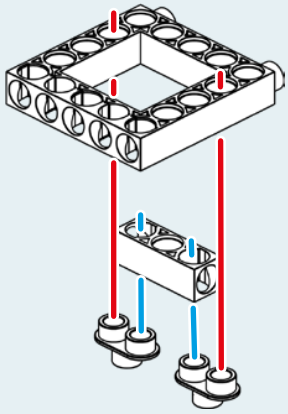

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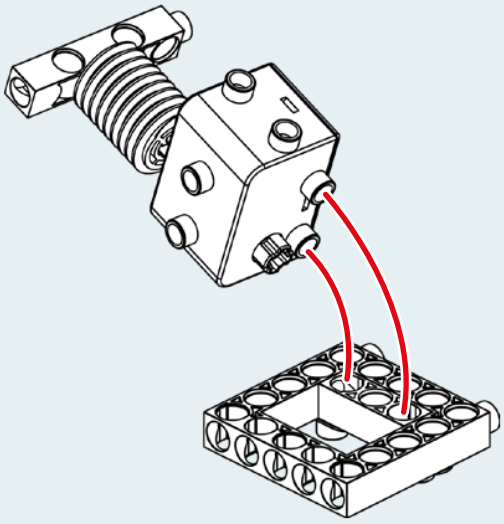

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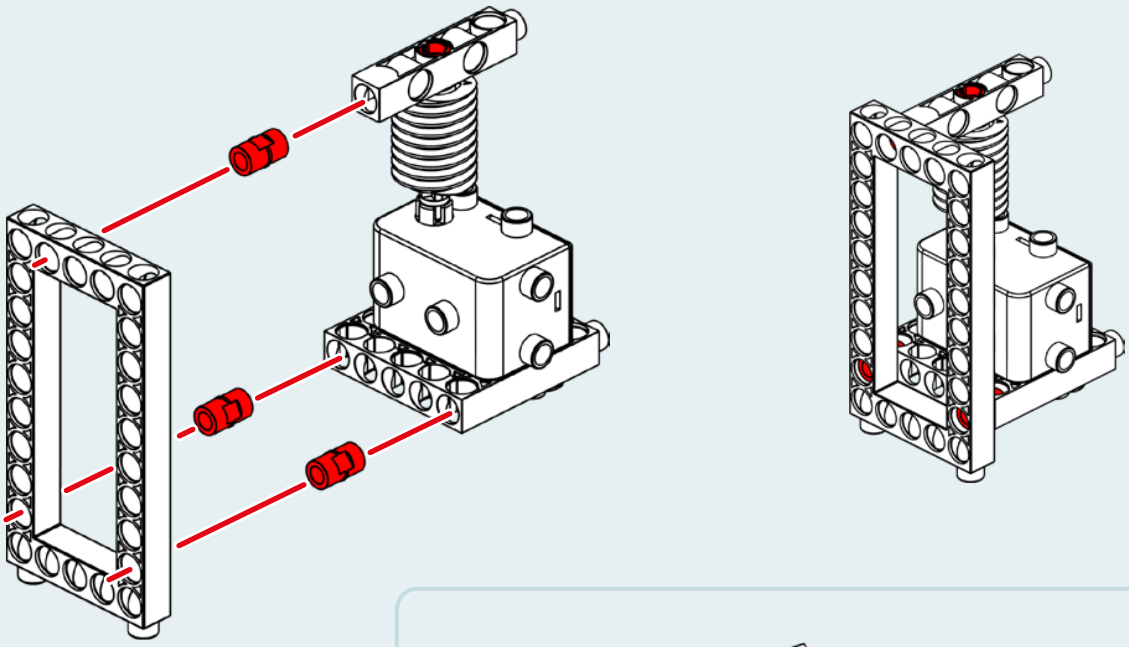

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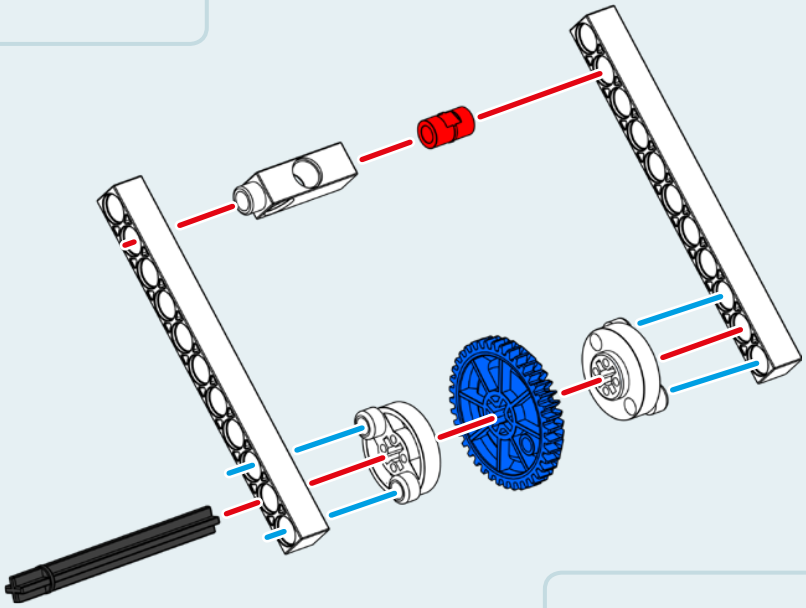

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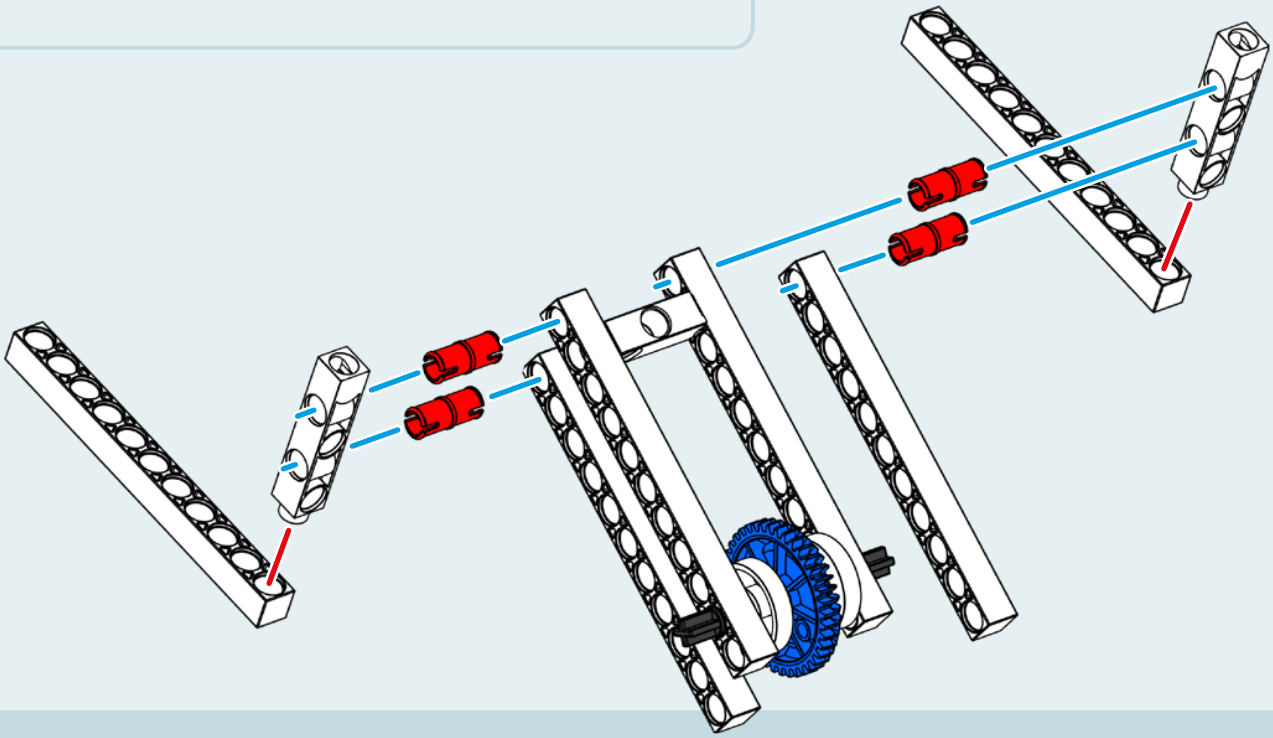

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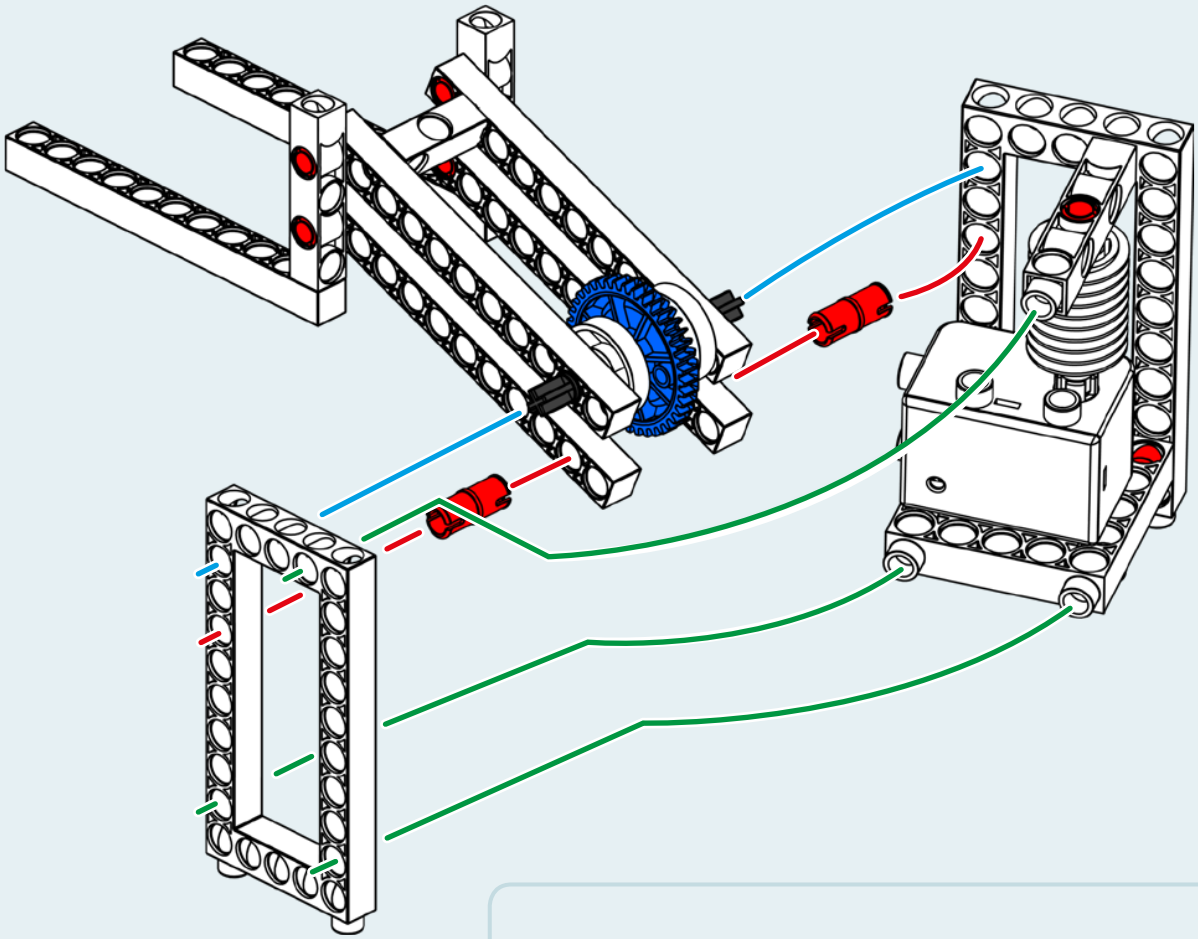

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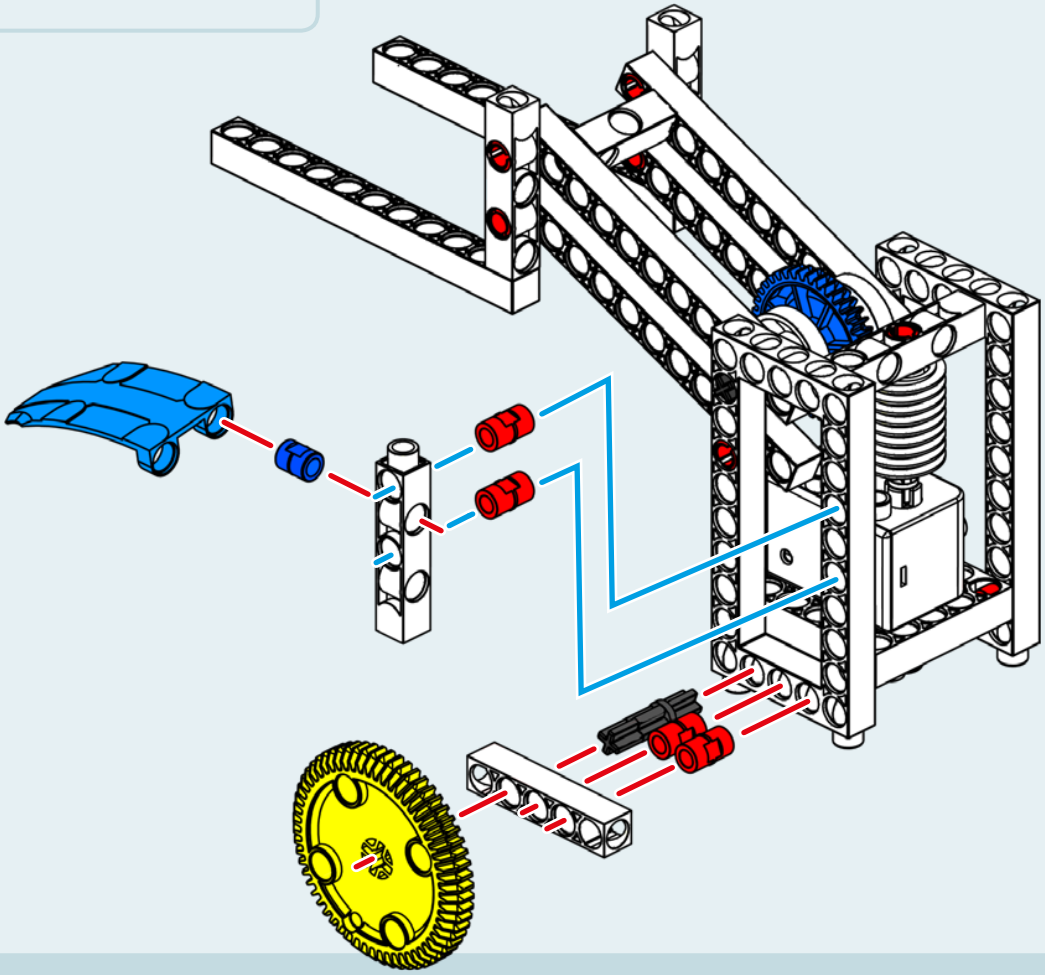

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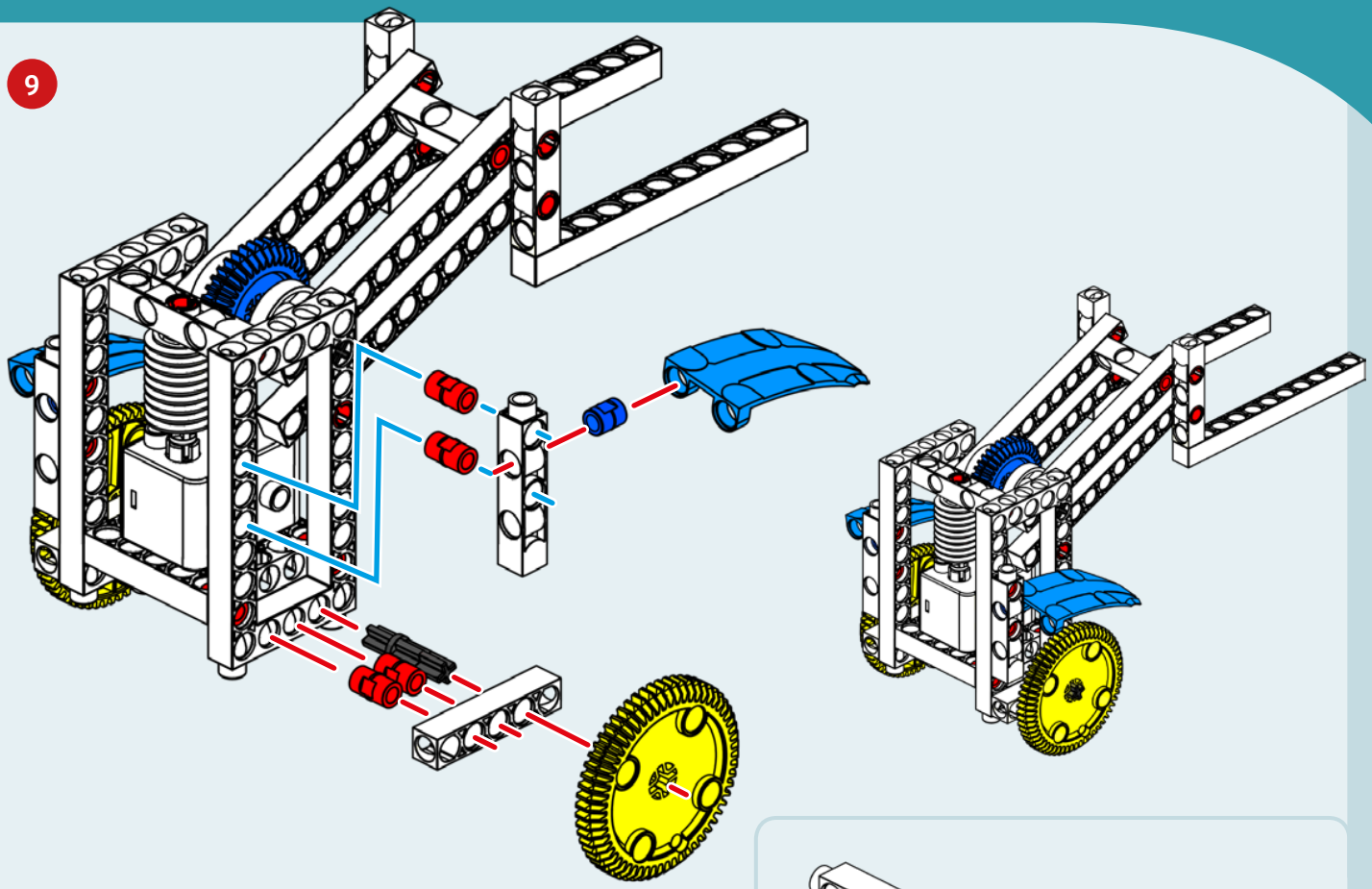

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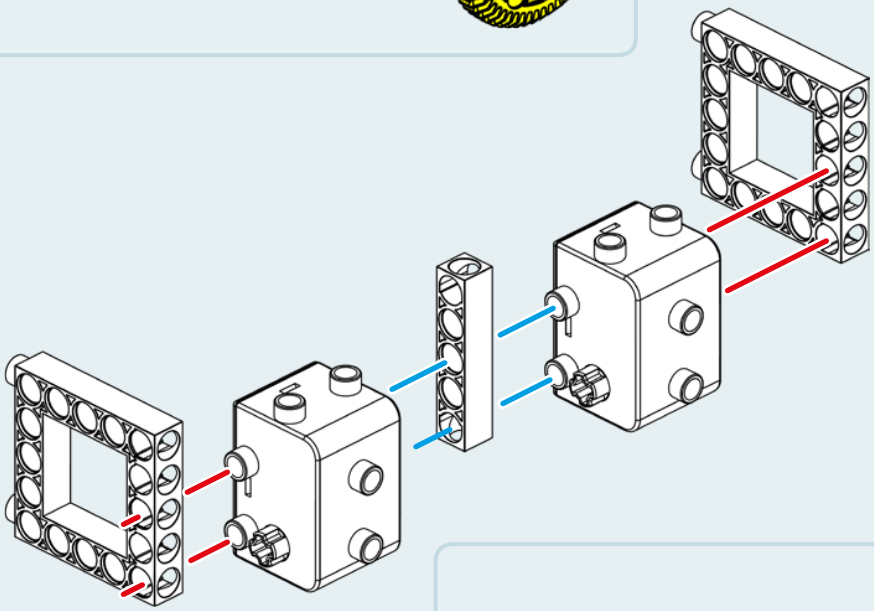

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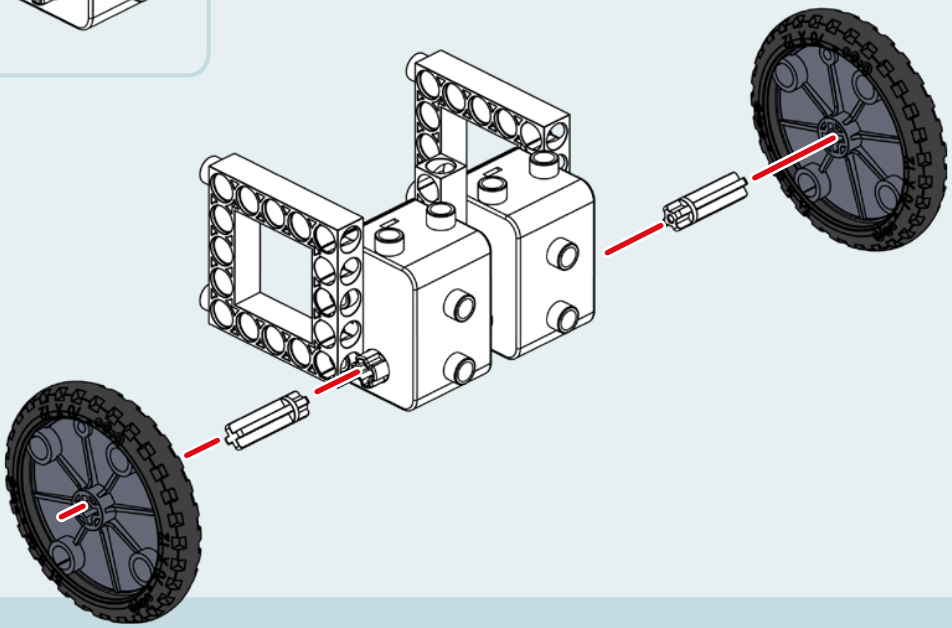

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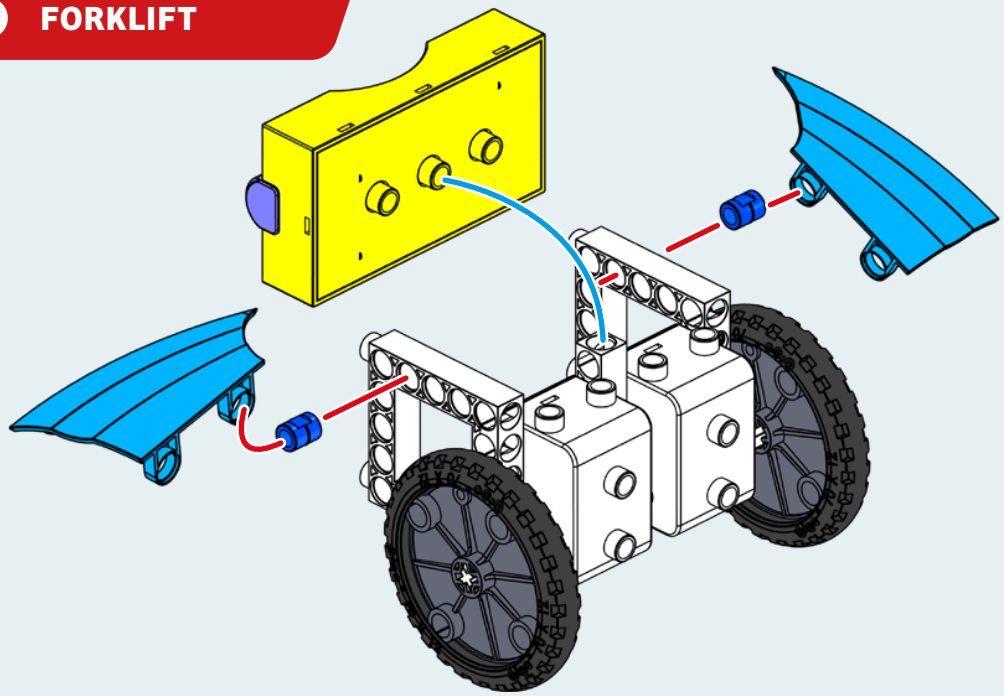

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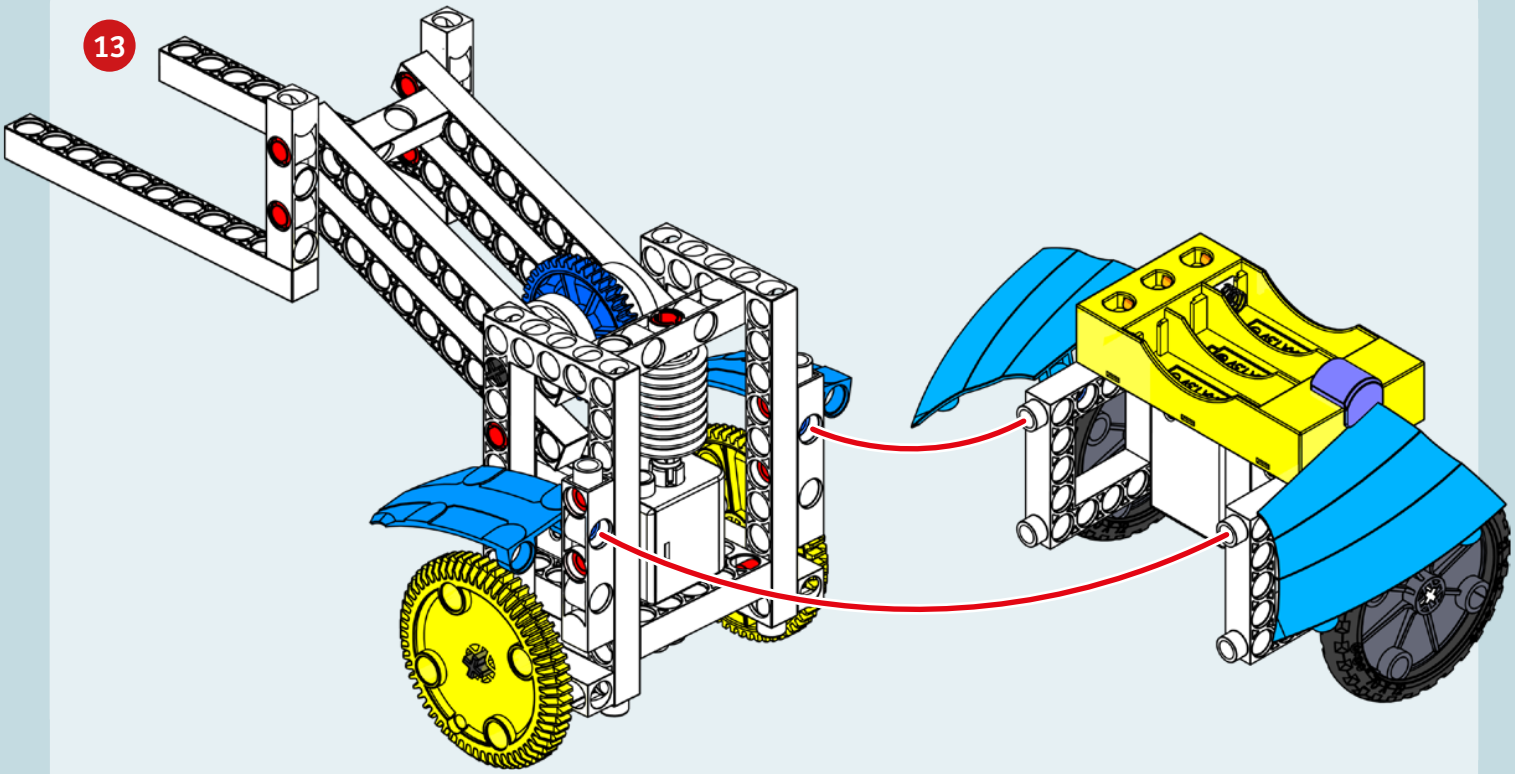

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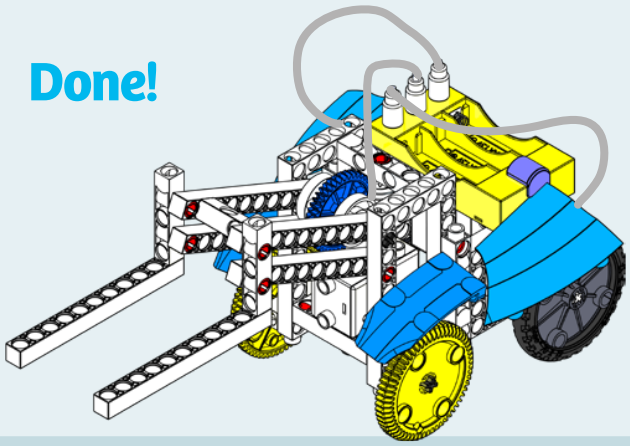
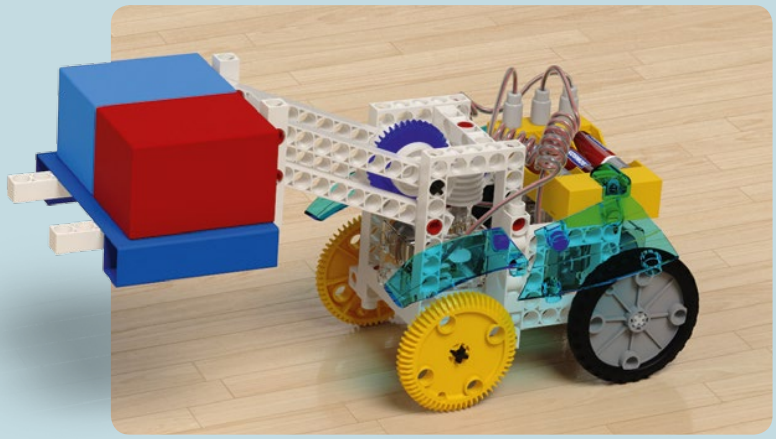


EXPERIMENT 7

Stacking boxes with the forklift



YOU WILL NEED

- **The assembled forklift**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Several pallets (see page 128)*
- *Several boxes (see page 127)*

HERE'S HOW

1. Familiarize yourself with the controls of the forklift. Which touch pad buttons control which motor? And most importantly: How skillfully can you operate them?
2. Set a pallet on the floor and place some boxes on top of it. For starters, two boxes side by side should be enough
3. Drive your forklift up to the boxes. Lower the fork almost to the floor and maneuver it under the pallet.
4. Now lift the pallet up and drive the forklift to another location in the room where you would like to deposit it. But be careful: Don't drop your cargo!
5. Set your load down carefully and move the fork back away from the pallet so the forklift can move freely again.
6. Try this same exercise with taller and taller stacks of boxes. How many can you carry at the same time without dropping a single one? Can you also stack pallets on top of one another?

WHAT'S HAPPENING?

When the weight on the front fork is too great, the forklift will tip forward over the front axle. The principle behind that is known as **leverage**. This refers to the action of a system consisting of a rigid body fastened to a point of rotation. In this case, the rigid body is the forklift, while the point of rotation is the front axle.

The physical science description of this kind of system is called the lever principle. In simplified form, and applied to the forklift, it says that the greater the weight and the farther forward from the front axle it is, the greater the leverage. If it is too great, the forklift tips forward.

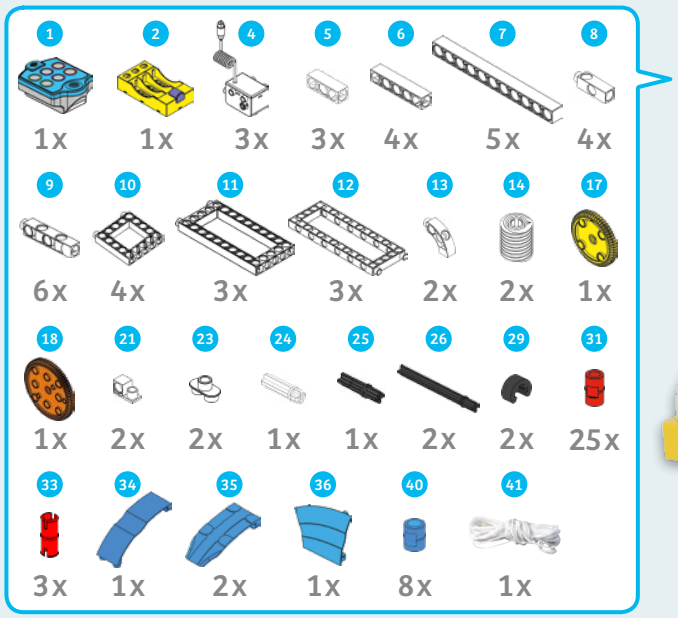
WANT MORE?

Use a counterweight at the rear in order to be able to carry greater weights at the front. You'll achieve the same result by lengthening the wheel base — for example, by using longer frames along the sides rather than the square frames.

KEYWORD: LEVER ARM

A seesaw gives you an easy way to visualize the lever principle at work. The point of rotation is right in the center of the seesaw. If both people are the same weight and are sitting equally far from the point of rotation, the seesaw works well. If one person is heavier, an extra person has to sit on the opposite side. Or, the lighter person can slide farther away from the point of rotation, thus lengthening the **lever's arm**.

CRANE


1 1x
2 1x
4 3x
5 3x
6 4x
7 5x
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14 2x
17 1x
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21 2x
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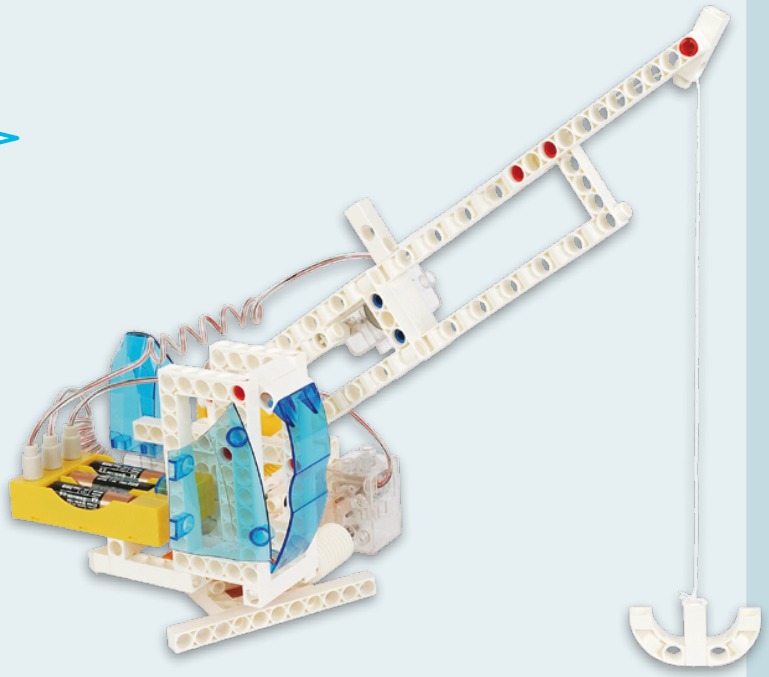
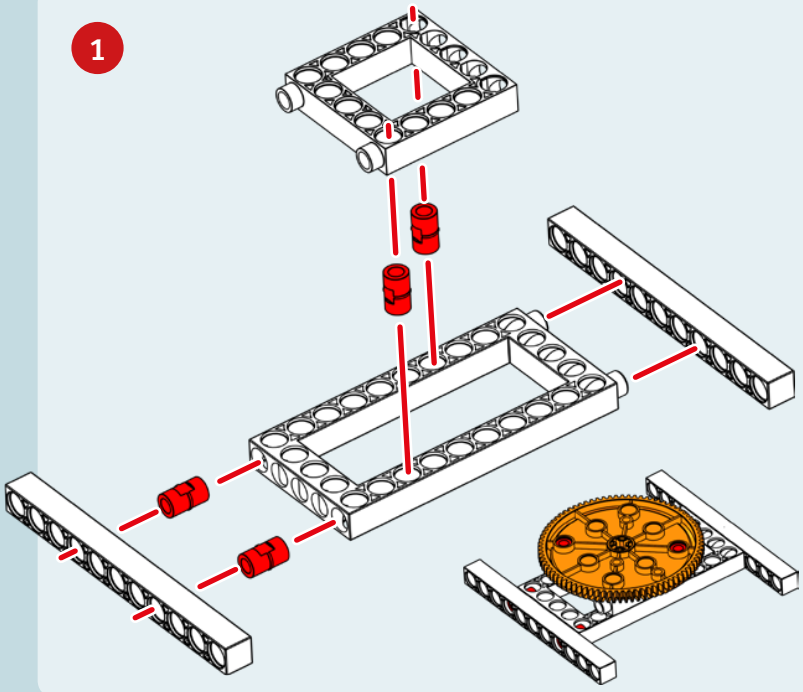
36 1x
40 8x
41 1x

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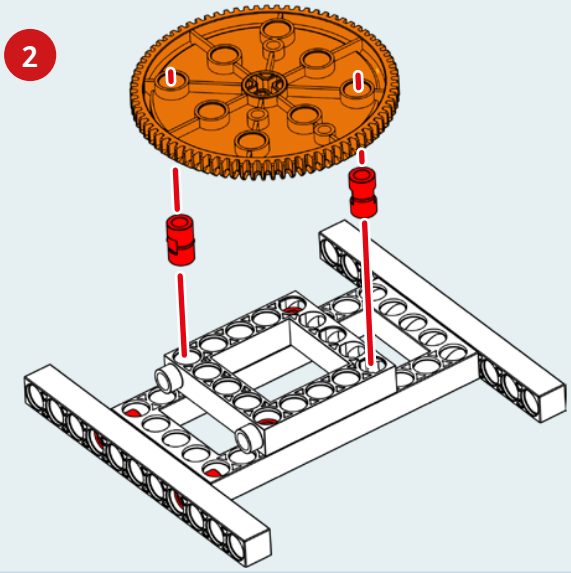
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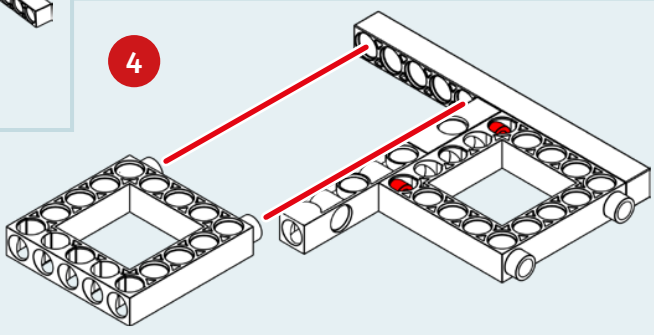
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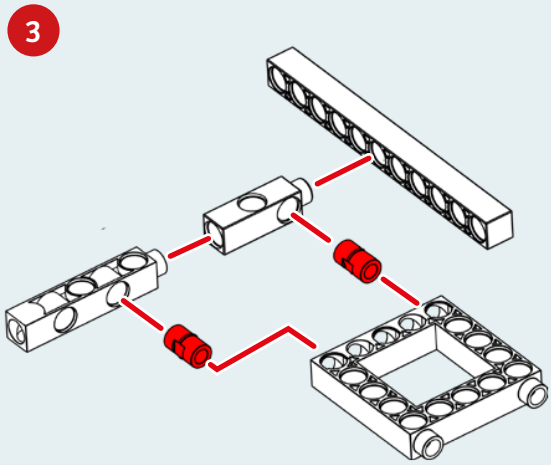
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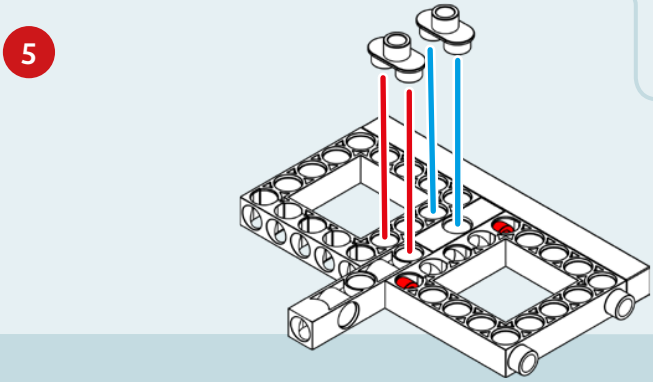
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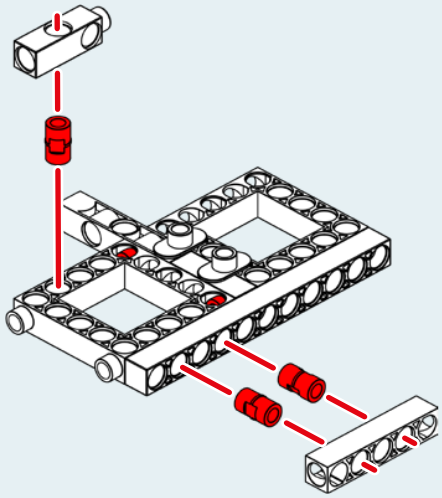

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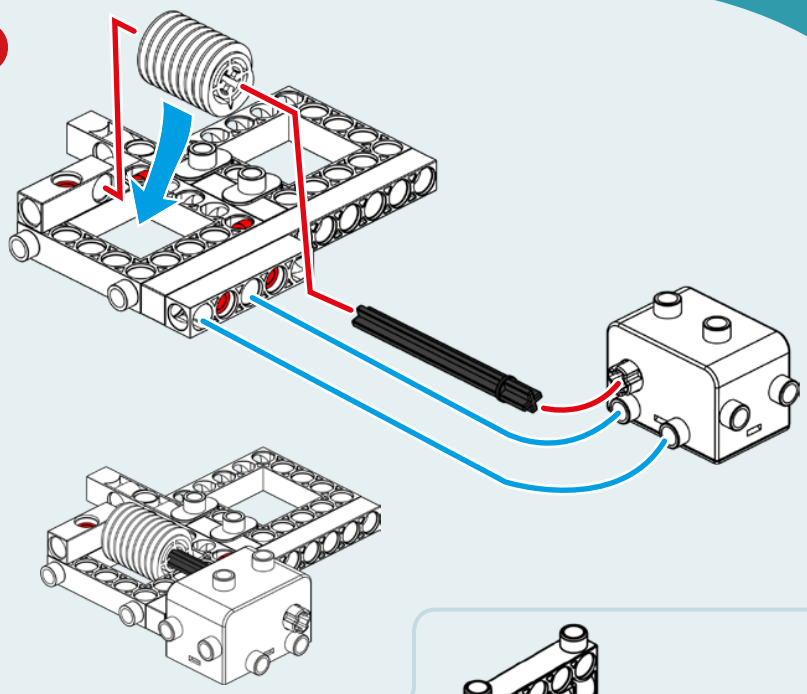

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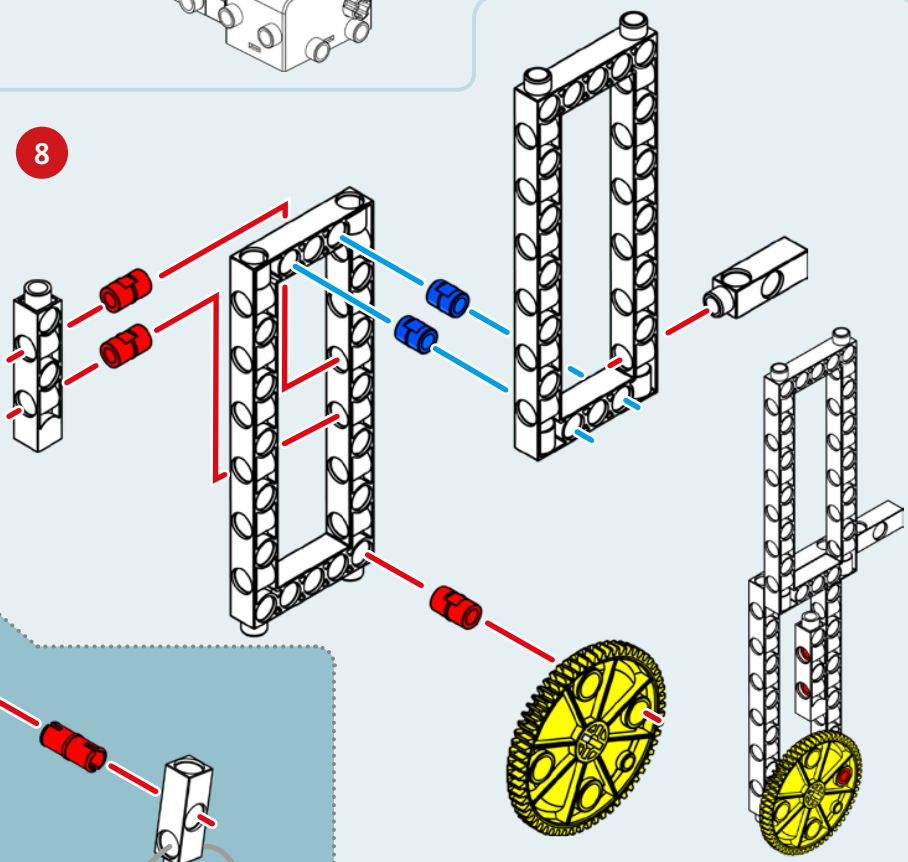

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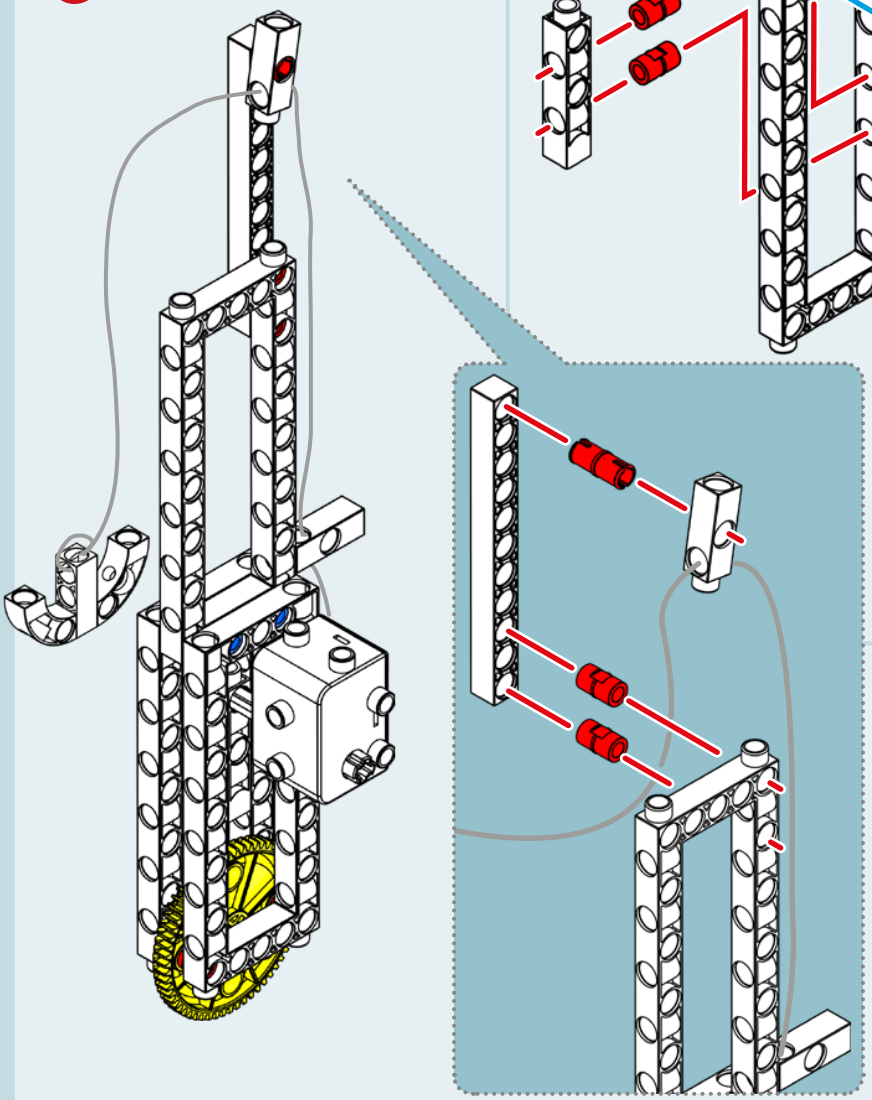

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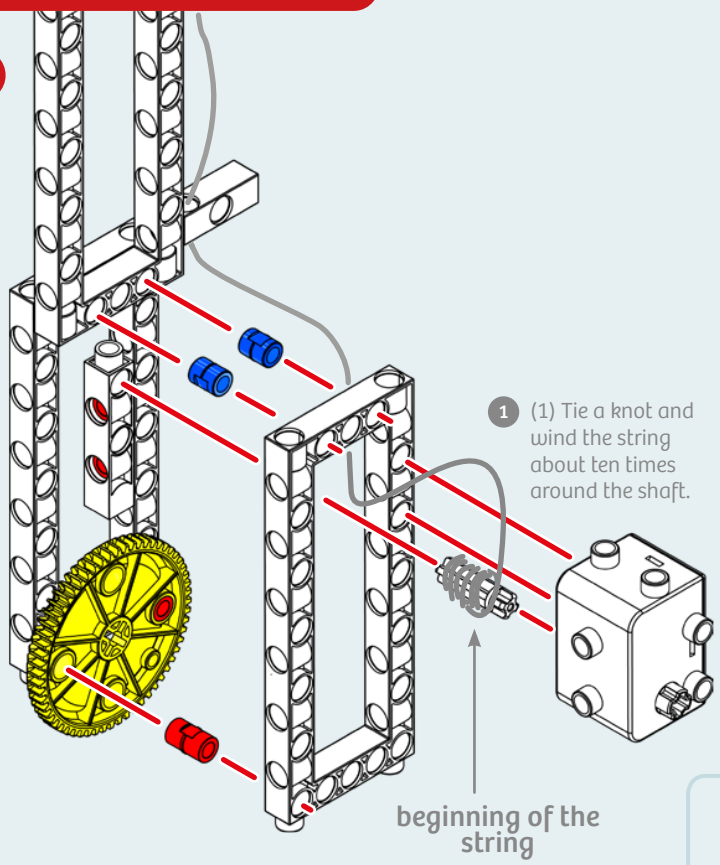
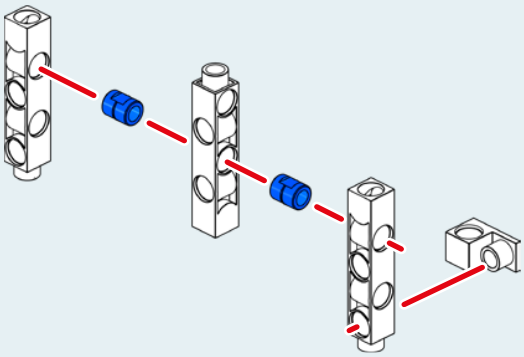

1 (1) Tie a knot and wind the string about ten times around the shaft.
beginning of the string

12



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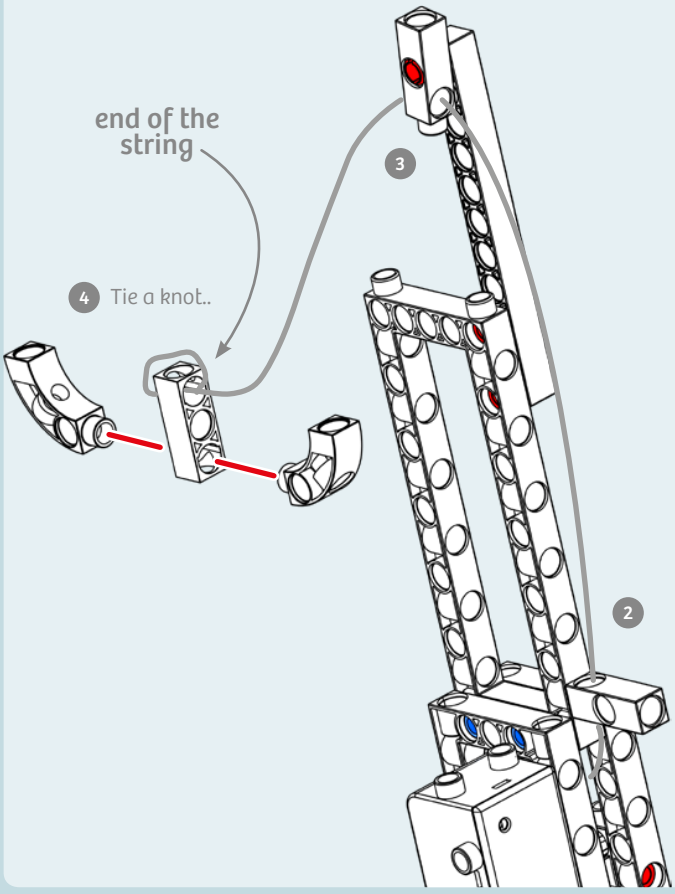
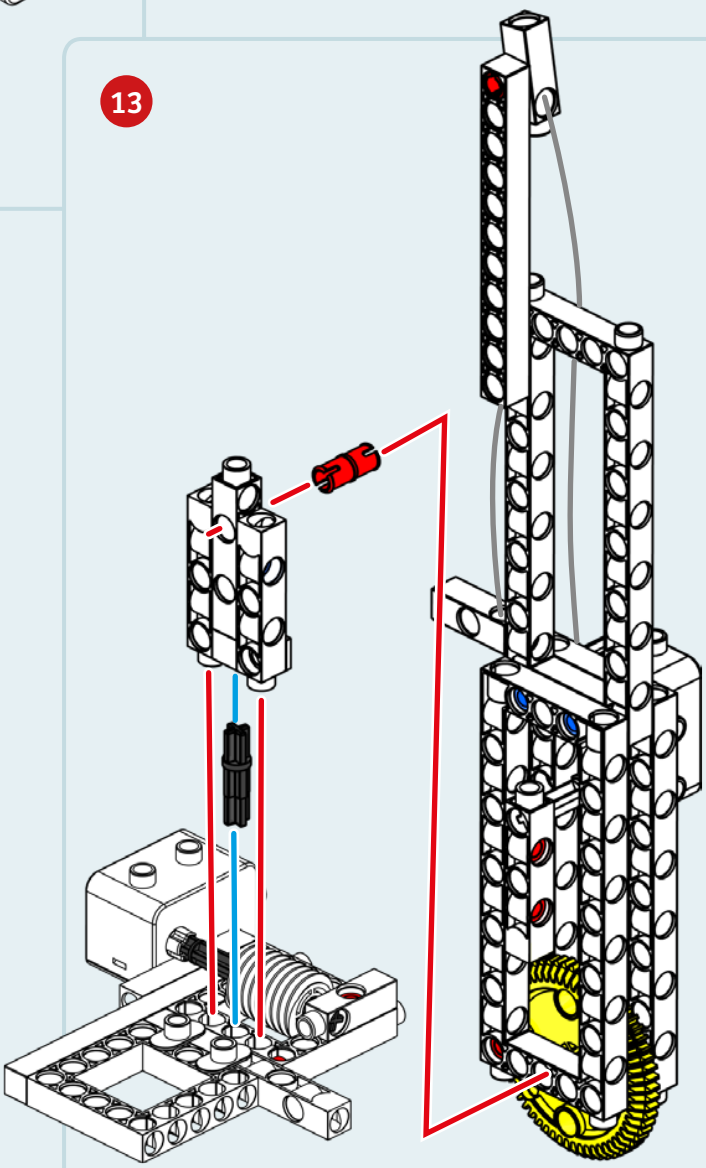

end of the string
3
4 Tie a knot..
2

13



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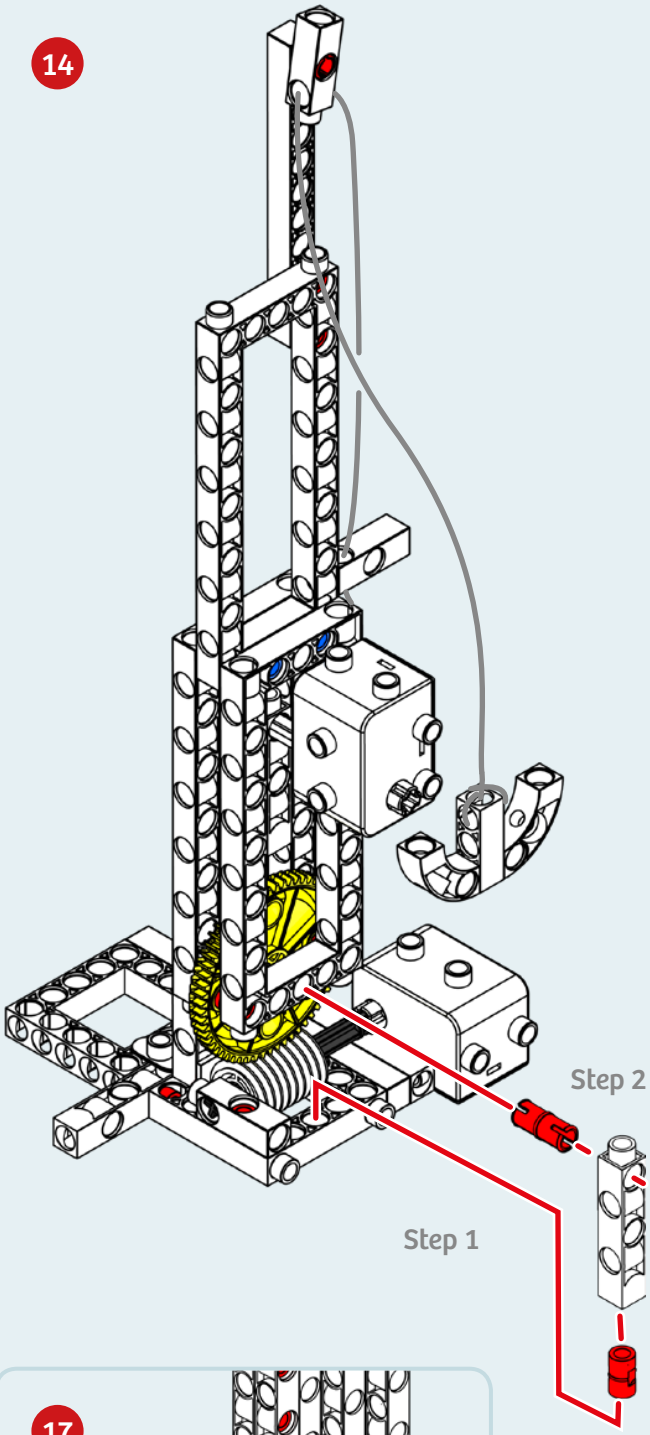

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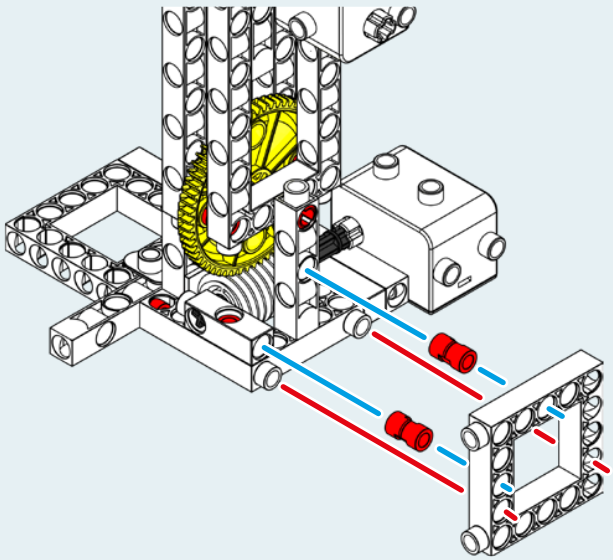

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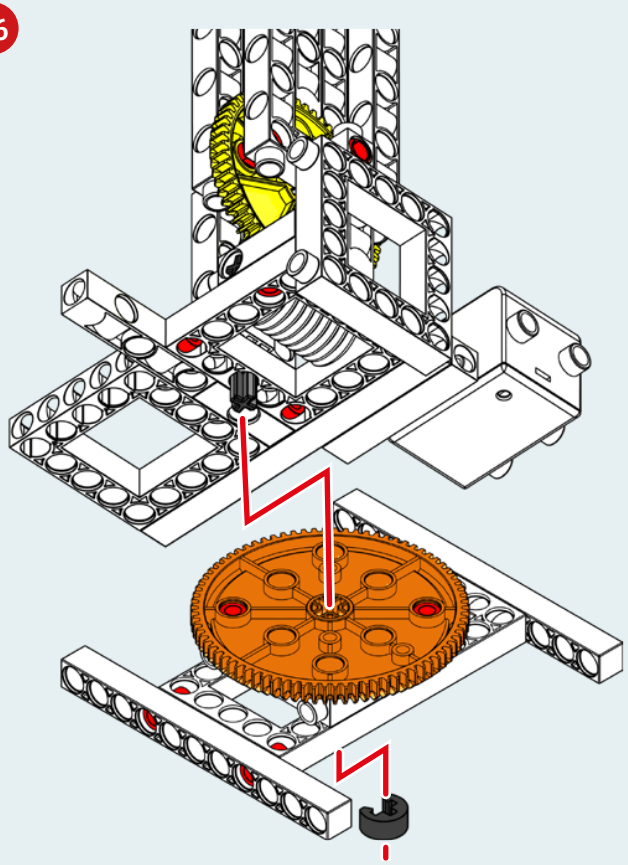

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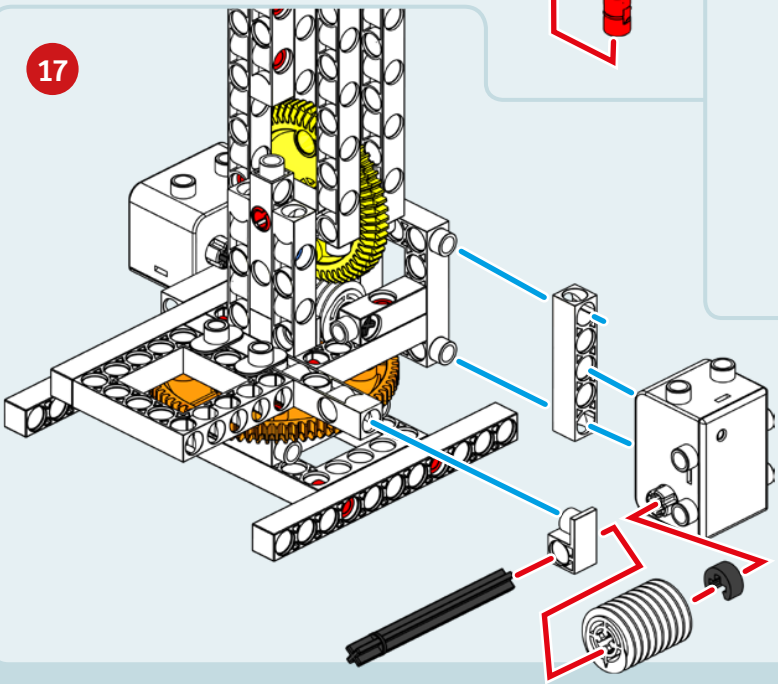

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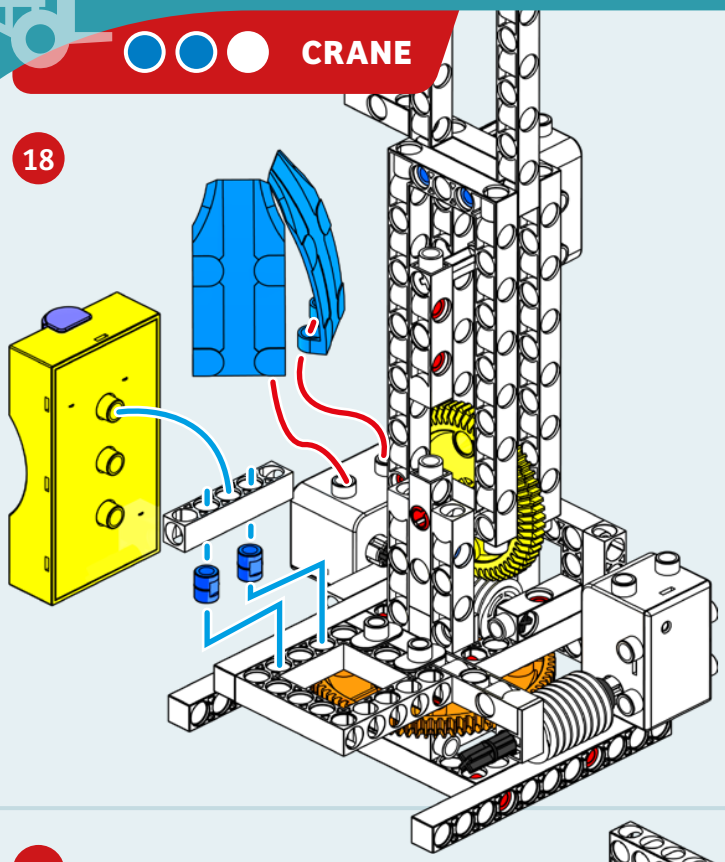

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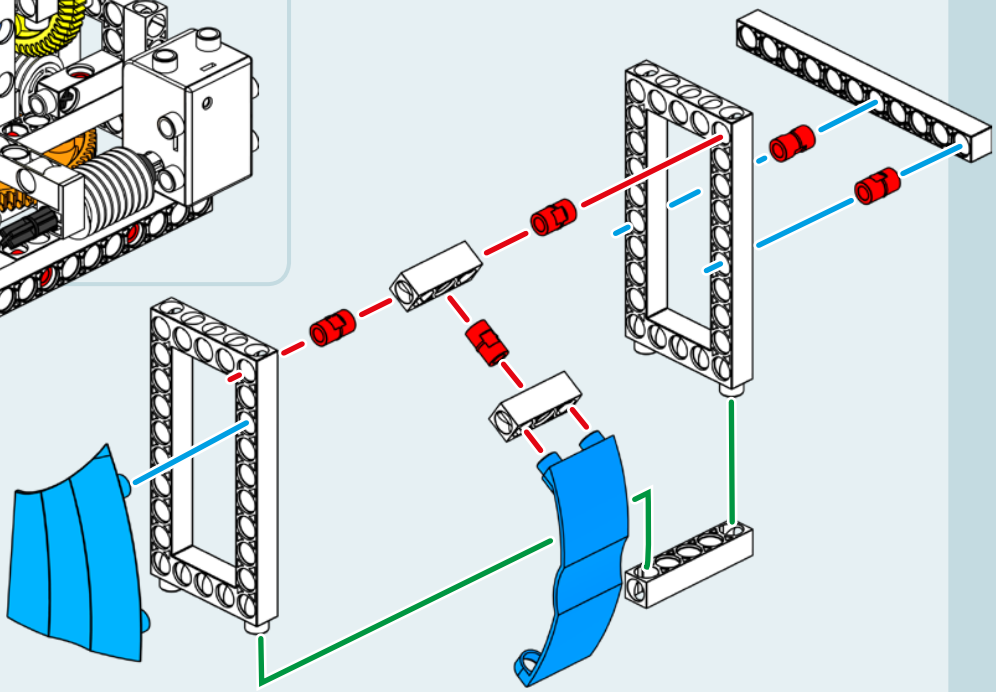

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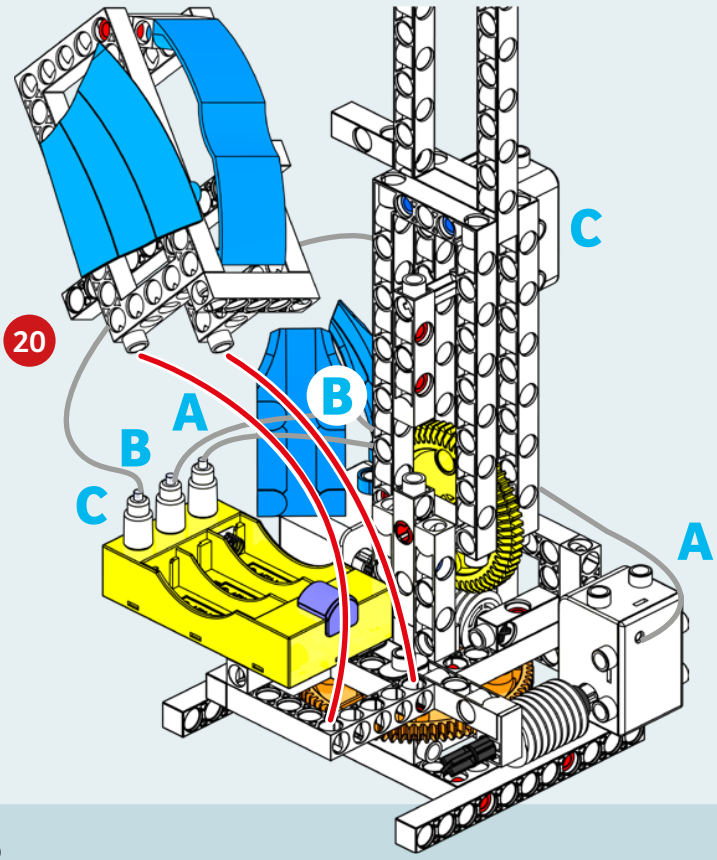

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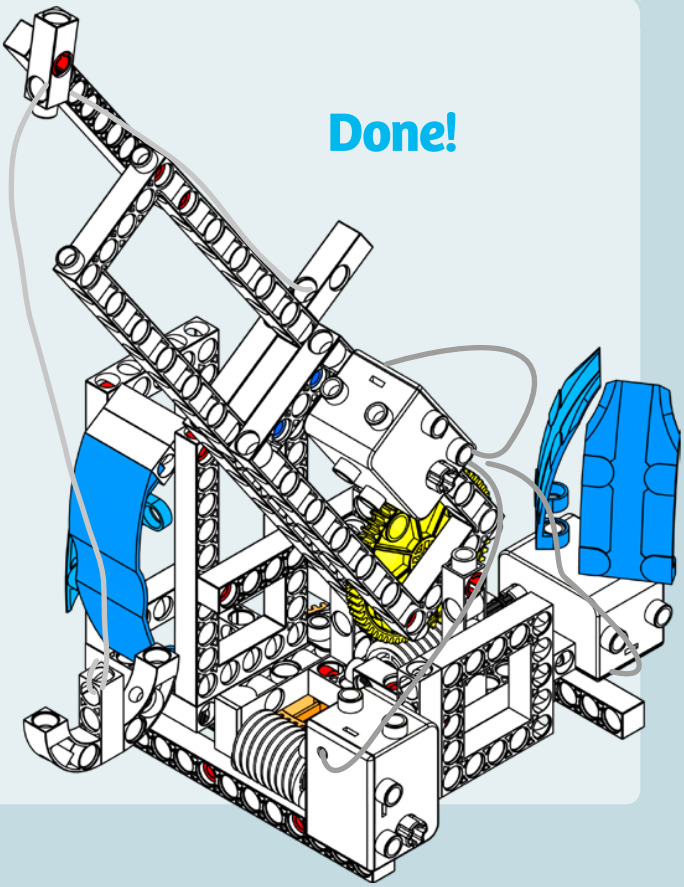


EXPERIMENT 8

Drawing a circle of sand with the crane

YOU WILL NEED

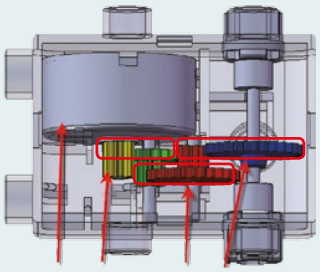
- **The assembled crane**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Small paper cup*
- *2 paper clips, pin*
- *Fine sand*
- *Trowel and hand broom*

HERE'S HOW

1. Use the pin to poke two small holes on opposite sides near the cup's rim. Thread a paper clip through each hole. Now you have made a cargo basket that you can carry around with the crane.
2. Familiarize yourself with the controls of the crane and set the basket within the reach of its arm.
3. Drive the crane up to the cargo basket so that all you have to do next is hang the paper clips through the holes of the crane's hook.
4. Then lift the basket up. Swing the arm around in a circle and set the basket down in another spot.
5. You can also use the crane to draw a circle. It's best to do this outside.
6. To do that, take your cargo basket and poke a hole in its bottom. Make it just big enough to let the sand trickle out slowly.
7. Set the paper cup on the ground and fill it with sand. Depending on how much sand you use, you might have to mount a counterweight on the driver's cab behind the receiver.
8. Hang the cup on the hook. Now you can slowly lift the cup and swing it around in a circle. As the sand trickles out, it will create a circle of sand all around the crane. How cleanly can you draw it?
9. Don't forget to sweep up the sand afterwards.

WHAT'S HAPPENING?

Since the motors are mounted on the crane in a way that makes them easy to see, let's take this opportunity to look into the motor box. You can see how the transmission system is assembled in the motor and how the different gears mesh with one another. There's an important concept at work here: the **transmission ratio**. This refers to the ratio among the numbers of gear wheel teeth.

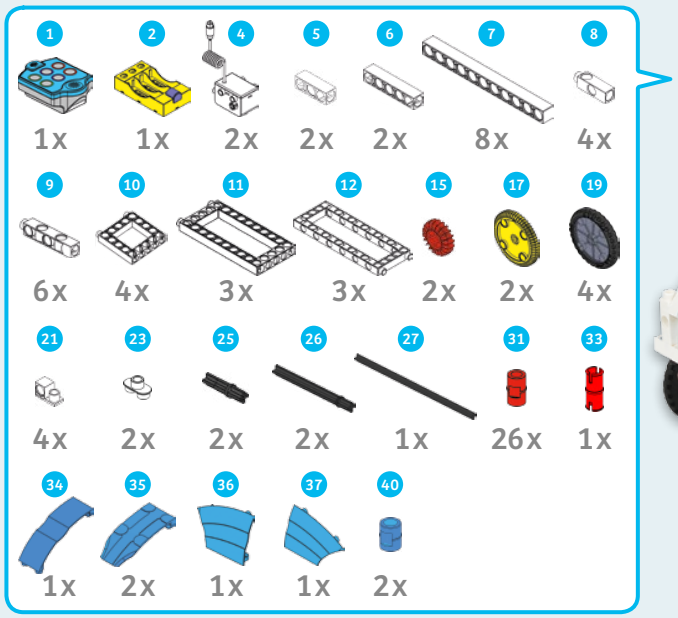


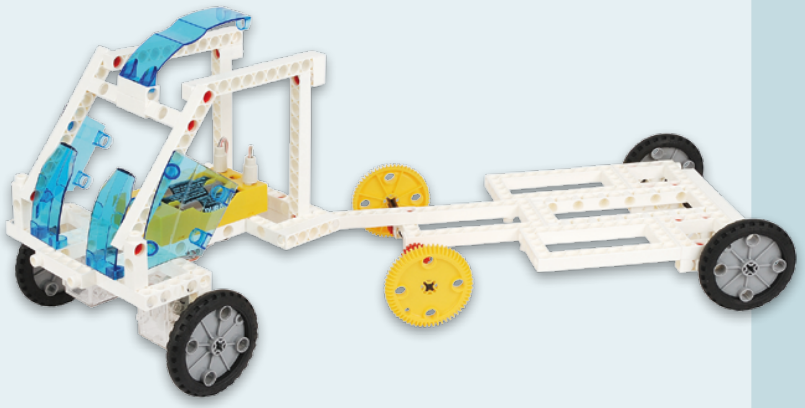
Your motor's transmission system consists of three transmissions: Set A has a ratio of 20 to 8, Set B a ratio of 28 to 8, and Set C a ratio of 30 to 8. So the overall ratio is 20/8 x 28/8 x 30/8, or 32.8125 to 1.

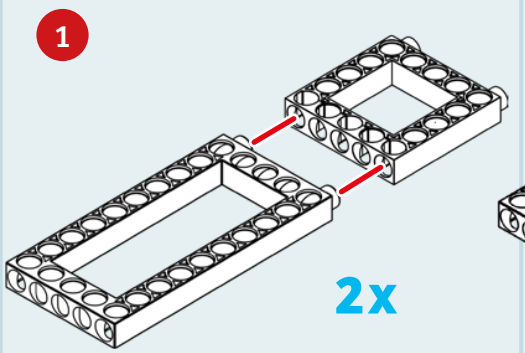
In other words: If the motor turns 32.8125 times, the shaft will turn once. If the motor is turning at 3,200 rotations per minute, the shaft will turn about 100 times.

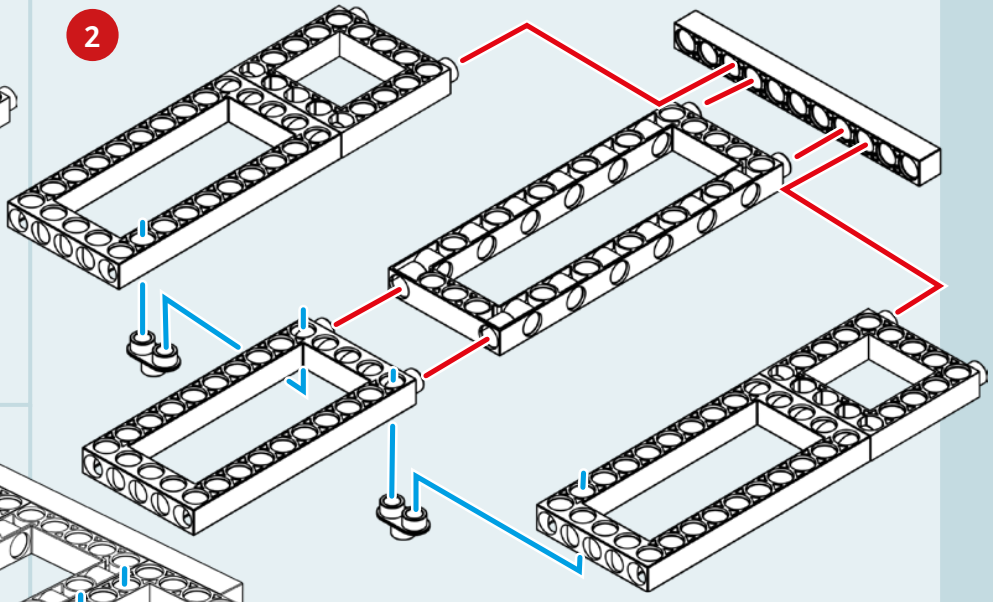
This kind of transmission ratio lets the motor exert a lot of force to the shaft through the gears. That way, you can use the crane to lift heavier weights.

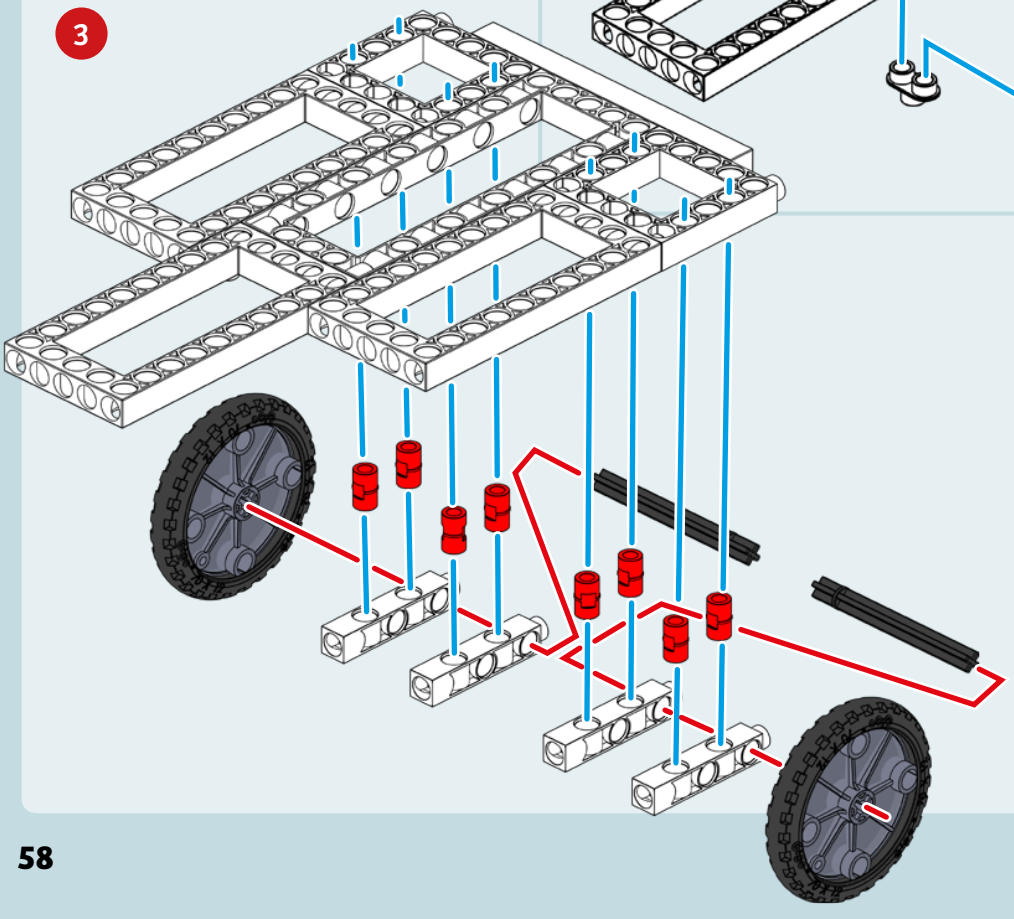
TRACTOR TRAILER











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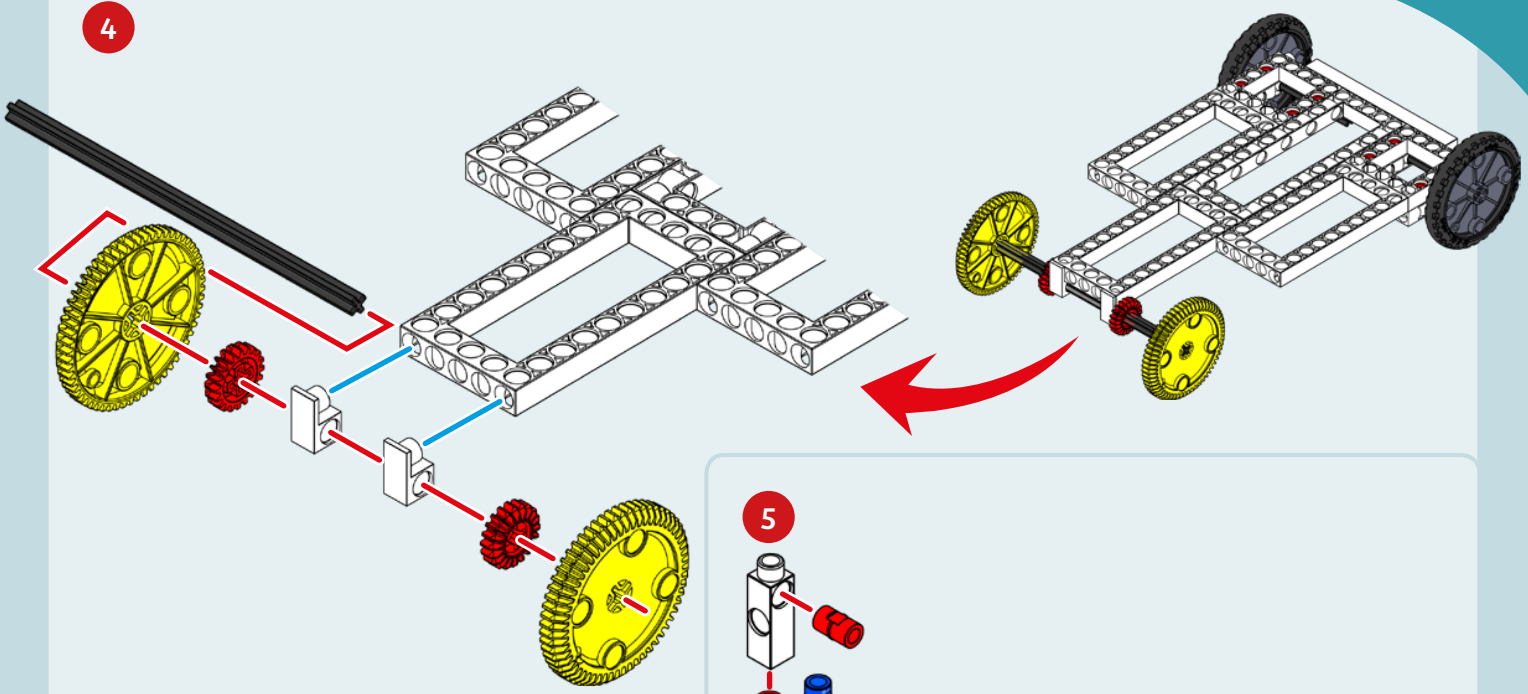

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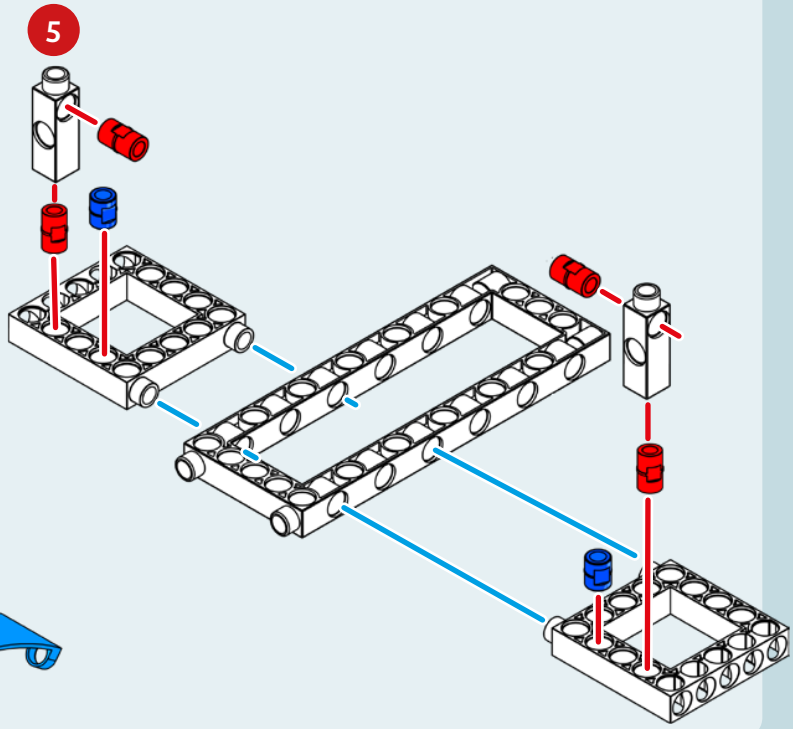

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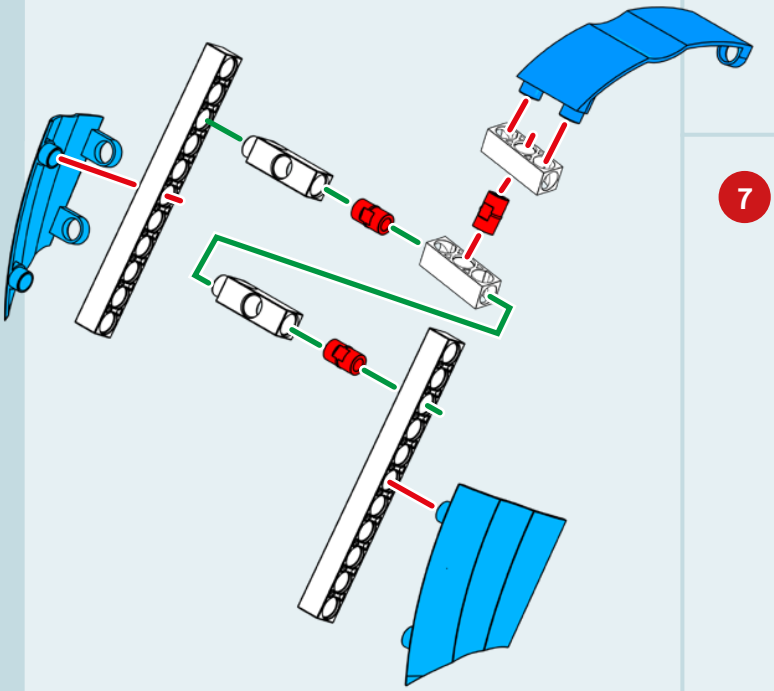

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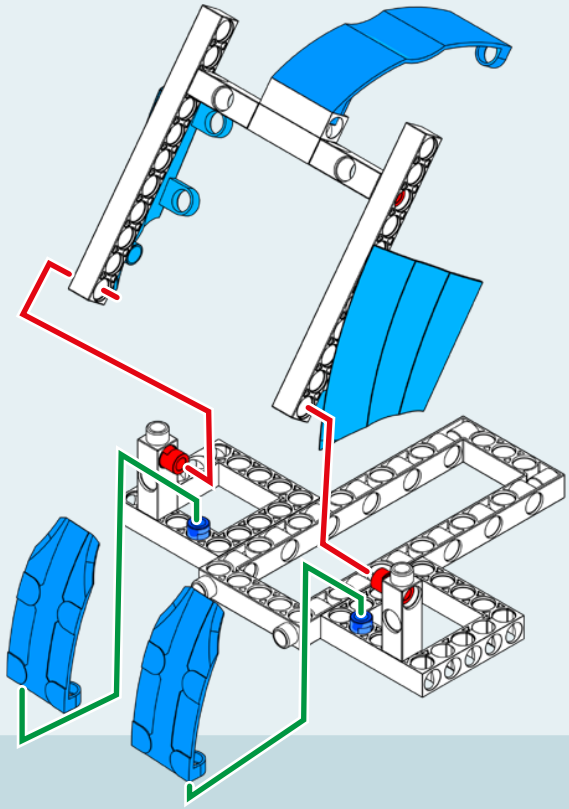

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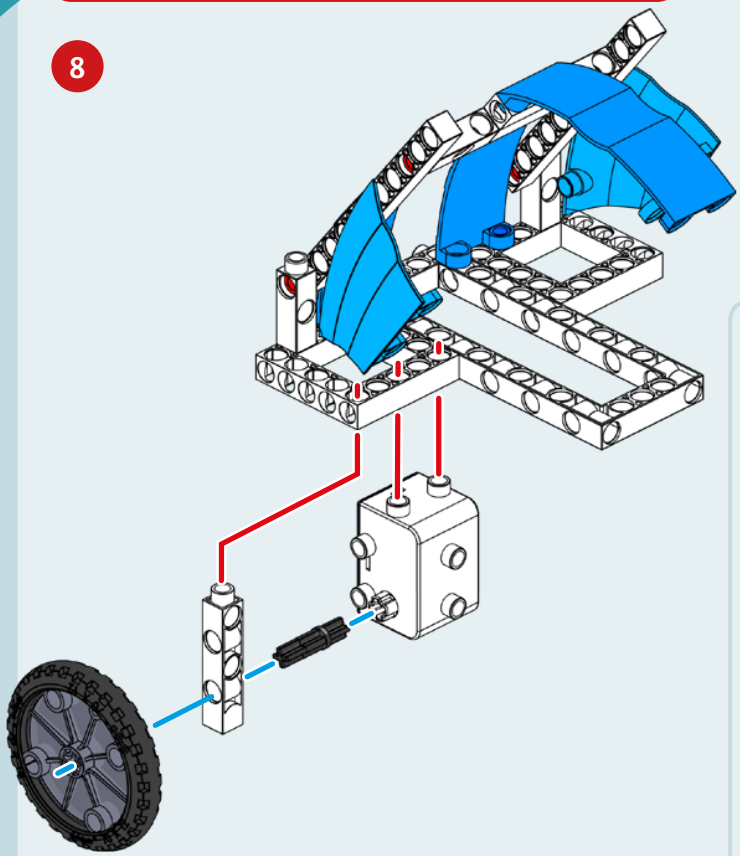

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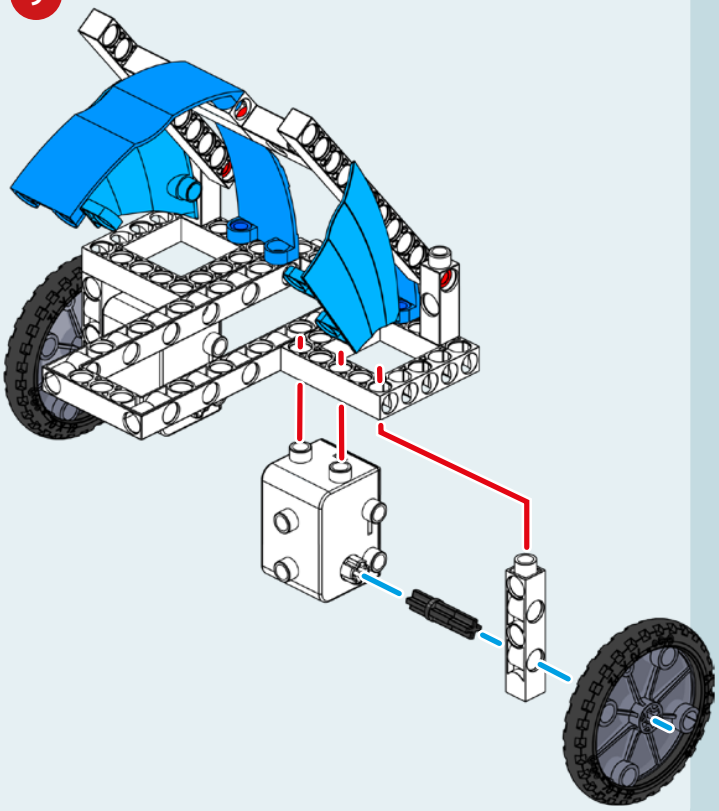

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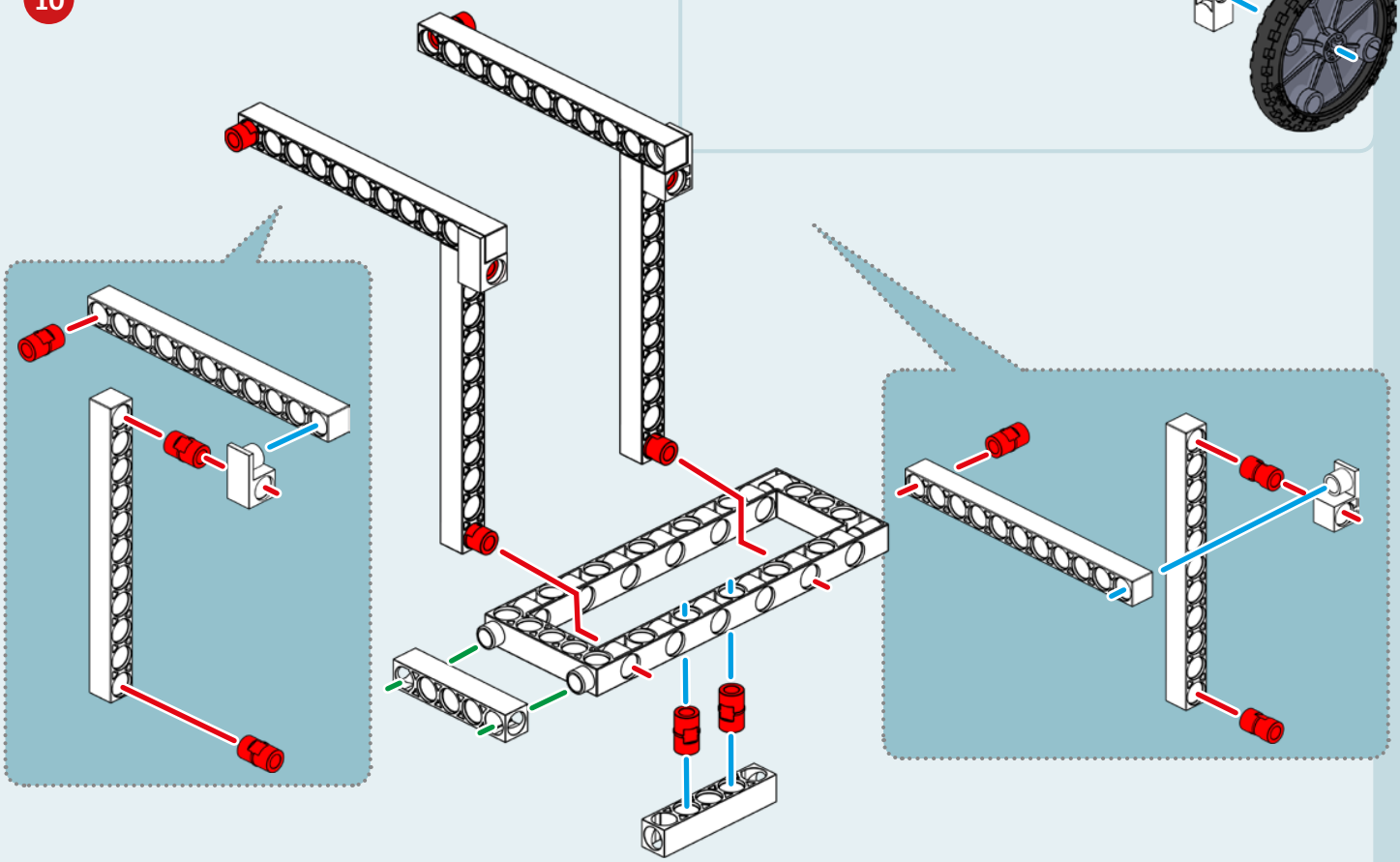

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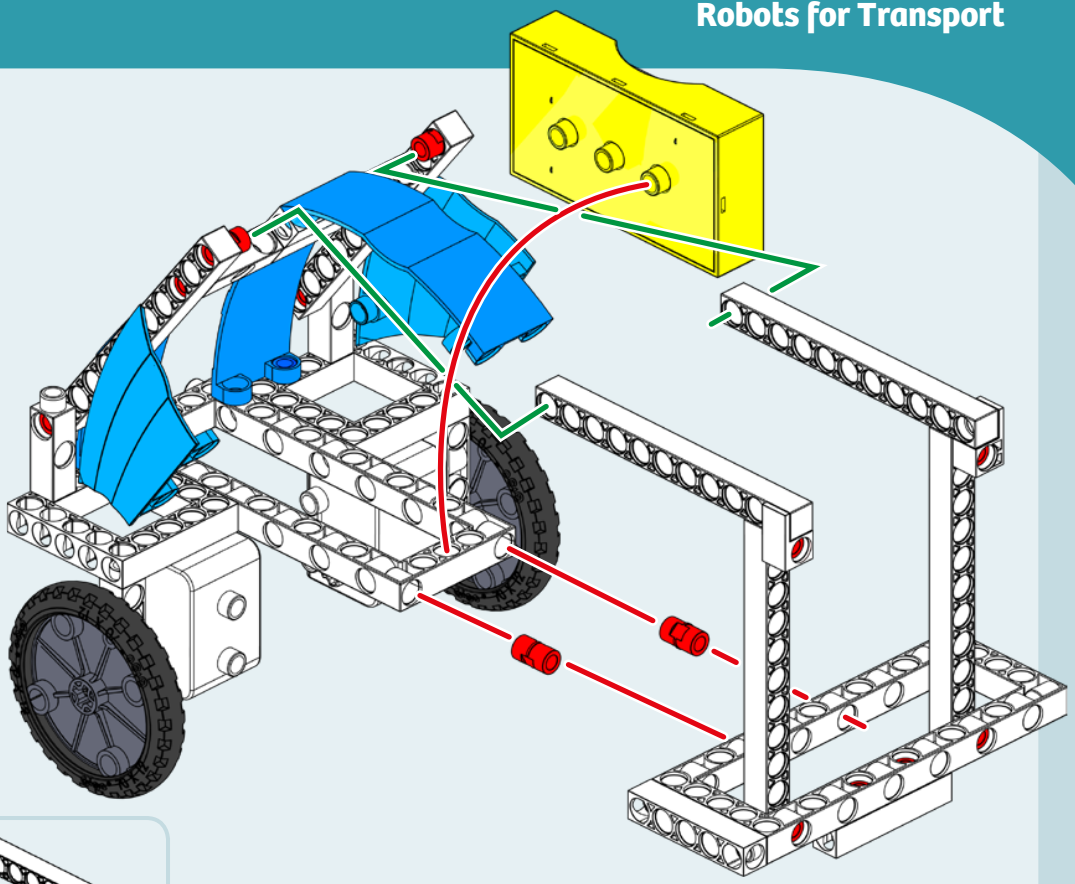

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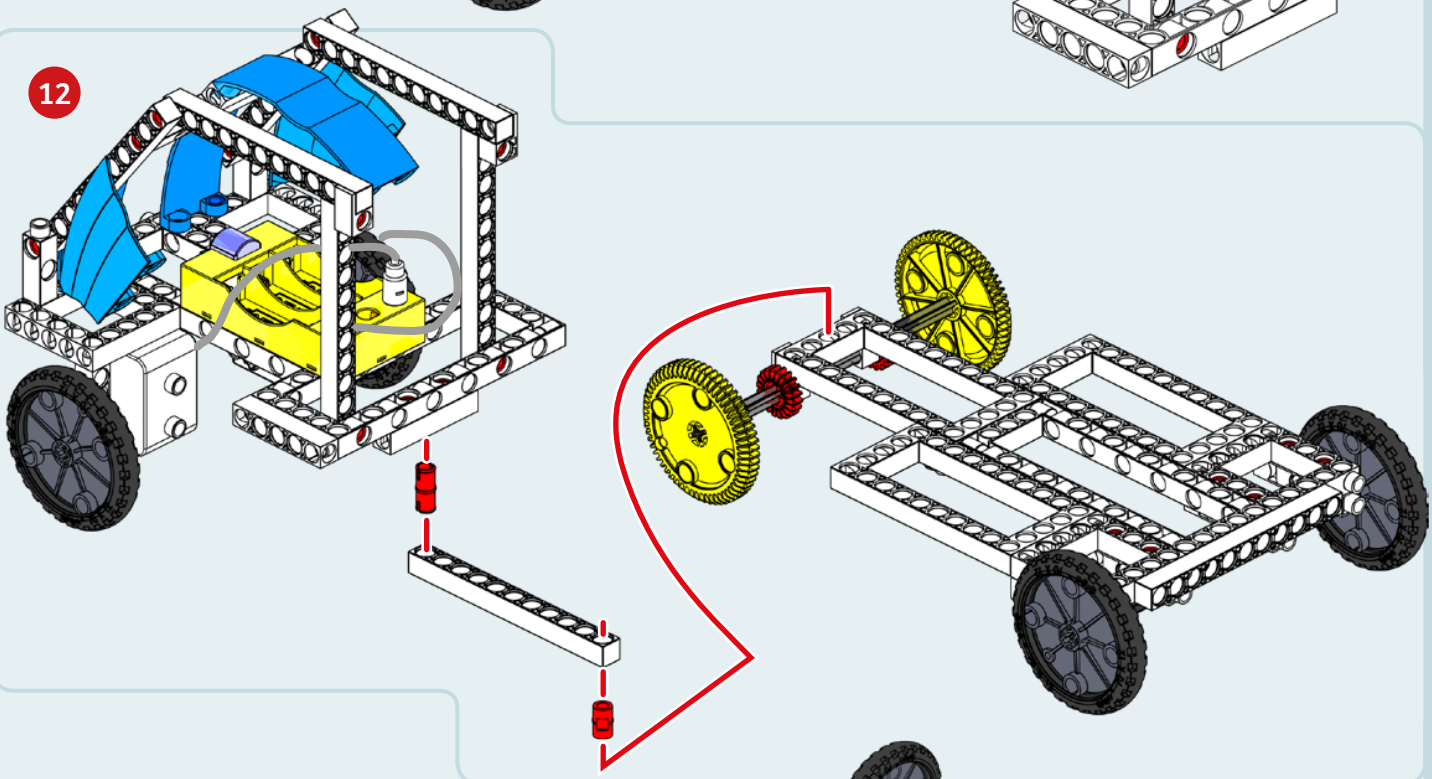
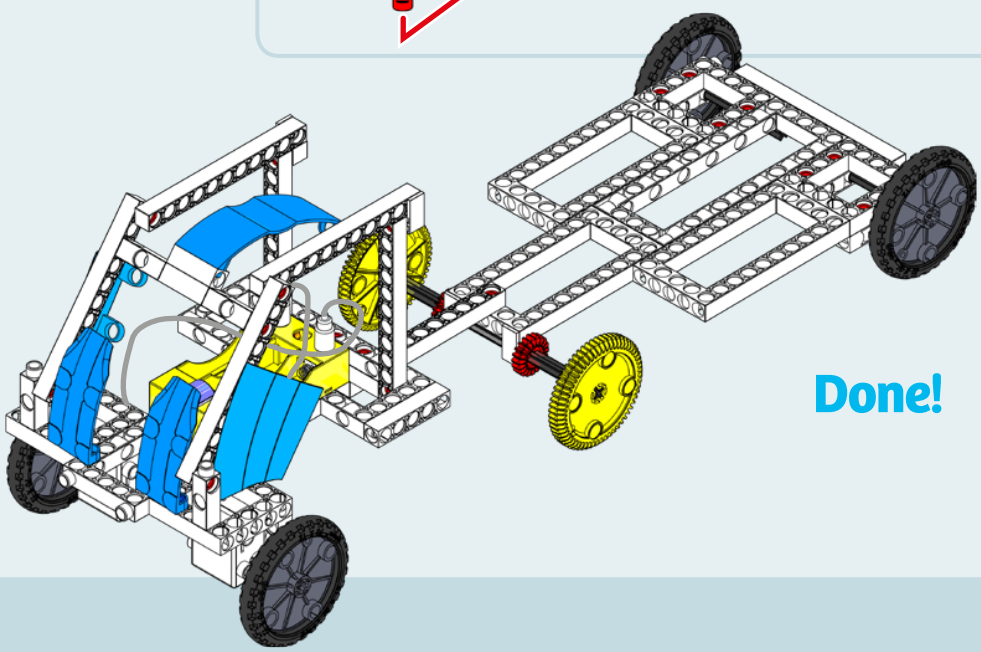
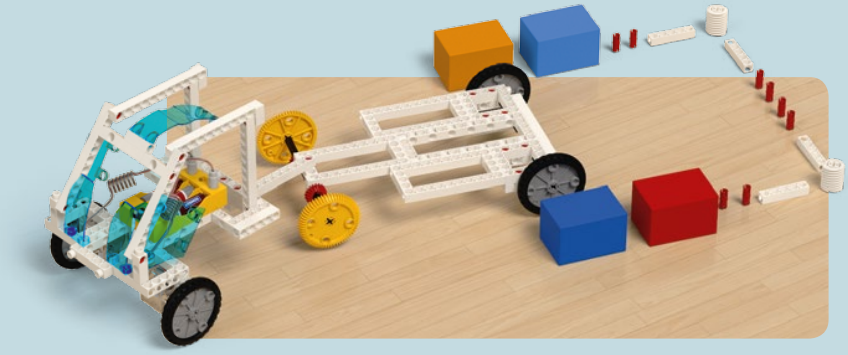




Done!

Parking the tractor trailer in Reverse

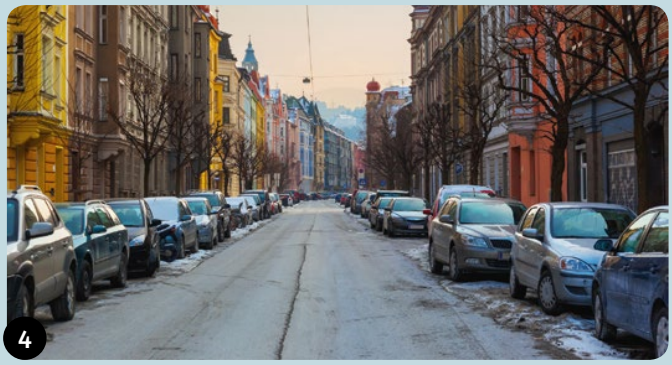


YOU WILL NEED

- **The assembled tractor-trailer truck**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *"Boundary markers" such as extra pieces from the experiment kit or boxes (see page 127)*

HERE'S HOW

1. First, take a few dry runs. Which touch pad buttons control which motor? And above all: Learn how to drive the tractor-trailer in reverse.
2. Take a few "boundary markers" such as assembly pieces or boxes, and use them to make a parking space in which you can park by driving straight backwards.
3. Now position the tractor trailer just in front of the parking space and try backing into the space. Try starting from different positions.
4. Make another parking space in which you can park parallel to the driving direction.
5. Now drive your tractor-trailer alongside the parking space and try to reverse into it.



WHAT'S HAPPENING?

If you want the trailer to move to the right as you back up, you have to drive the truck in the opposite direction, to the left. It's also important to turn carefully and not too sharply, and to drive slowly. That way, you'll have time to see how the trailer is responding and make adjustments.

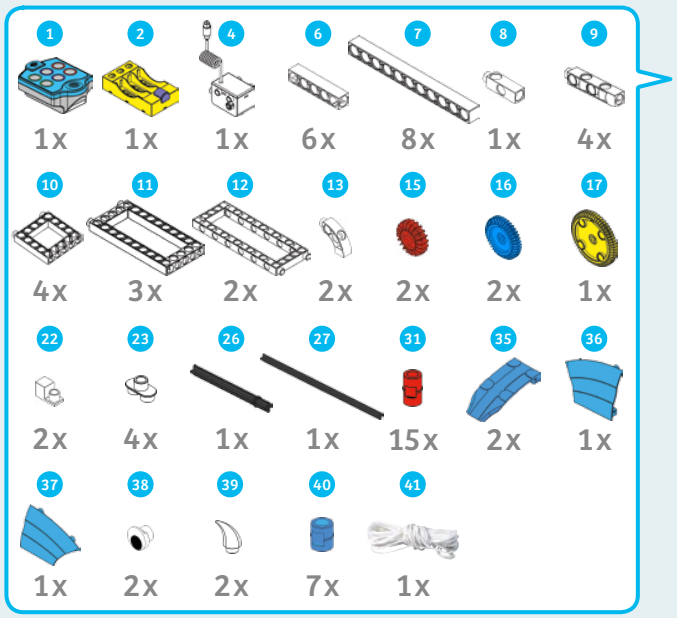
DID YOU KNOW?

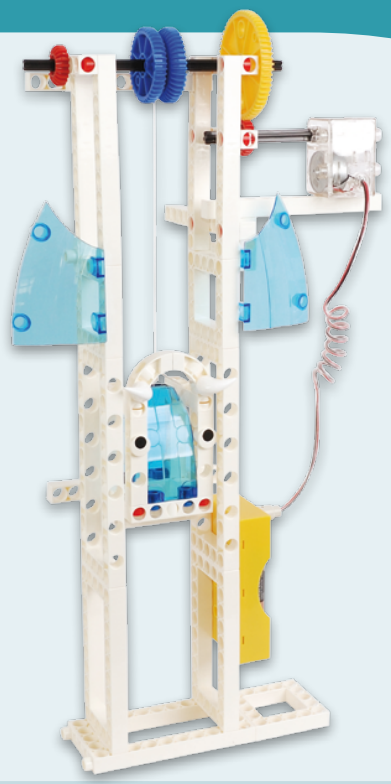
There are also other kinds of vehicles whose great weight slows down their reaction time. Large ships are an example. The captains of these ships have to have a lot of training to be able to estimate how and when the ship will respond to steering or stopping commands. The Titanic, for example, had a stopping distance of almost a kilometer!

KEYWORD: ROAD TRAIN

A tractor-trailer consists of a truck in the front and a trailer in the back. In the vast open territory of Australia, combinations like this are sometimes used with more than one trailer. They are known as **road trains**, since they can be really long — up to 50 meters! They supply areas that are not connected to the rail network.

ELEVATOR





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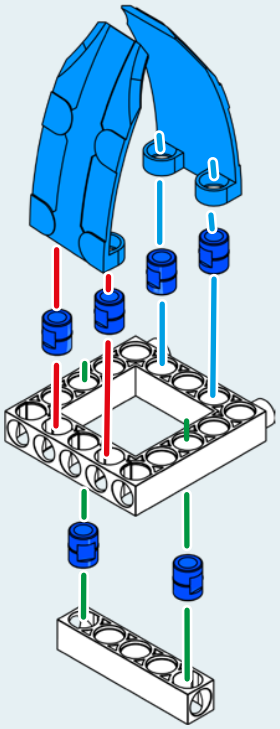

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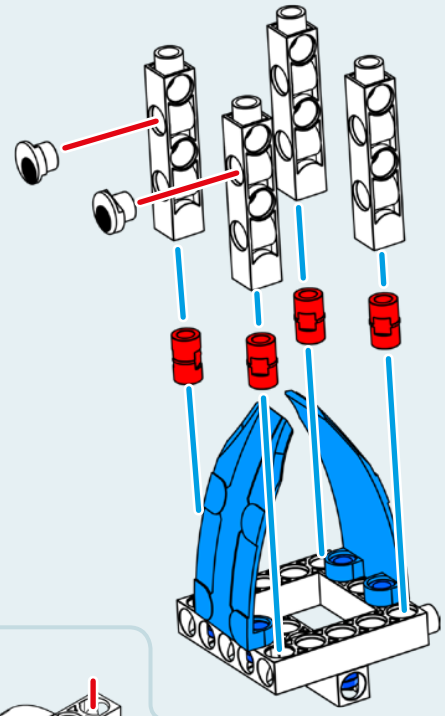

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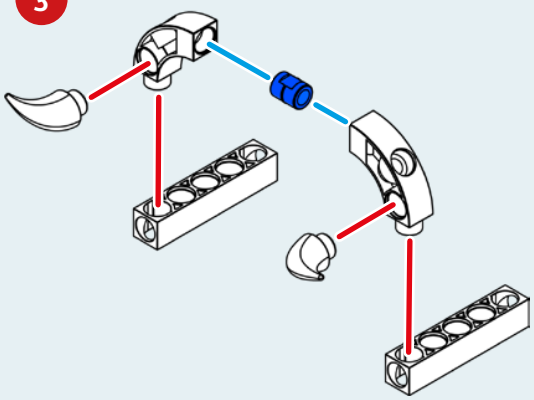

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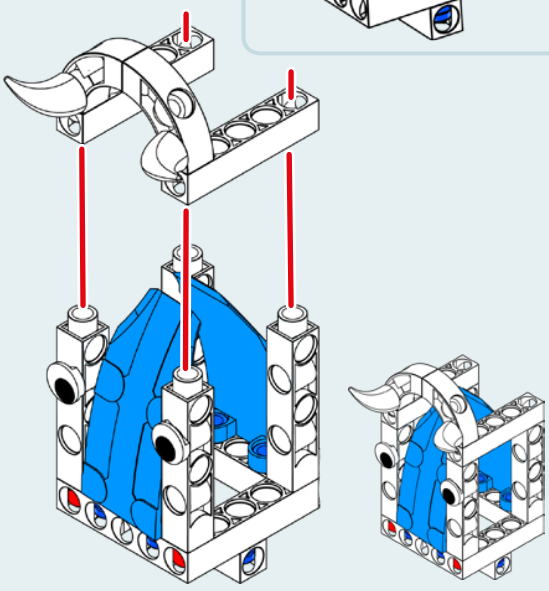

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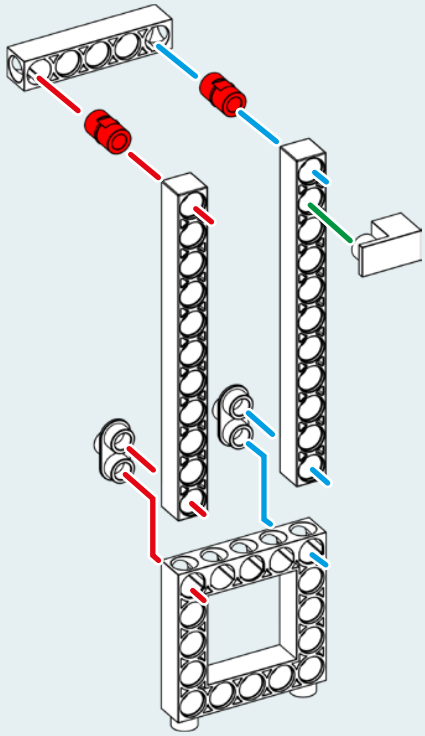

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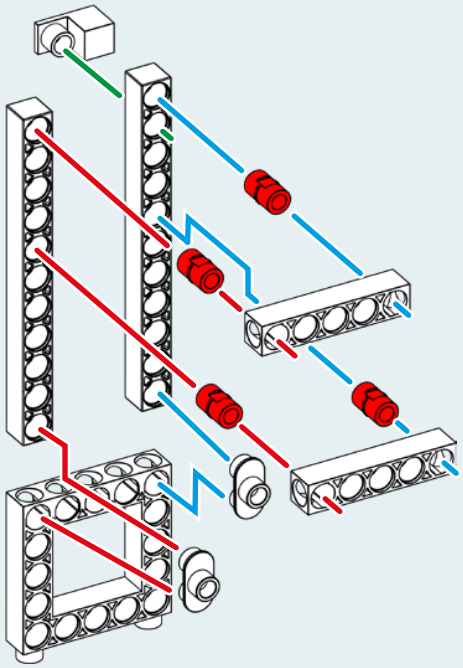

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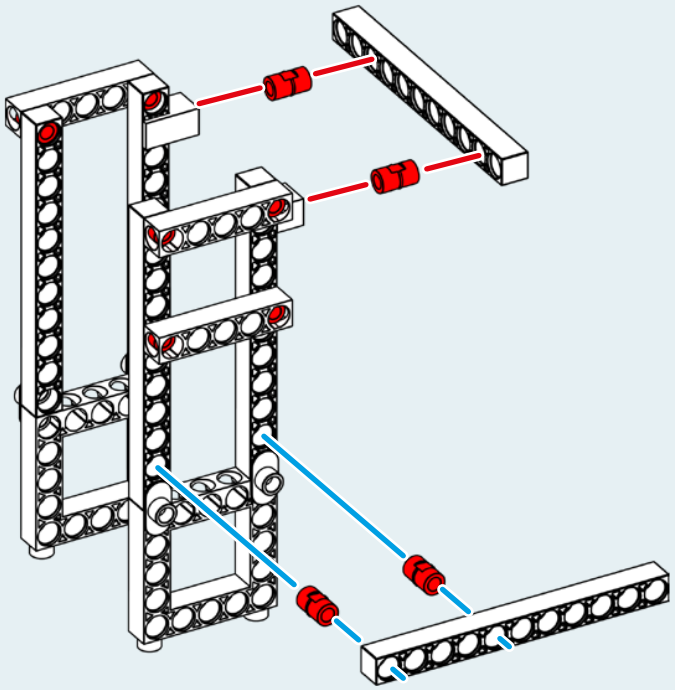

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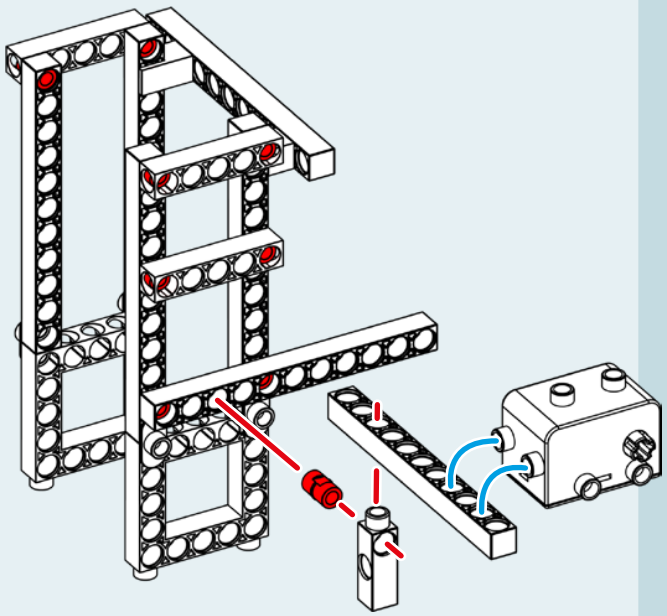

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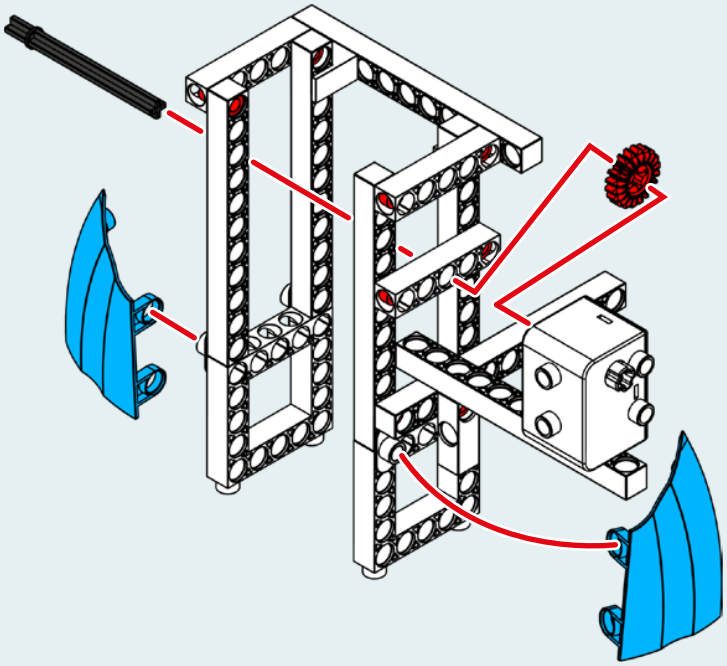

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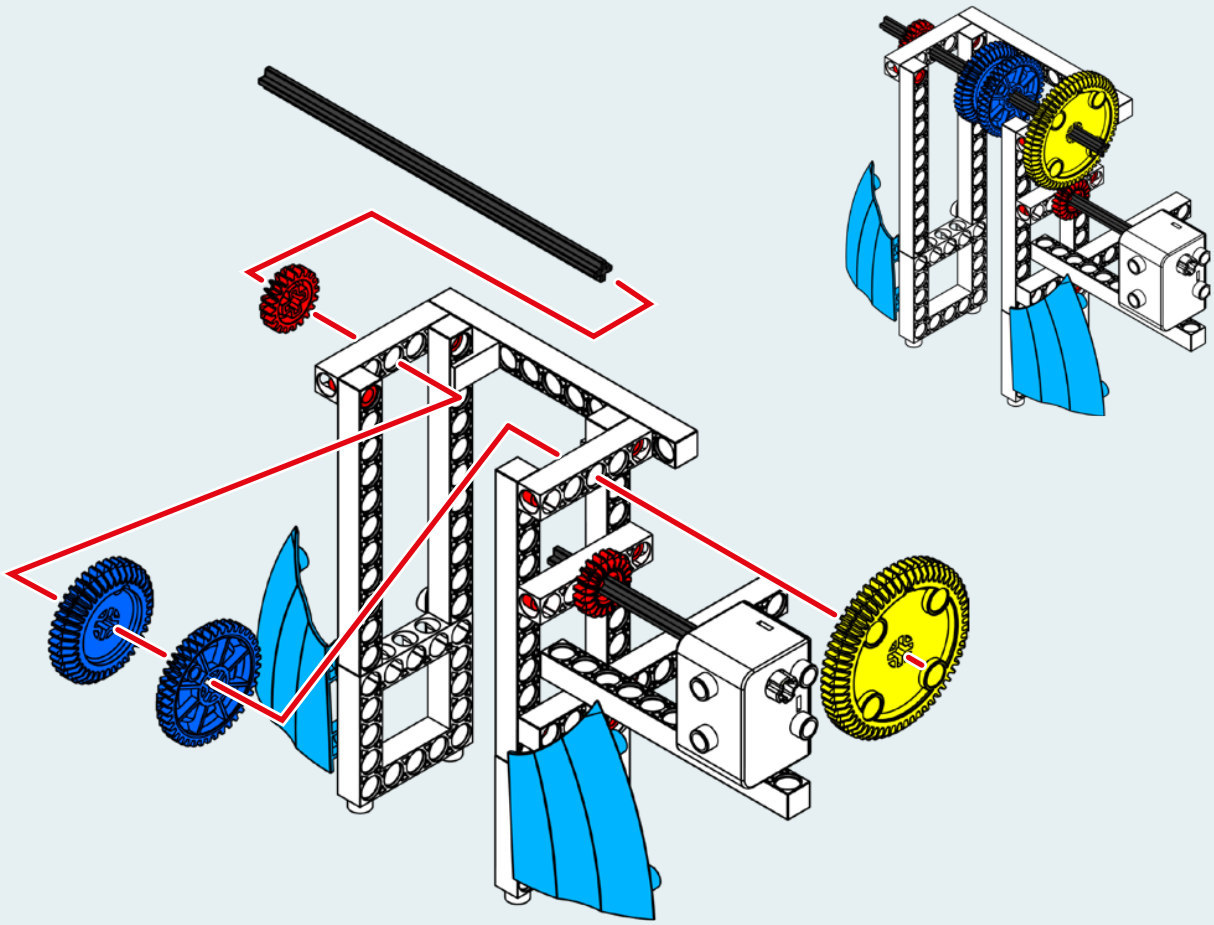

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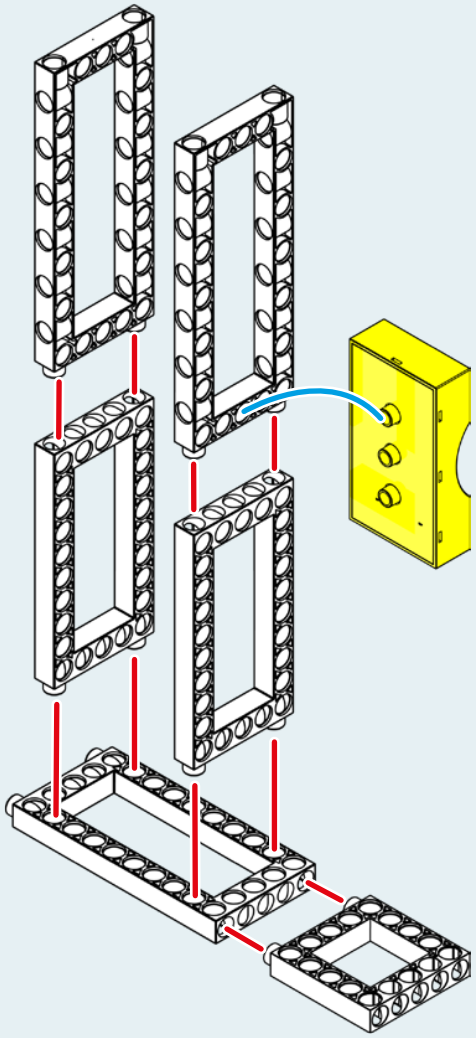

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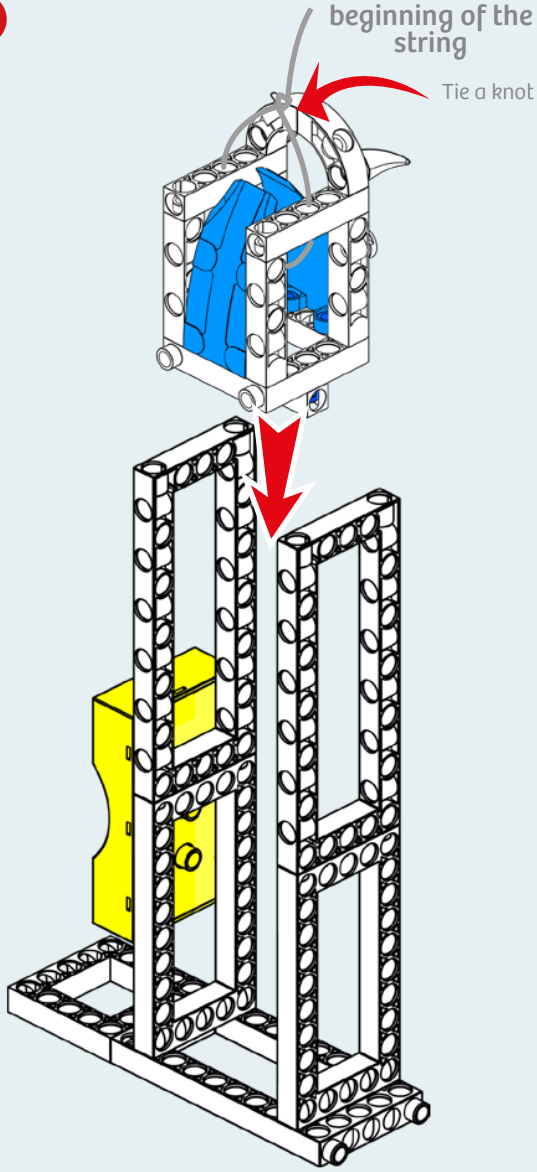

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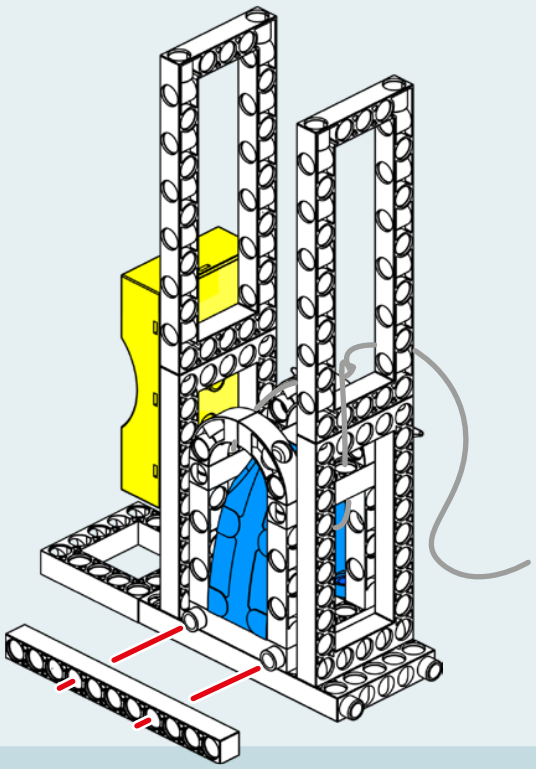

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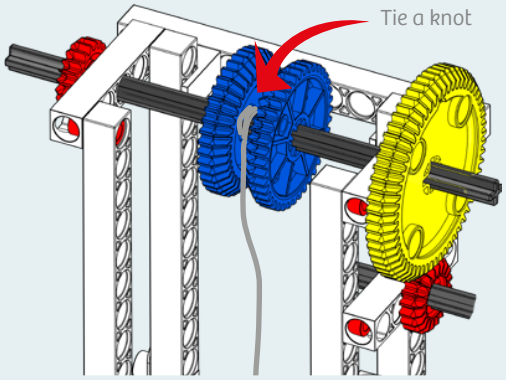

end of the string

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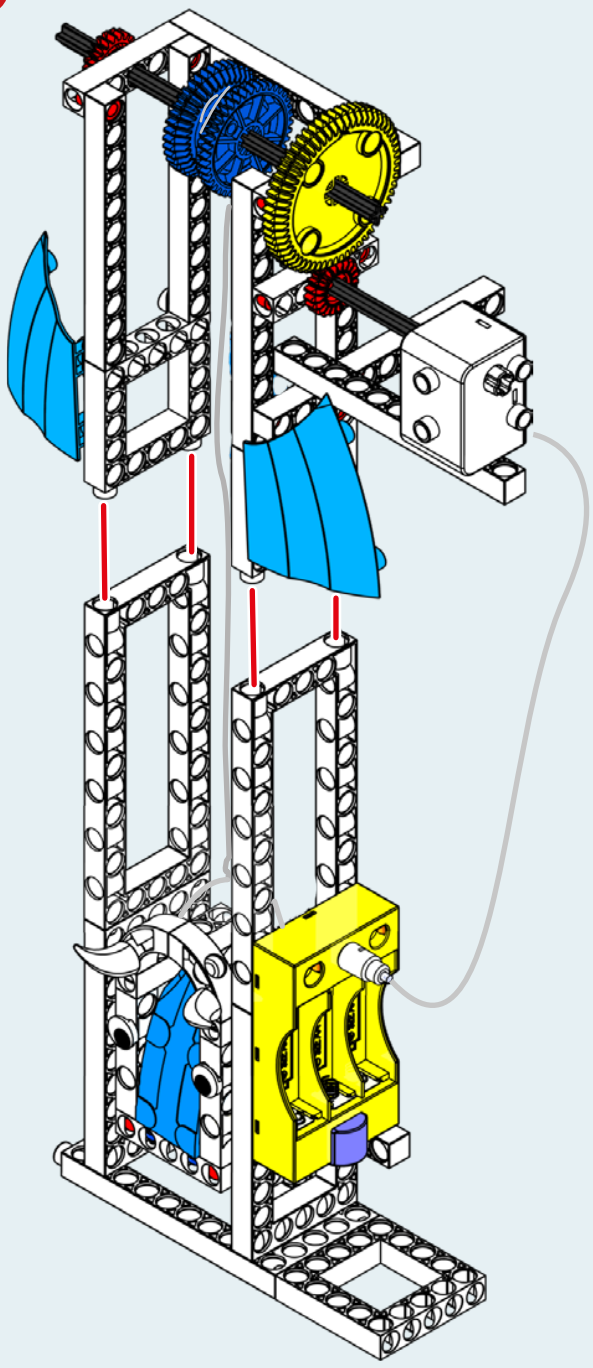
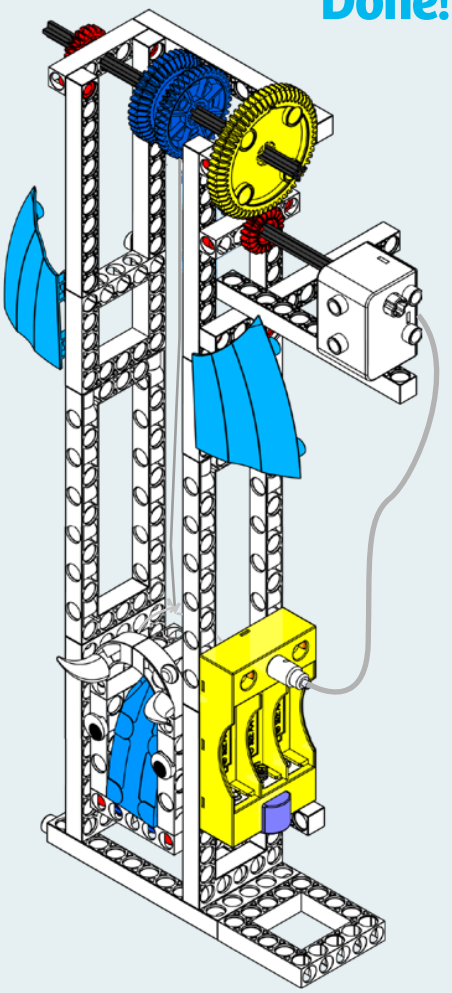
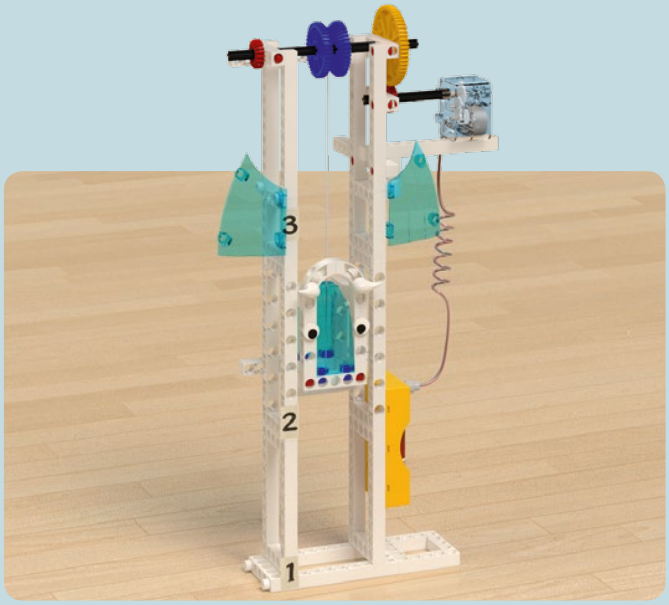


Done!



EXPERIMENT 10

Elevator with rope winch



YOU WILL NEED

- **The assembled elevator**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Masking tape*
- *Toy figure*

HERE'S HOW

1. Use three small pieces of masking tape to mark the "floor levels" of three different "stories" on one of the four vertical support pieces.
2. If you like, place a toy figure in the cabin of your elevator.
3. Now try operating the elevator between different stories. See if you can stop the bottom edge of the elevator cabin right at the marked locations.

DID YOU KNOW?

Passenger elevators have been in existence for a long time. They didn't really start to become popular until 1853, when the American Elisha Graves Otis invented the fall-proof elevator. As soon as passenger elevators were safe, the era of the skyscraper followed. After all, you wouldn't be able to reach their top stories very easily without an elevator.

WHAT'S HAPPENING?

By now you should be familiar with the IR remote. IR stands for **infrared**, which is electromagnetic radiation that comprises light waves in the range between visible light (700 nanometers) and longer wavelengths (up to 1 millimeter). When transmitting data by infrared, the devices have to be in sight of each other. Obstacles such as bookcases or tables will result in loss of contact. The range of your IR remote control is about 7 meters. To control devices over longer distances, people use options such as WLAN and UMTS (see "Check it out," page 87).

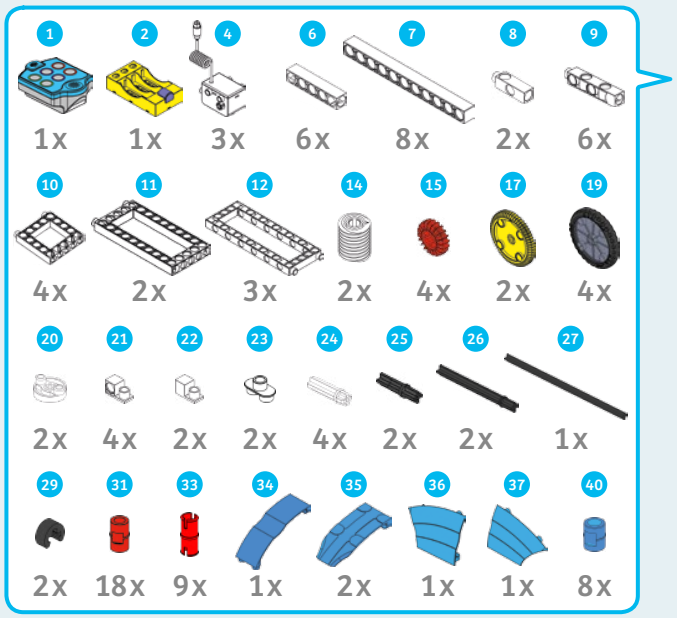
KEYWORD: IR REMOTE CONTROL

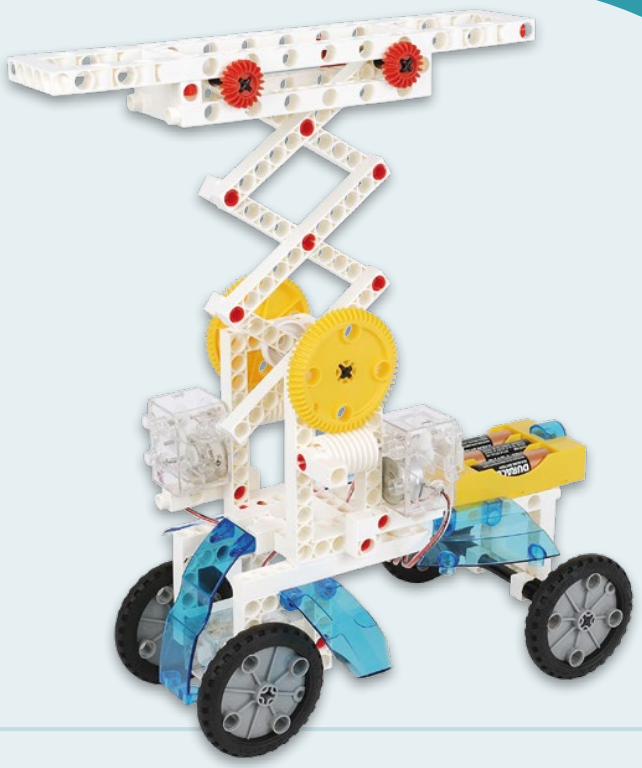
You are already familiar with this kind of remote control, since it's the same technology used in the remote for your stereo or television set.

TIP!

It is possible for the signals from your IR remote to interfere with those from other IR remotes or vice versa.

SCISSOR LIFT





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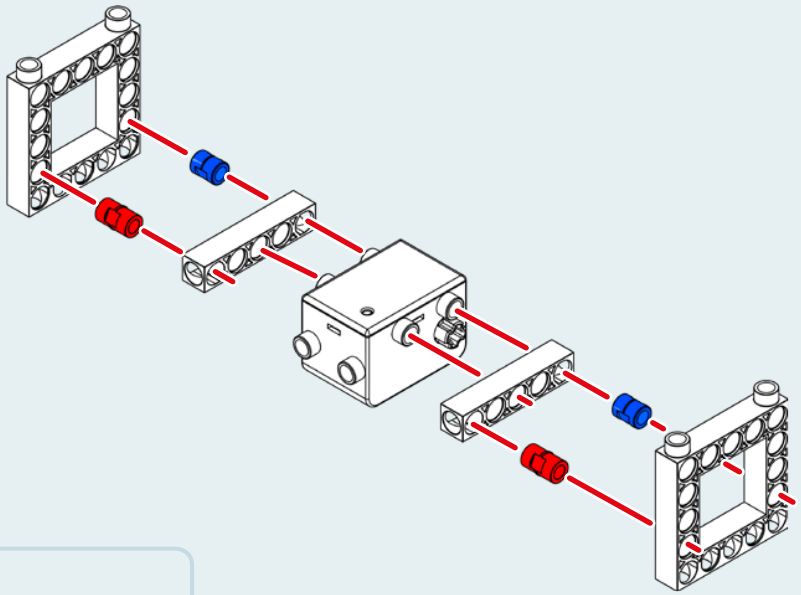

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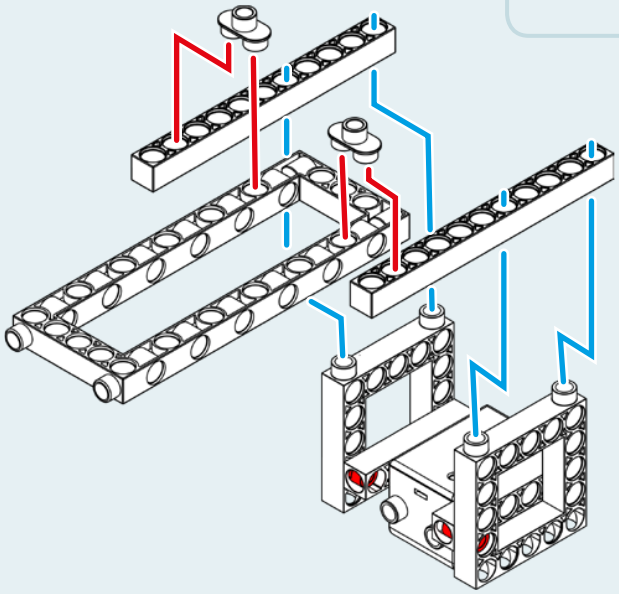

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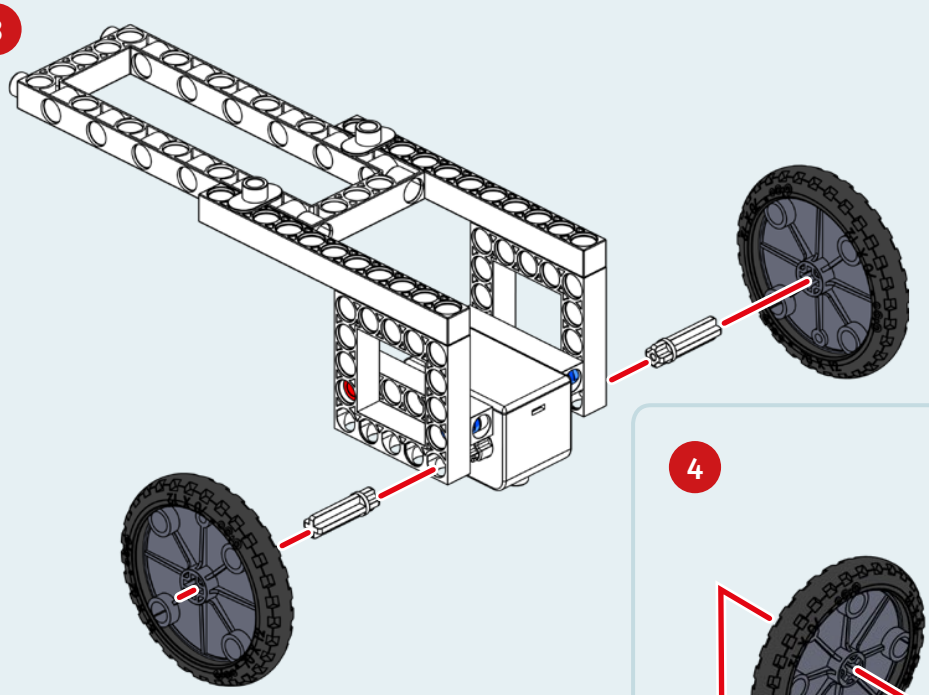

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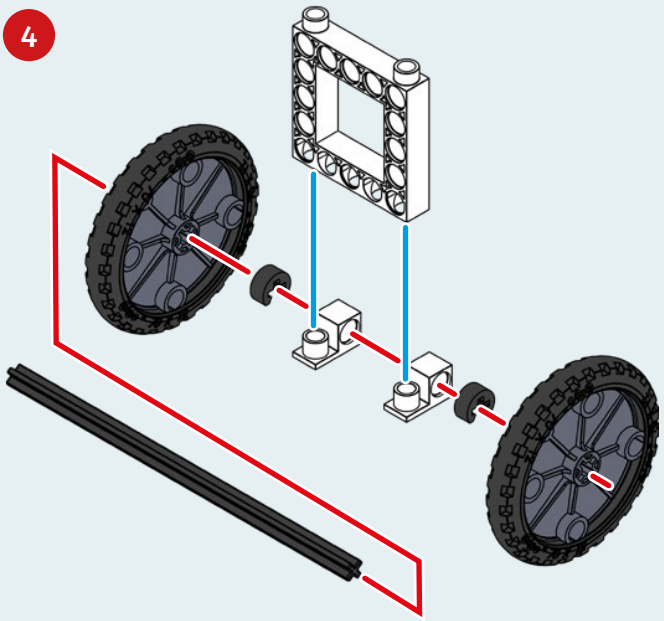

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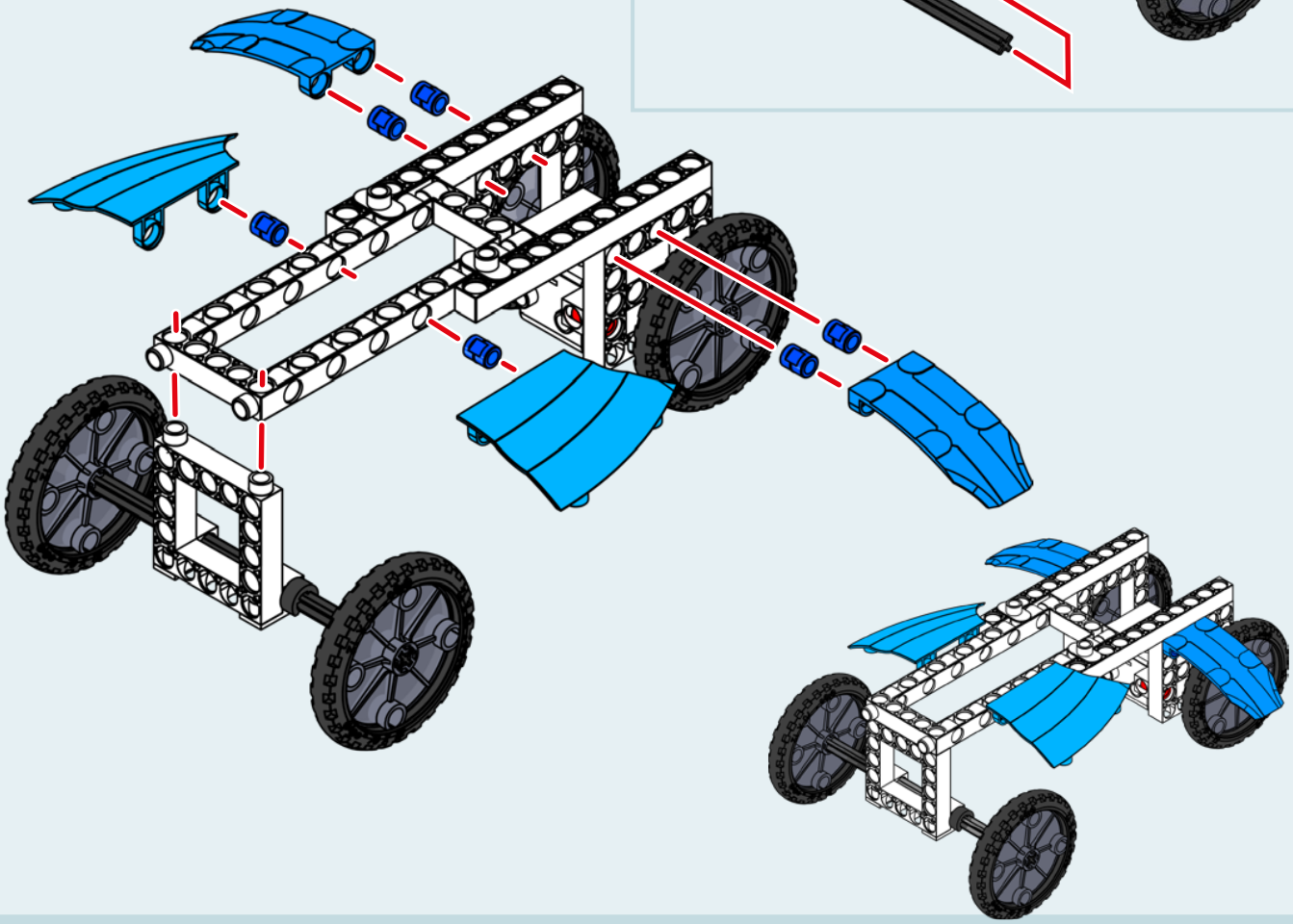

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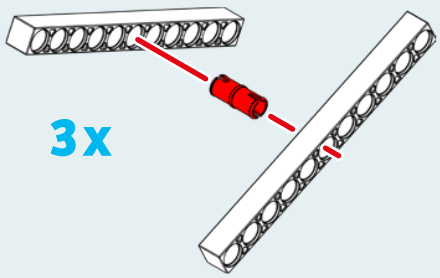

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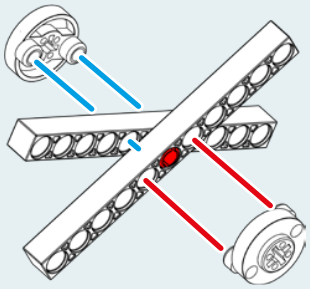

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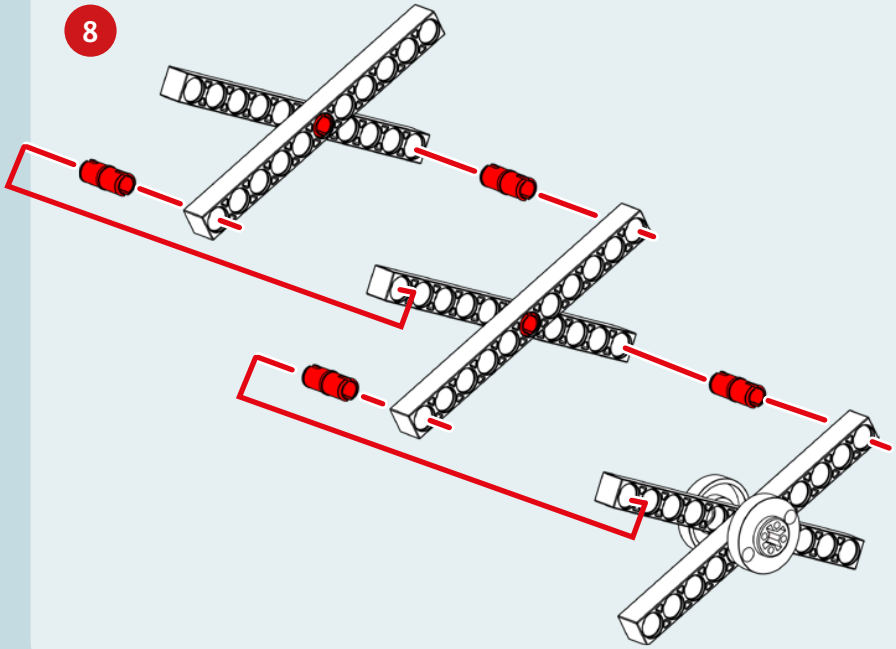

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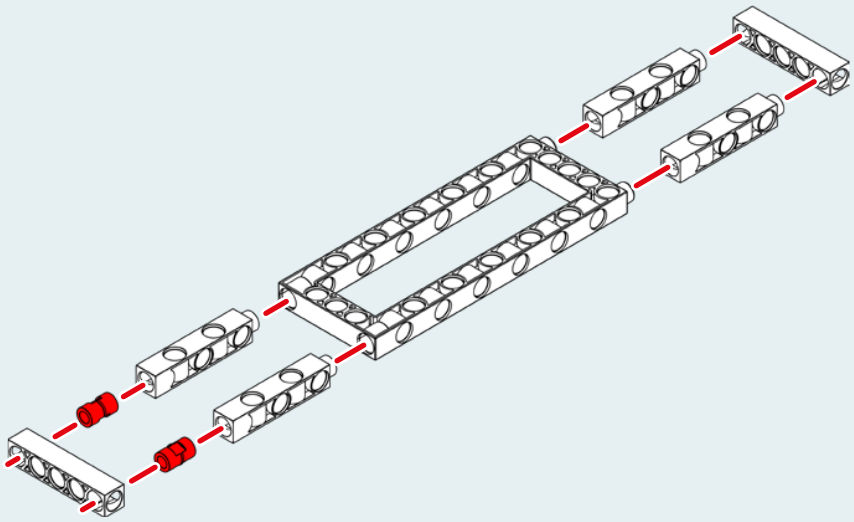

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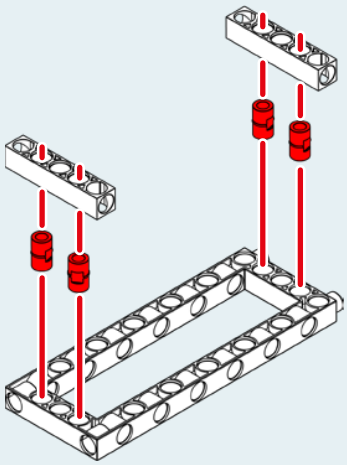

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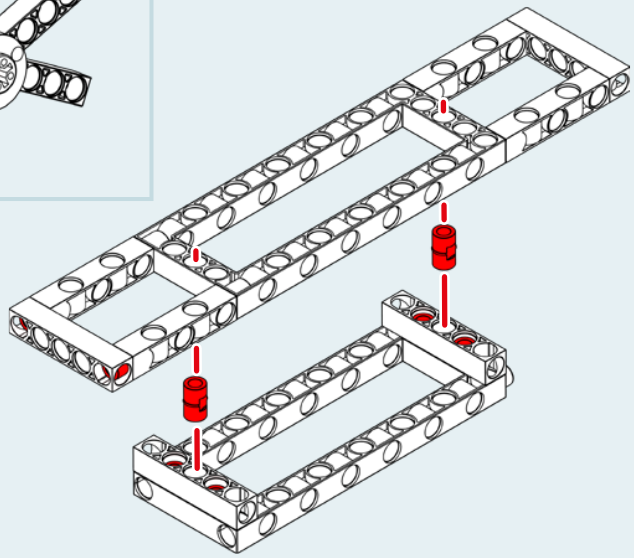

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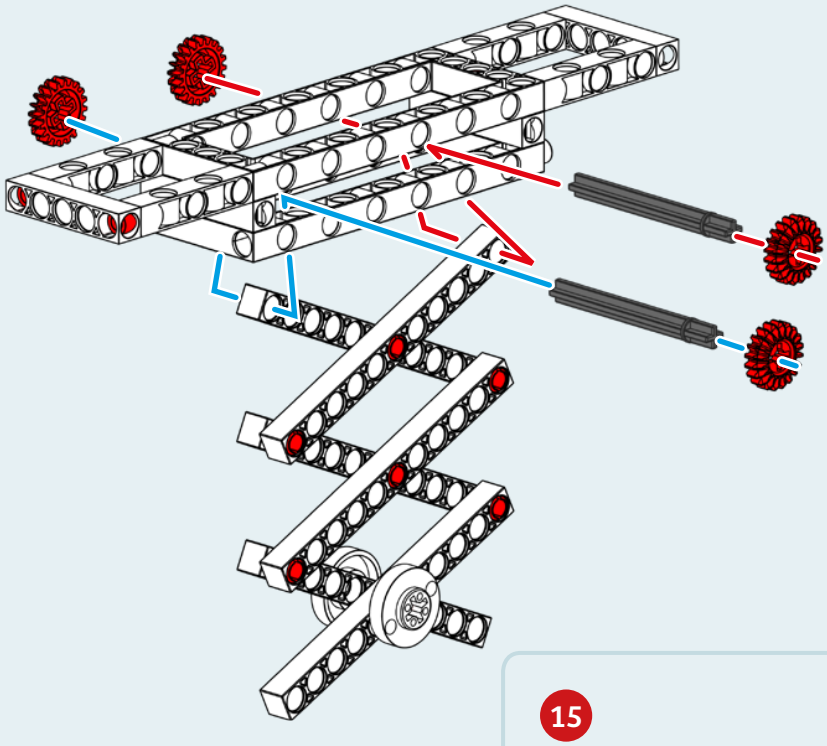

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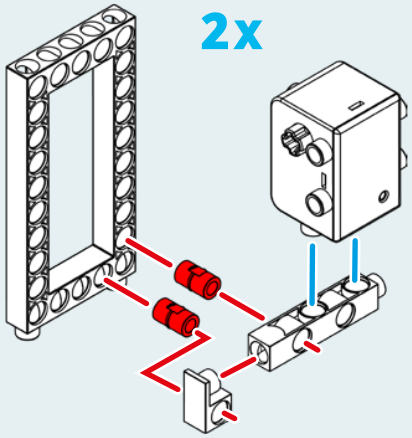

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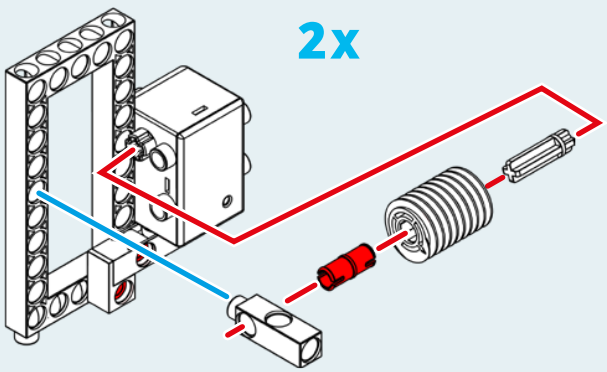

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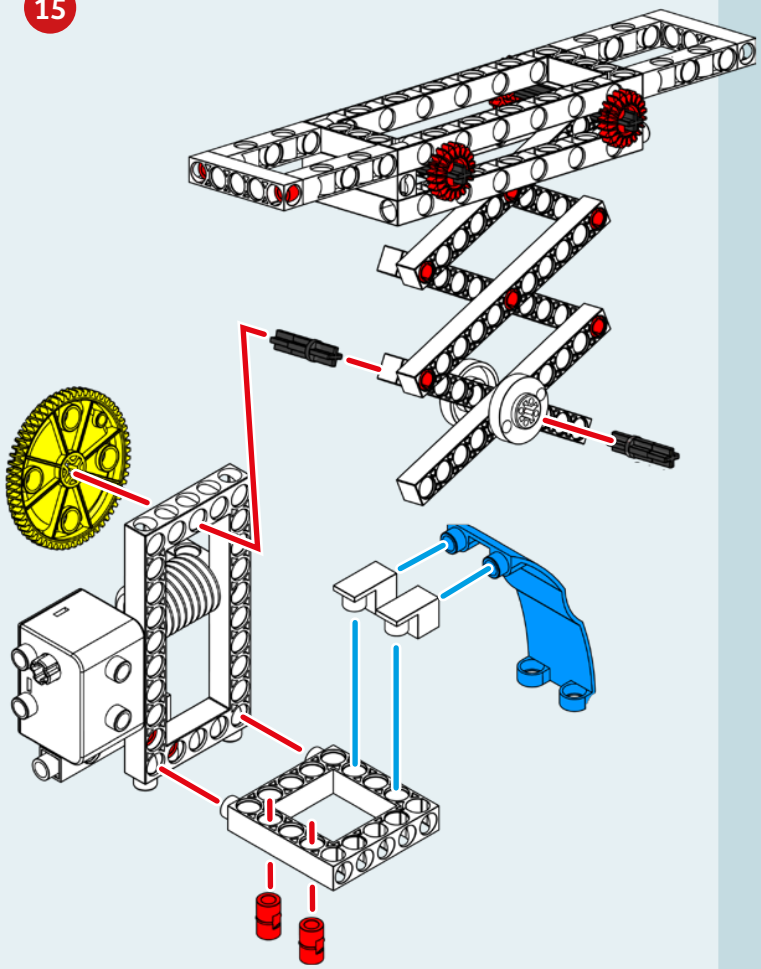

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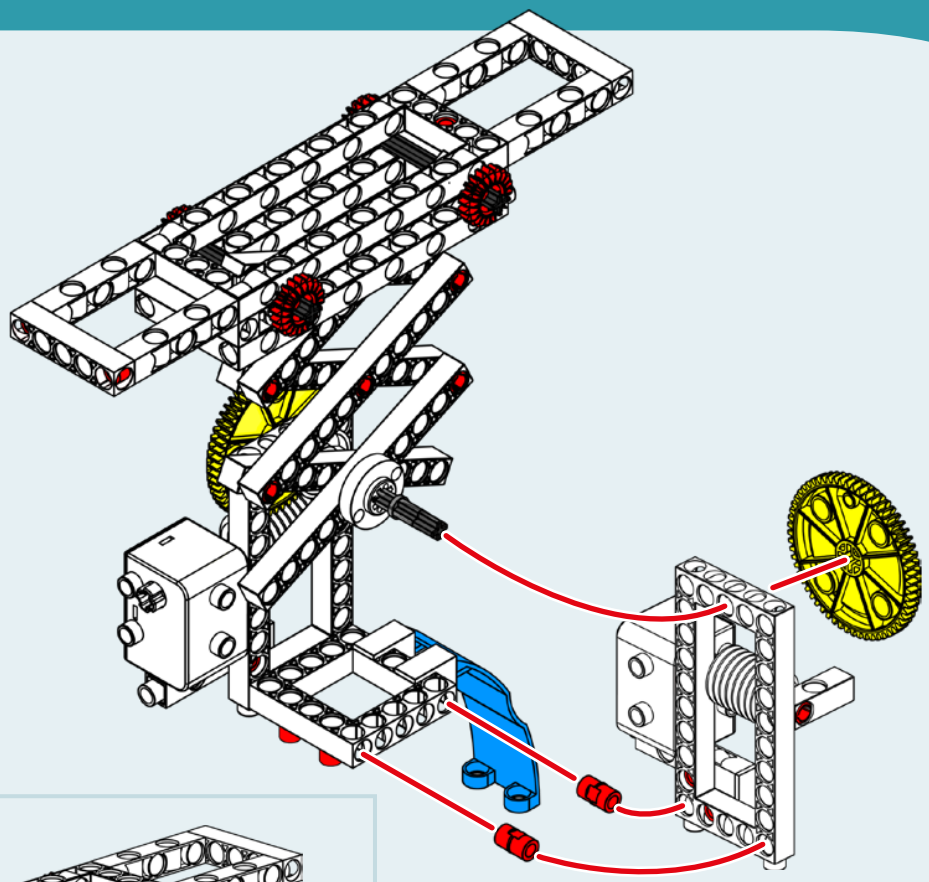

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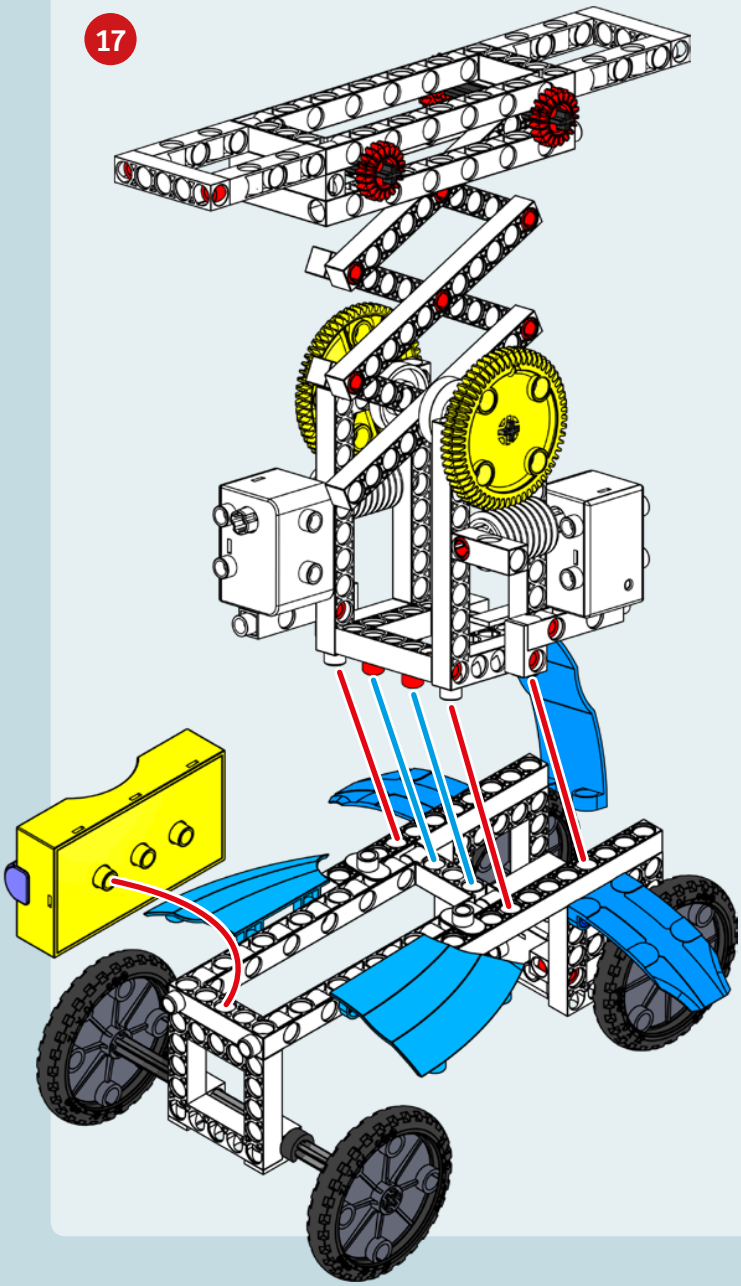

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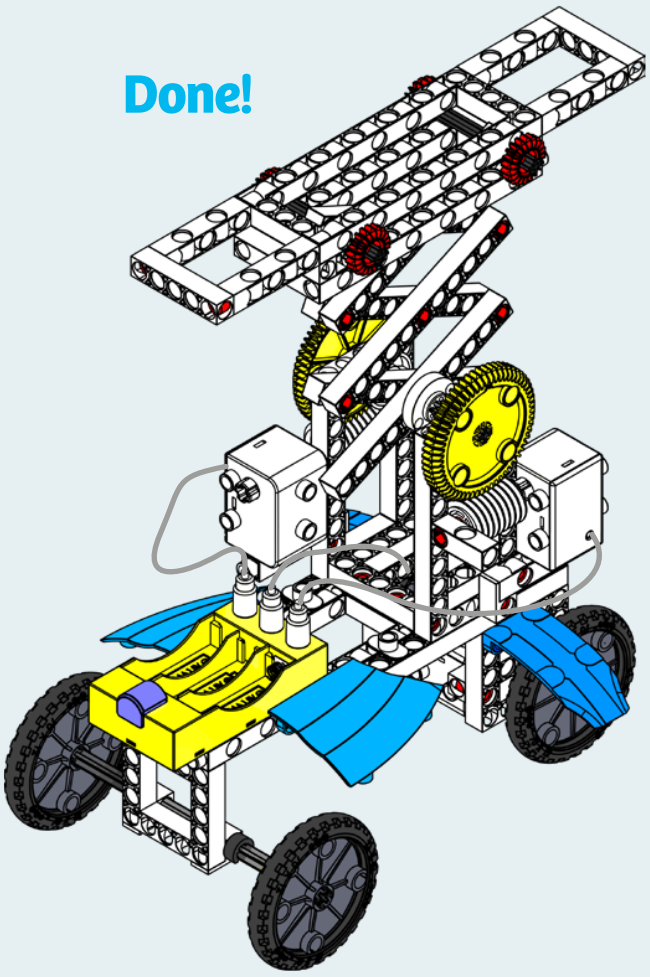
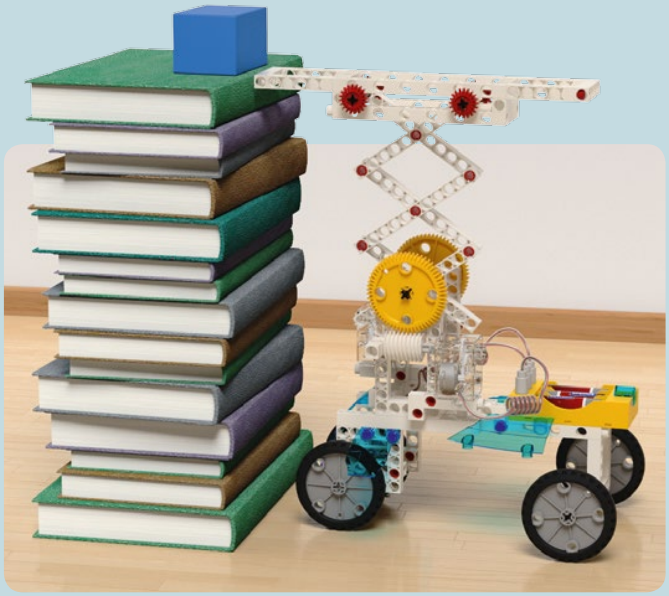


EXPERIMENT 11

Transporting loads with the scissor lift



YOU WILL NEED

- **The assembled scissor lift**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Measuring tape*
- *Books or blocks*
- *Several boxes (see page 127)*

HERE'S HOW

1. Familiarize yourself with the controls of the scissor lift. Which touch pad buttons control which motor? Note: You can tilt the loading platform too!
2. How high is the maximum height of the lift? Raise it as high as you can and take a measurement. How high is the minimum height? Measure that as well.
3. Build two columns out of something like books or blocks. One should be about five centimeters lower than the maximum height, the other about the minimum height. Place the two a little distance apart.
4. Now set a box on top of the higher column and drive the lift right up to it so that the front of the lift platform touches the column.
5. Raise the lift precisely to the height of the column. At this point, you might have to adjust the lift's position a little.
6. At the end, it should be right against the column so that you can slide the box off the column onto the lift platform — just as a worker on a large lift might do.
7. Now drive the lift to the other column and place the lift platform at a slant against it, so the box slides off by itself.

WHAT'S HAPPENING?

Your scissor lift consists of a sort of chain made of several crossed bars or levers. This technique creates very strong and stable lifts that are useful for handling things like air freight. They are also used as elevators and work platforms for performing installation work at great heights.

DID YOU KNOW?

The lift in this experiment uses the principle of the Nuremberg Scissors. This is a name for a toy that used to be popular in Germany. Figures were mounted on wooden sticks that were connected to each other in a movable manner. Then, the entire structure could be opened and closed like scissors.

CHECK IT OUT

Revolutionizing the Way We Live: Transport Robots

GETTING TO THE RIGHT SHELF BY BARCODE

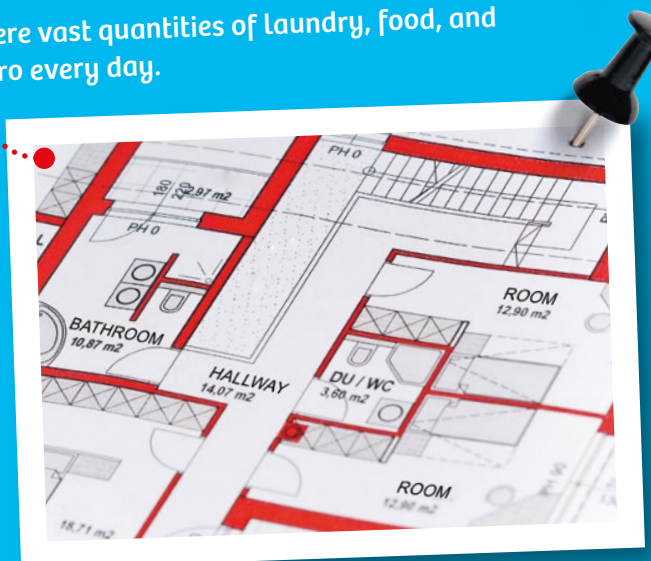
Warehouse robots assist warehouse workers by retrieving goods from shelves and then transporting the goods all by themselves. Transport robots like these can be seen driving through warehouses completely on their own, without human operators.

In this task, the robots are guided by barcodes (see "Check it out," page 96) placed on the floor by the shelves. A laser scanner on the robot recognizes the barcodes and lets the robot locate just the right shelf from among hundreds. Then the robot slides under the shelf and turns on its own axis. In the process, it attaches itself to the shelving unit and lifts it a few centimeters. The parts that are stored on the shelves can then be transported under the guidance of a computer to a different location, for packing, shipping, or storage.

IN THE "WARNING ZONE": SLOW DOWN, IN THE "SAFETY ZONE": STOP!

Similar conditions can be found in hospitals, where vast quantities of laundry, food, and medical equipment must be transported to and fro every day.

Robots find their way around with the use of hosptial floor plans stored inside them. Of course, any fixed installations such as lockers are included in the floor plans as well. To use clinic robots like these, you need a wireless communication network such as a WLAN (see "Check it out," page 97), which maintains contact between the robots and a control center — after all, someone has to keep track of their location. The WLAN has to be able to work inside elevators too, of course, because robots use them as well.



But what happens when a moveable obstacle gets in the robot's way? That's when the laser scanner's skills come into play. If there's an obstacle inside a "warning zone," the robot recognizes this thanks to its scanner and slows down. If it finds itself in a "safety zone," it stops altogether. Then it politely asks (using a synthesized voice) for someone to clear its path. After all, it can't just steer around the obstacle.

PATSY CAN FIND NEW PATHS ALL BY HERSELF

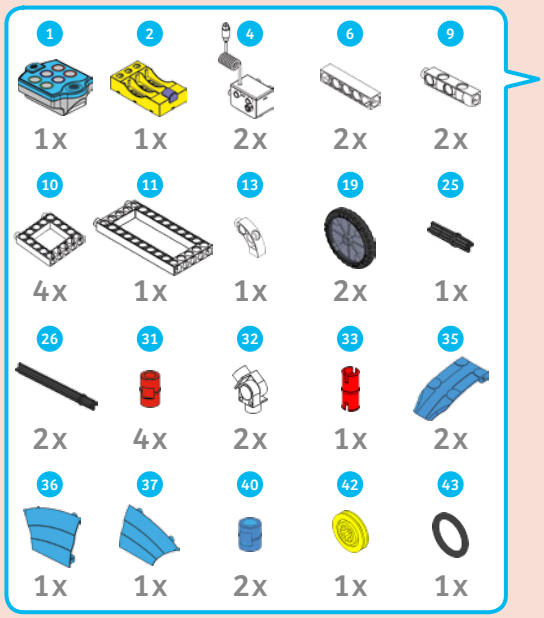
There are other robots that can maneuver their way around obstacles. One such robot is the PATSY system. PATSY, which stands for Person-recognizing Autonomous Transport System, is used for container transport inside hospitals.

In the future, PATSY will not only recognize obstacles, it will even be able to classify them all by itself. To do that, the robot is equipped with laser scanners and a 3D camera.

This autonomous technology might also come in handy for other applications. For example, forklifts would be able to pull pallets out of containers all by themselves and then arrange them on vehicles to be transported to another destination. Or a combine harvester could communicate with another driverless vehicle in order to get it to take delivery of the harvested grain — without even interrupting its work.

Driving Robots

Do you think cars will one day be able to drive all by themselves, without a driver? Automobile industry professionals answer that question with a resounding yes. Auto engineers have even set a firm date for that: By the year 2020, completely ordinary cars should be able to drive autonomously. The idea is a little spooky, isn't it? With the models and experiments that follow, though, you are still in the driver's seat.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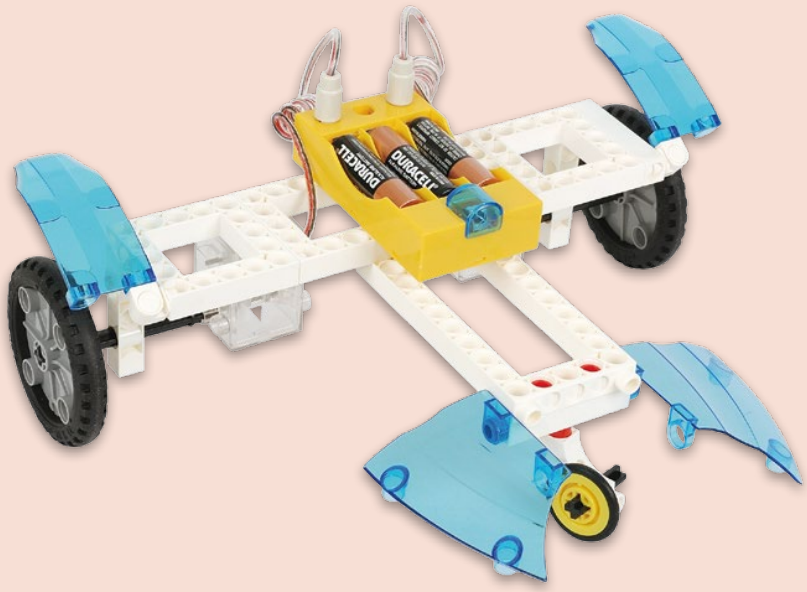
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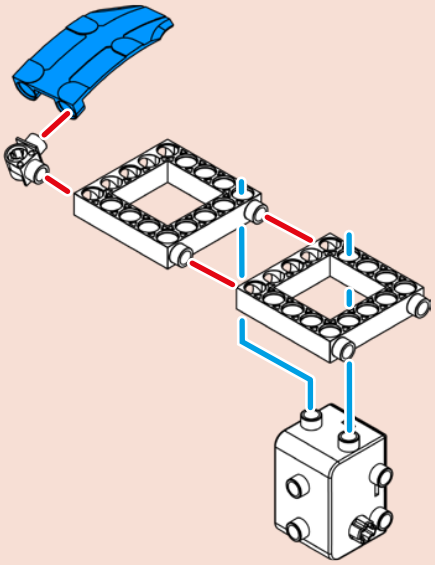

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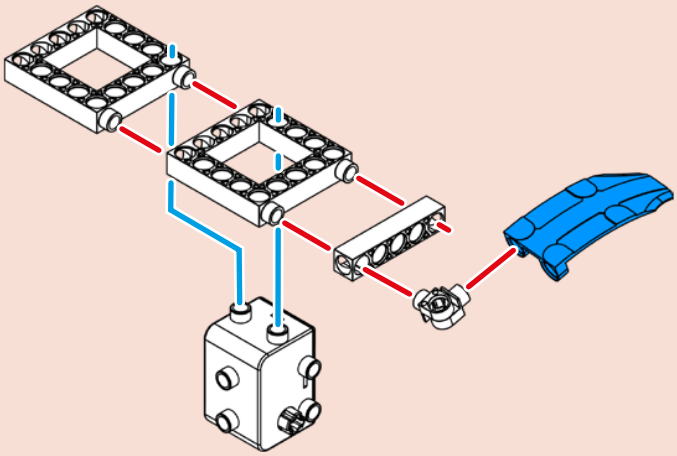

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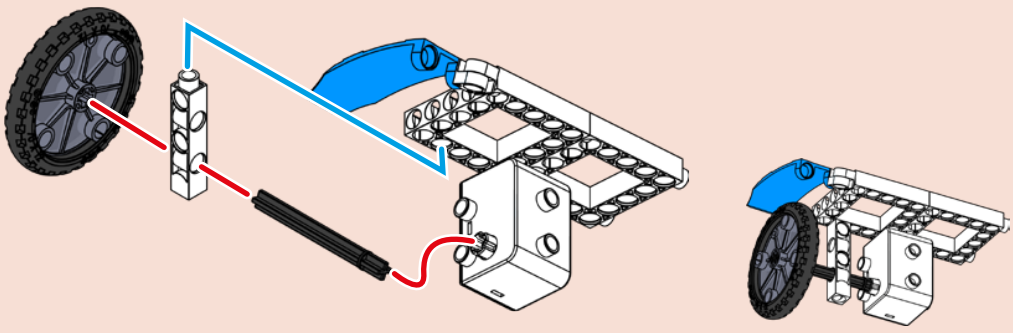

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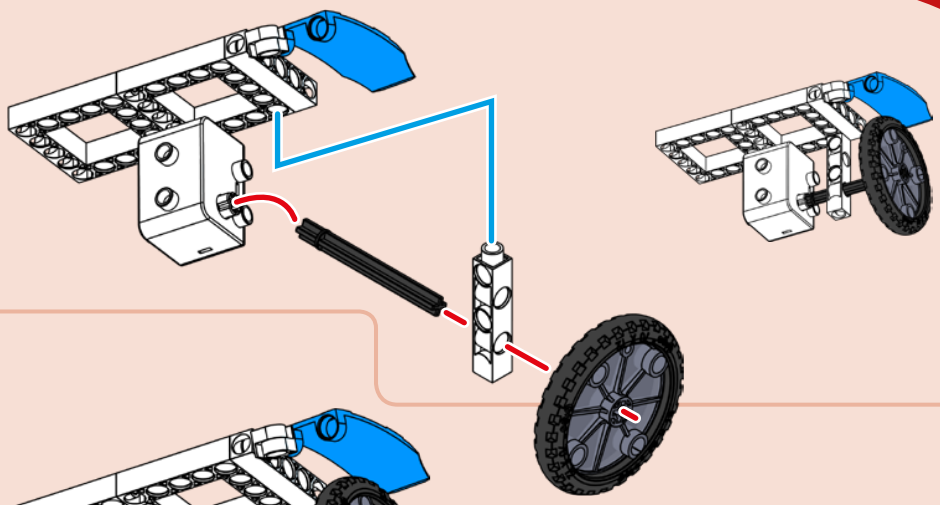

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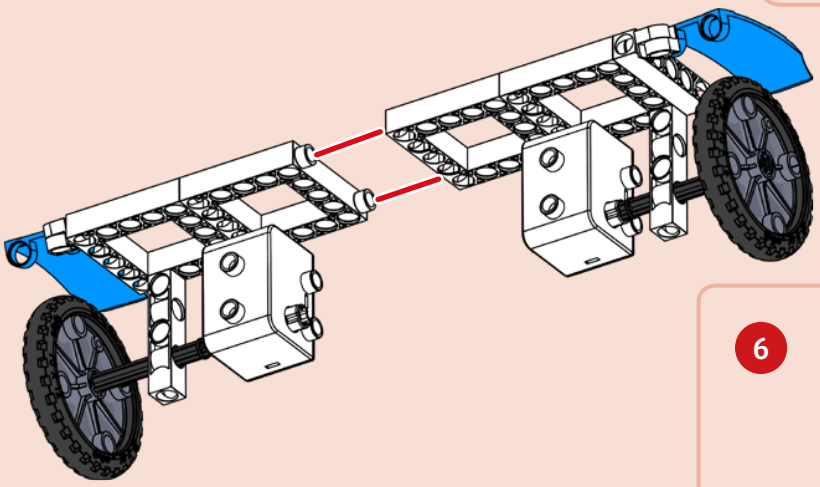

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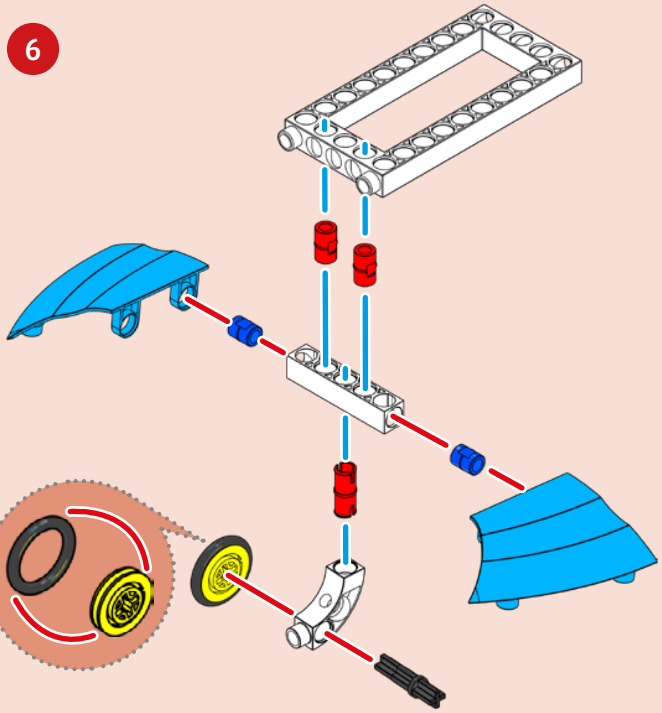

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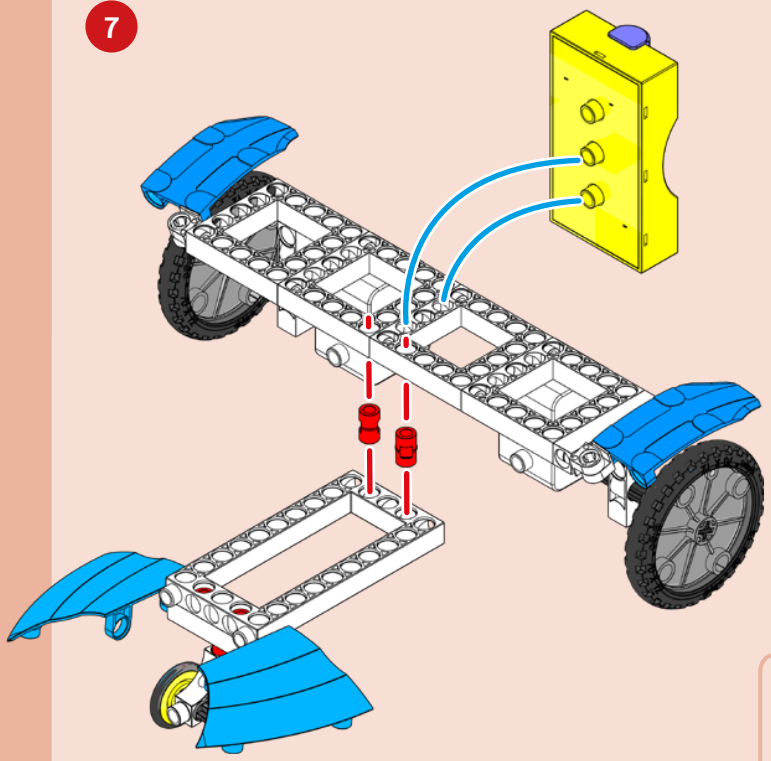

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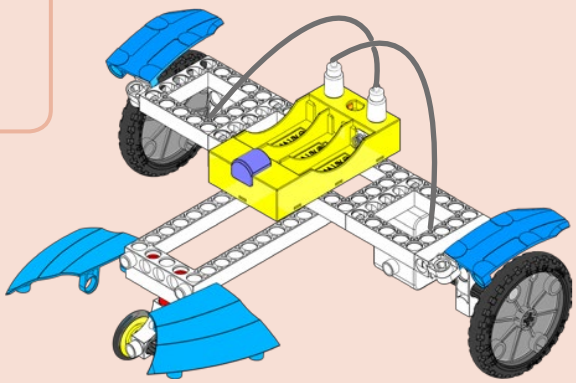
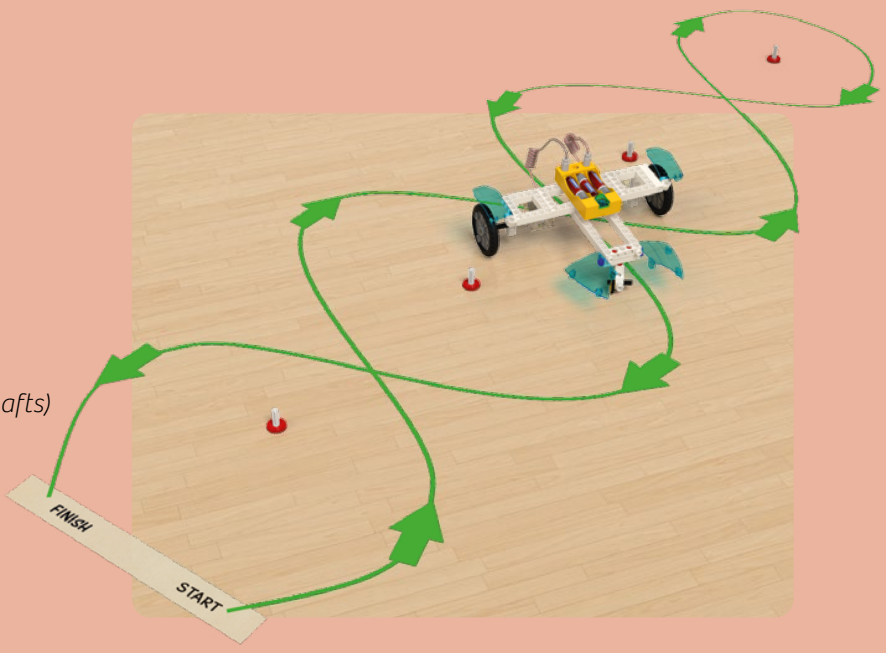


Car slalom



YOU WILL NEED

- **The assembled car**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Gate poles (made of red gear wheels and motor shafts)*
- *Measuring tape and masking tape*
- *Pocket calculator*
- *Stop watch, note pad, and pen*

HERE'S HOW

1. Build a slalom course using four red gear wheels with motor shafts spaced 50 centimeters apart in a single line (or a different layout if you wish).
2. Mark the start and finish lines with masking tape. The starting line is just to the right of the first gate and the finish line just to the left.
3. Drive the car to the starting point. Ask someone to operate the stop watch, preferably one of the other competitors. On your marks, get set, go!
4. Now zigzag between the gates with the stop watch running. At the last gate, turn back to the starting point and slalom back around the gates in the opposite direction.
5. At the end, you will cross the finish line just to the left of the first gate. Then it's your opponent's turn.

DID YOU KNOW?

Slalom competitions are held in the sports of snow skiing, canoeing, water skiing, and wind surfing, as well as snowboarding and skateboarding.

WHAT'S HAPPENING?

If you measure the length of your slalom course (or the tightest line that you can take around the gates) and keep track of the time it takes to complete it, you can calculate the speed of your car.

As an example, let's take these two values:

››› distance driven: 240 centimeters or 2.4 meters

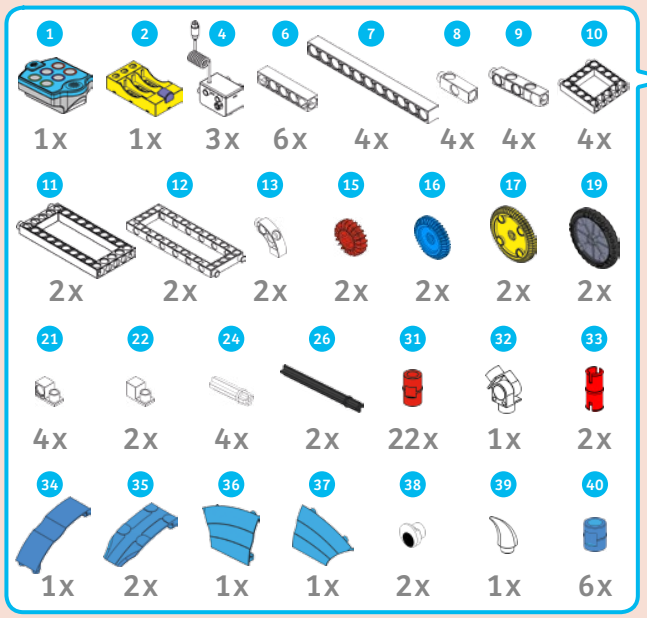
››› time needed: 20 seconds

In meters per second, that equals a speed of 2.4 m / 20 s = 0.12 m/s.

But driving speed is typically calculated in km/h, or kilometers per hour, in the scientific community (and in mph, miles per hour, in the United States.) To convert m/s to km/h, you will first have to know that a kilometer is 1,000 meters. One hour is 3,600 seconds. So we can set up this equation: One kilometer in one hour = 1,000 meters in 3,600 seconds. It's easier and clearer to write that in terms of fractions with shorter numbers: 1 km/h = 10 m / 36 s or 1 km/h = 1/3.6 m/s.

And that gives us the factor by which we have to work when converting km/h and m/s: 3.6. When converting m/s to km/h, then, we multiply the m/s value by 3.6. In our example, that means that our slalom car drove at a speed of 0.12 x 3.6 = 0.432 km/h. You can also use this same formula to calculate the top speed of the sports car in Experiment 15. Now, can you find out how to convert m/s into mph?

ROBOT



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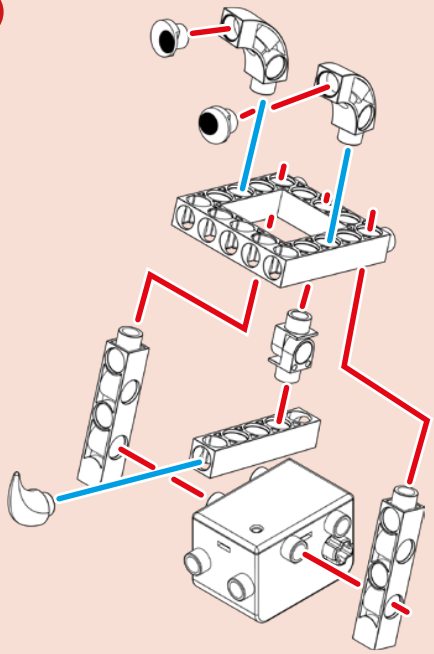

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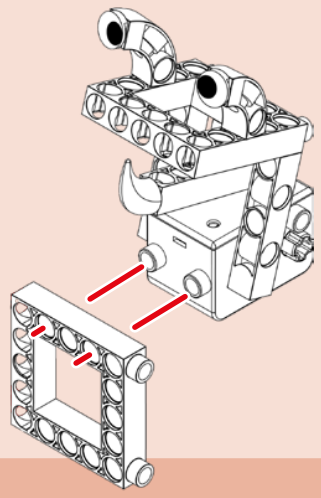

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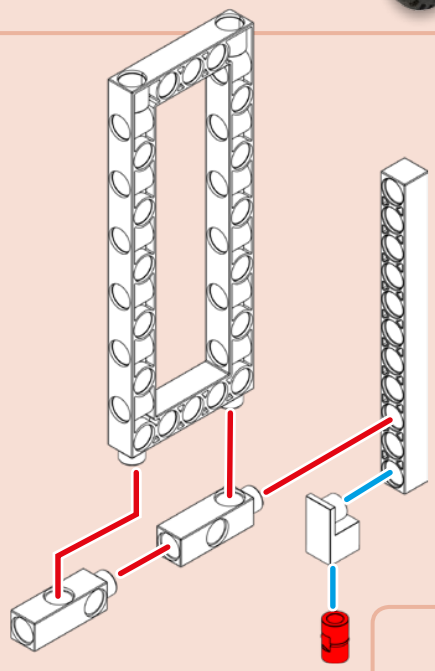

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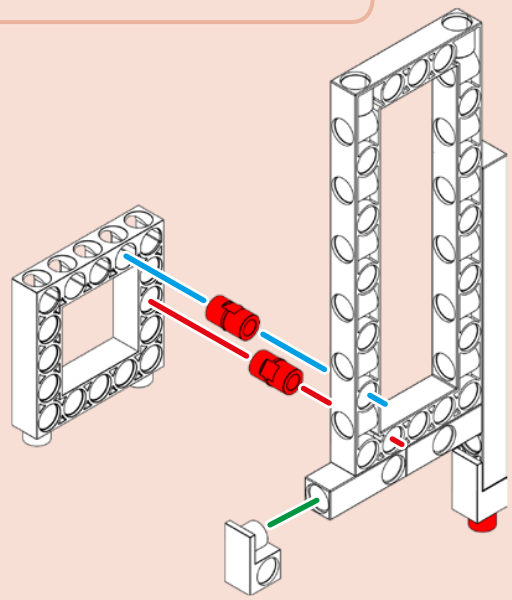

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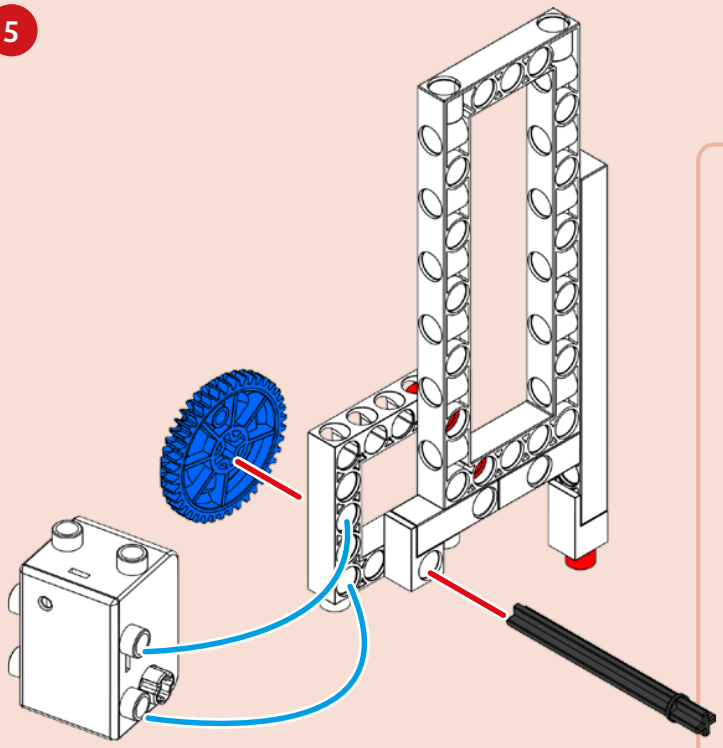

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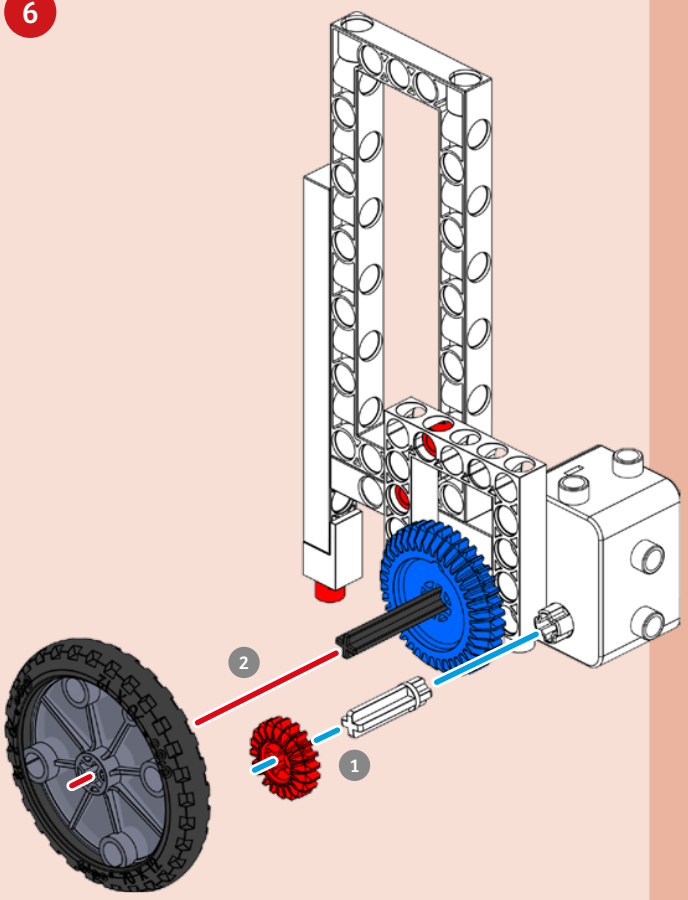

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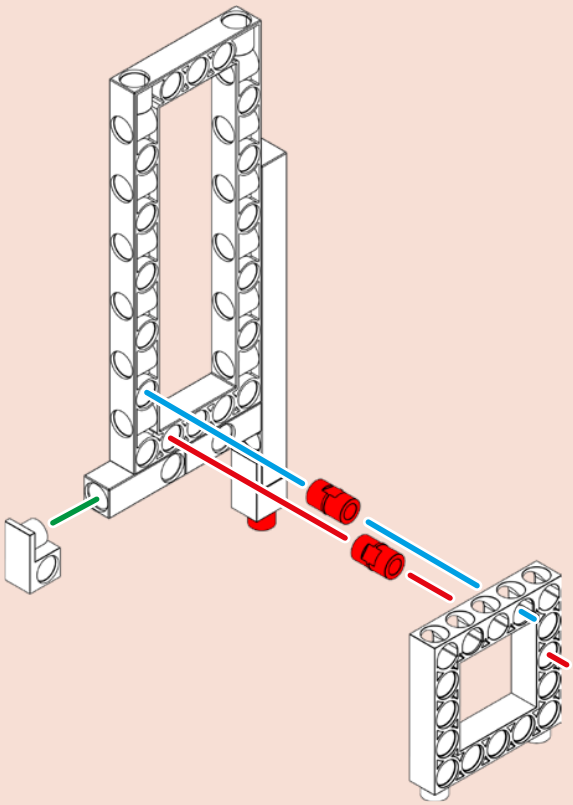

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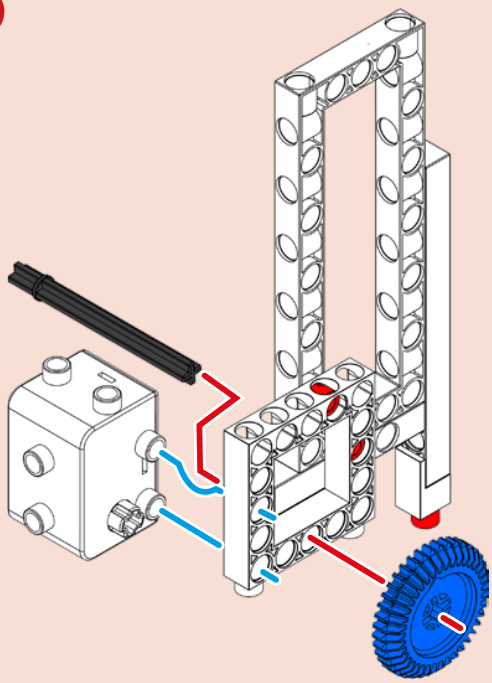

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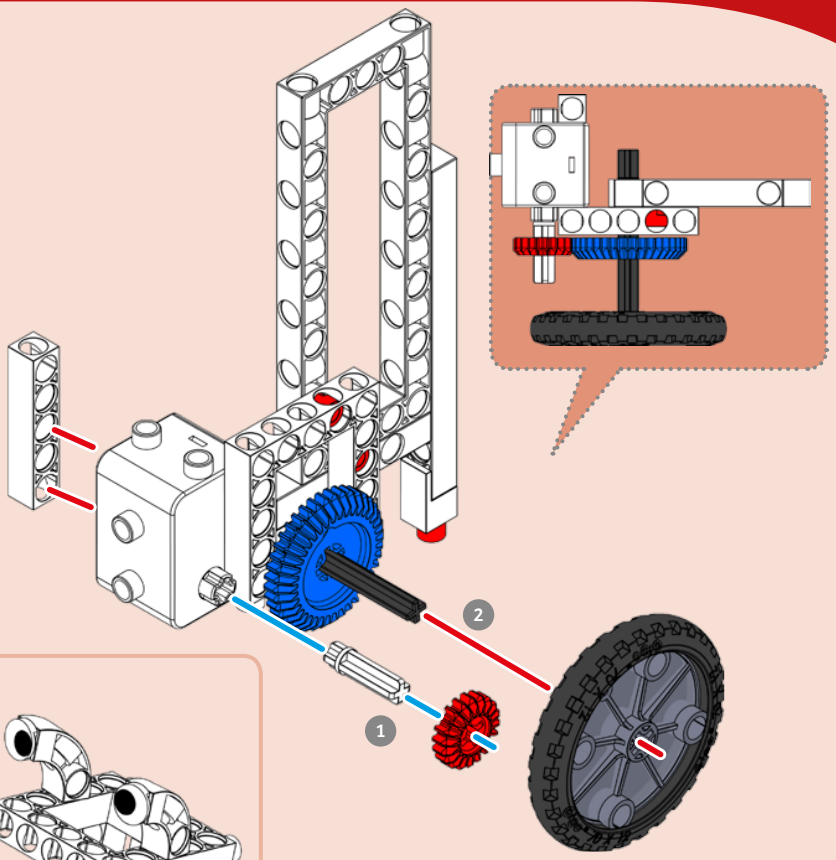

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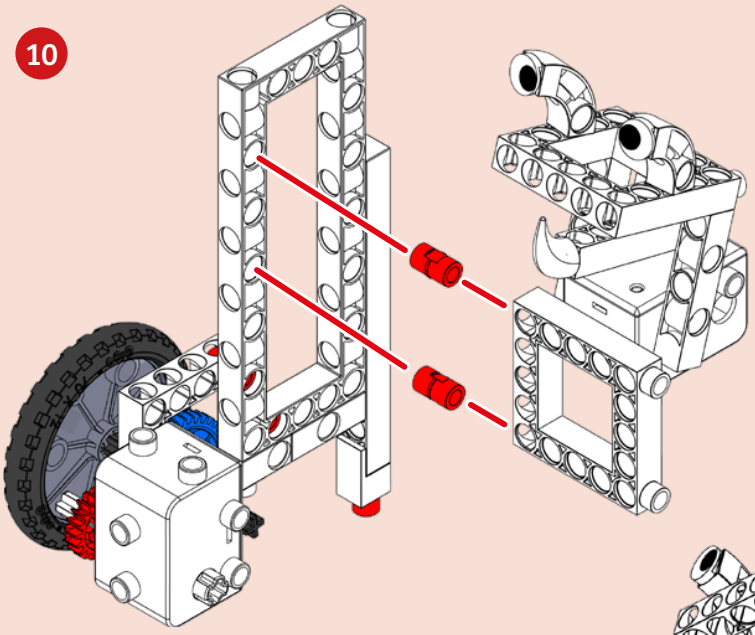

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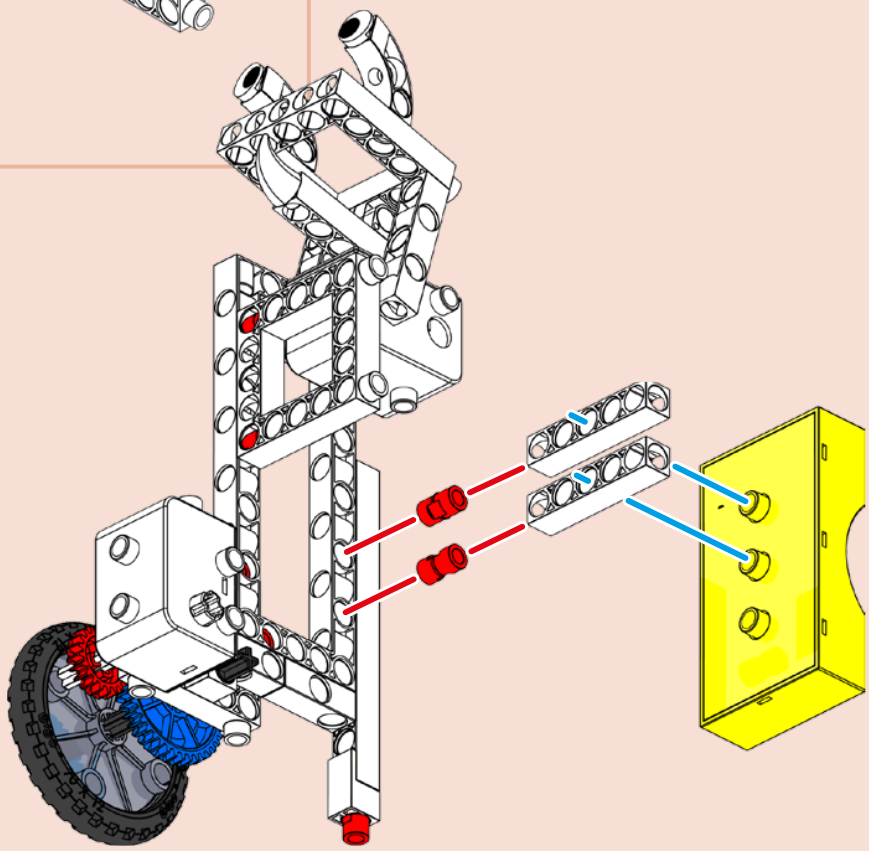

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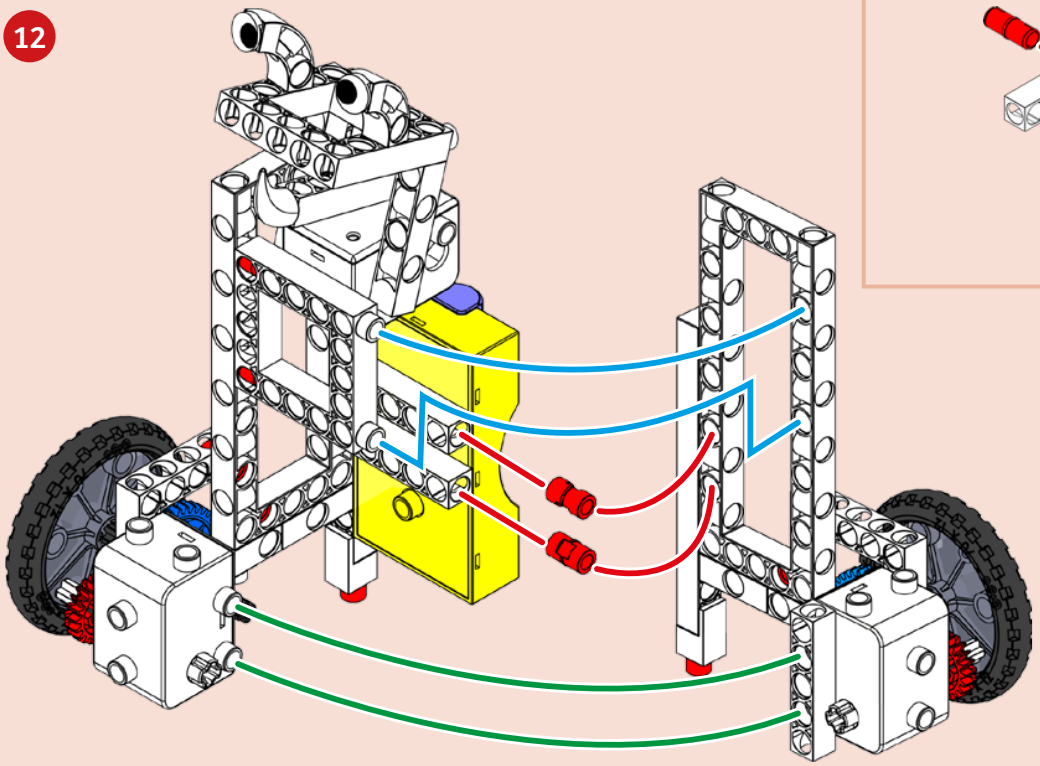

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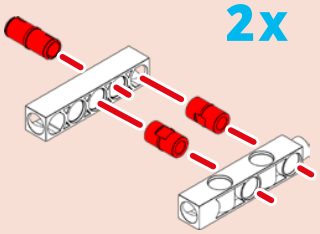

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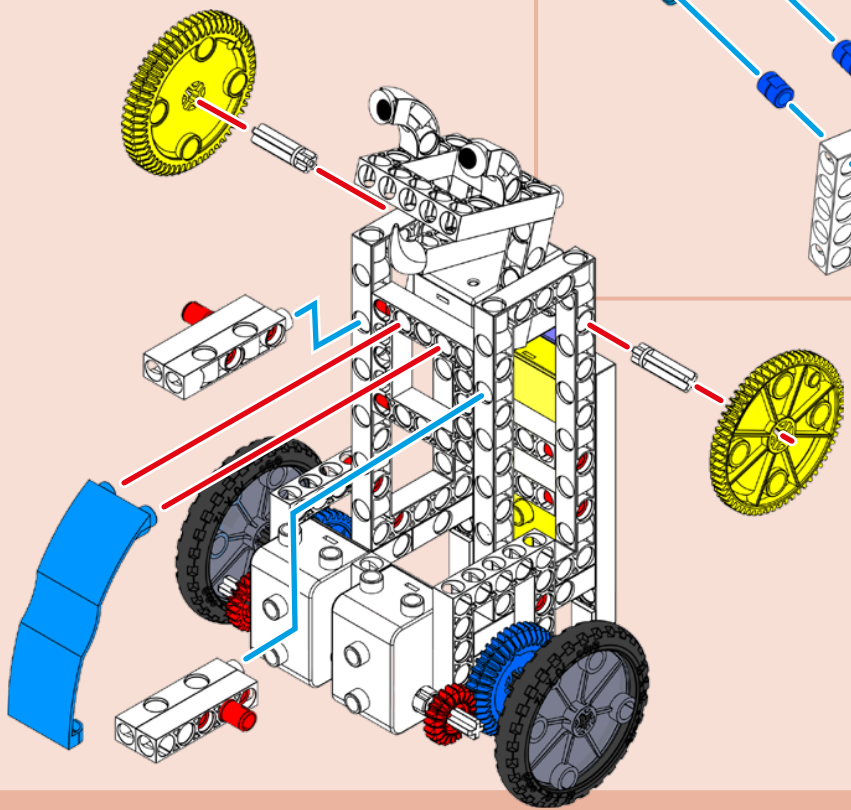

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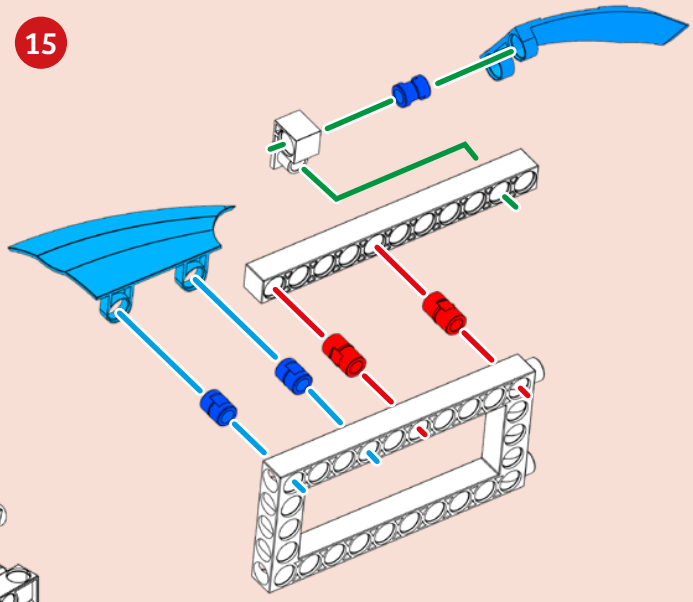

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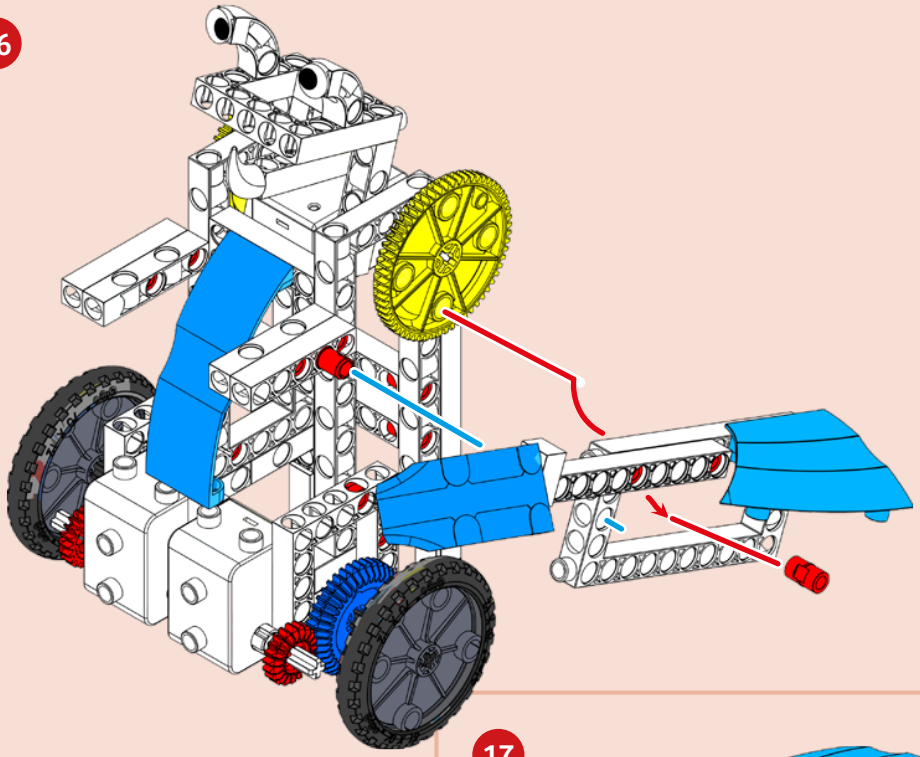

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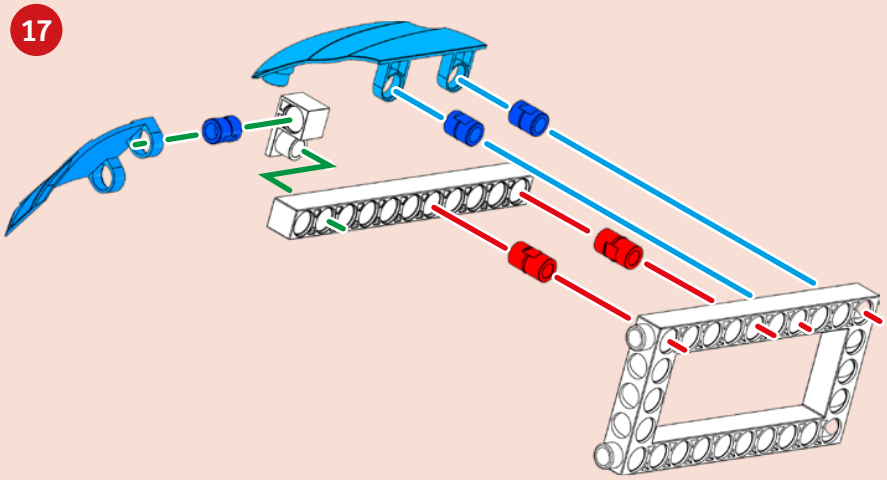

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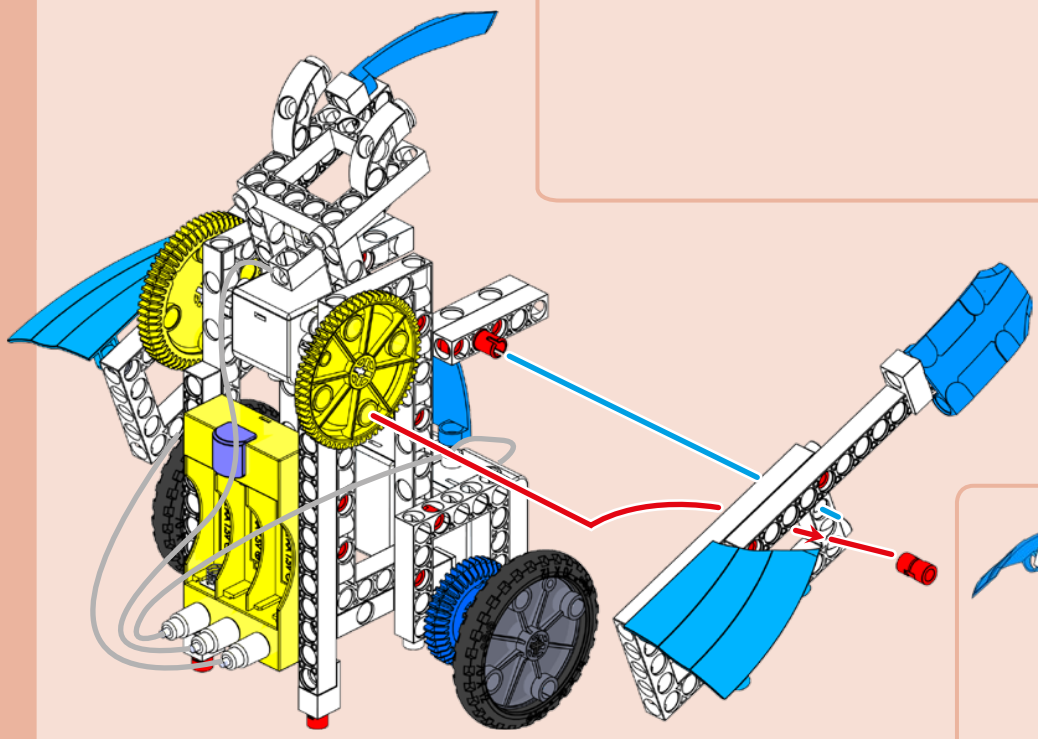

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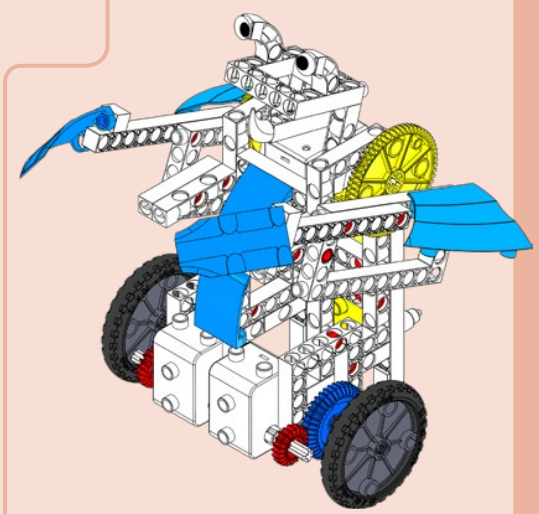
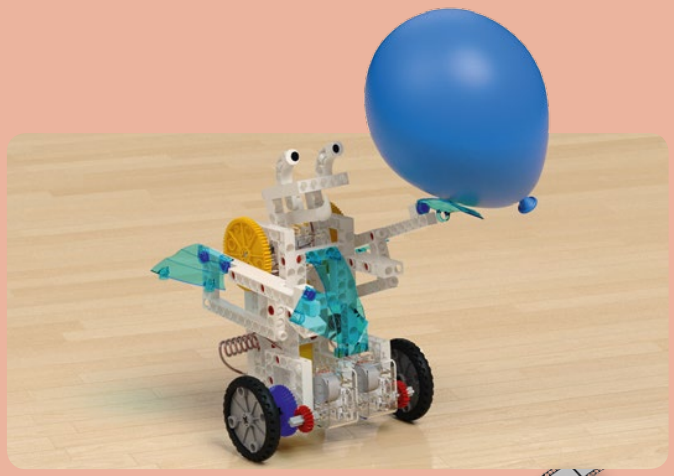


Juggling with the robot



YOU WILL NEED

- **The assembled robot**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Balloon*

TIP!
It's best to use a ball pump for blowing up the balloon.

HERE'S HOW

1. Familiarize yourself with the controls. Do you have a good feel for them now?
2. Inflate the balloon until it's just a little smaller than the robot, and tie it closed.
3. Let go of the inflated balloon so it drifts toward the ground.
4. Take the IR remote in your hand and drive the robot under the balloon, trying to use the robot arms to reach the balloon and tap it back up again — like a juggler or a soccer player keeping a ball in the air.
5. How many times in a row can you manage to "kick" the balloon back up before it hits the ground?

WHAT'S HAPPENING?

Keeping a ball in the air, also known as juggling, isn't very easy at first.

The best technique is to tap the balloon with a brief, well-aimed movement. Try not to hit the balloon too high in the air. That way, you will have better control.

WANT MORE?

Do you like to film things? How about having your robot play the starring role in your very own video? Let your imagination run free!

DID YOU KNOW?

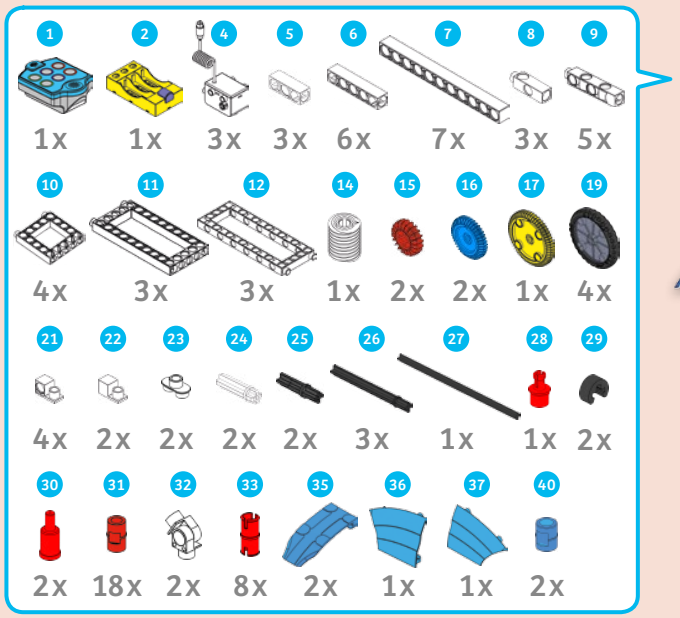
Robots are some of the most beloved characters in science fiction films. Here are just a few:

››› C-3PO and R2-D2 from "Star Wars"

››› Wall-E from "Wall-E"

- ››› **Bumblebee from "Transformers"**
- ››› **Number 5 from "Short Circuit"**
- ››› **Bender from "Futurama: Bender's Big Score"**
- ››› **Marvin from "The Hitchhiker's Guide to the Galaxy"**
- ››› **Rodney and Fender from "Robots"**

DUMP TRUCK



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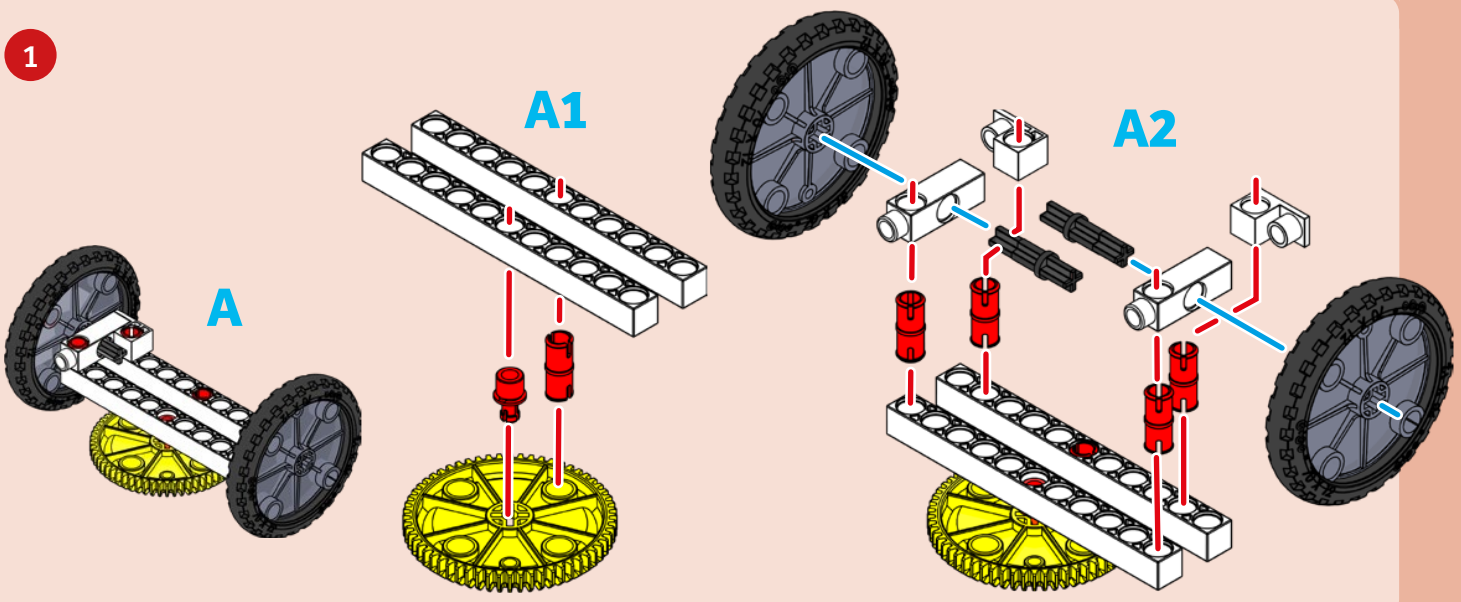

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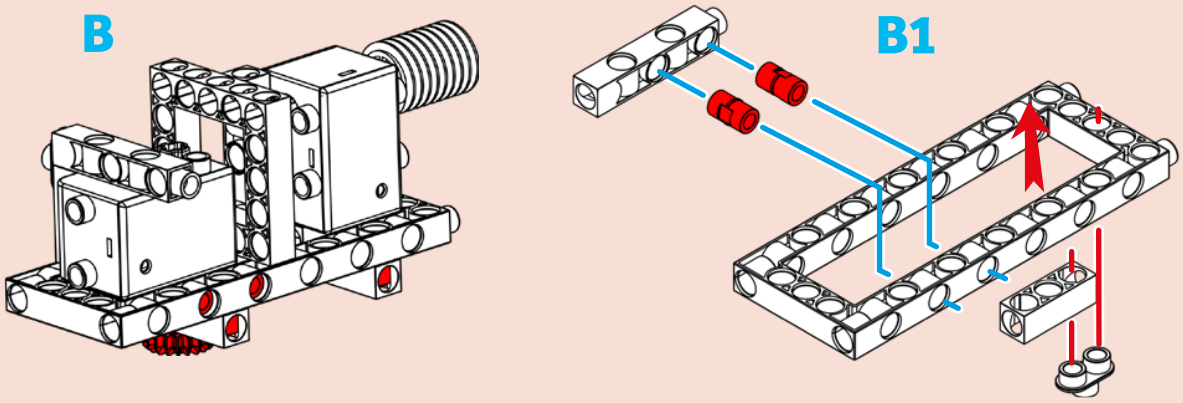

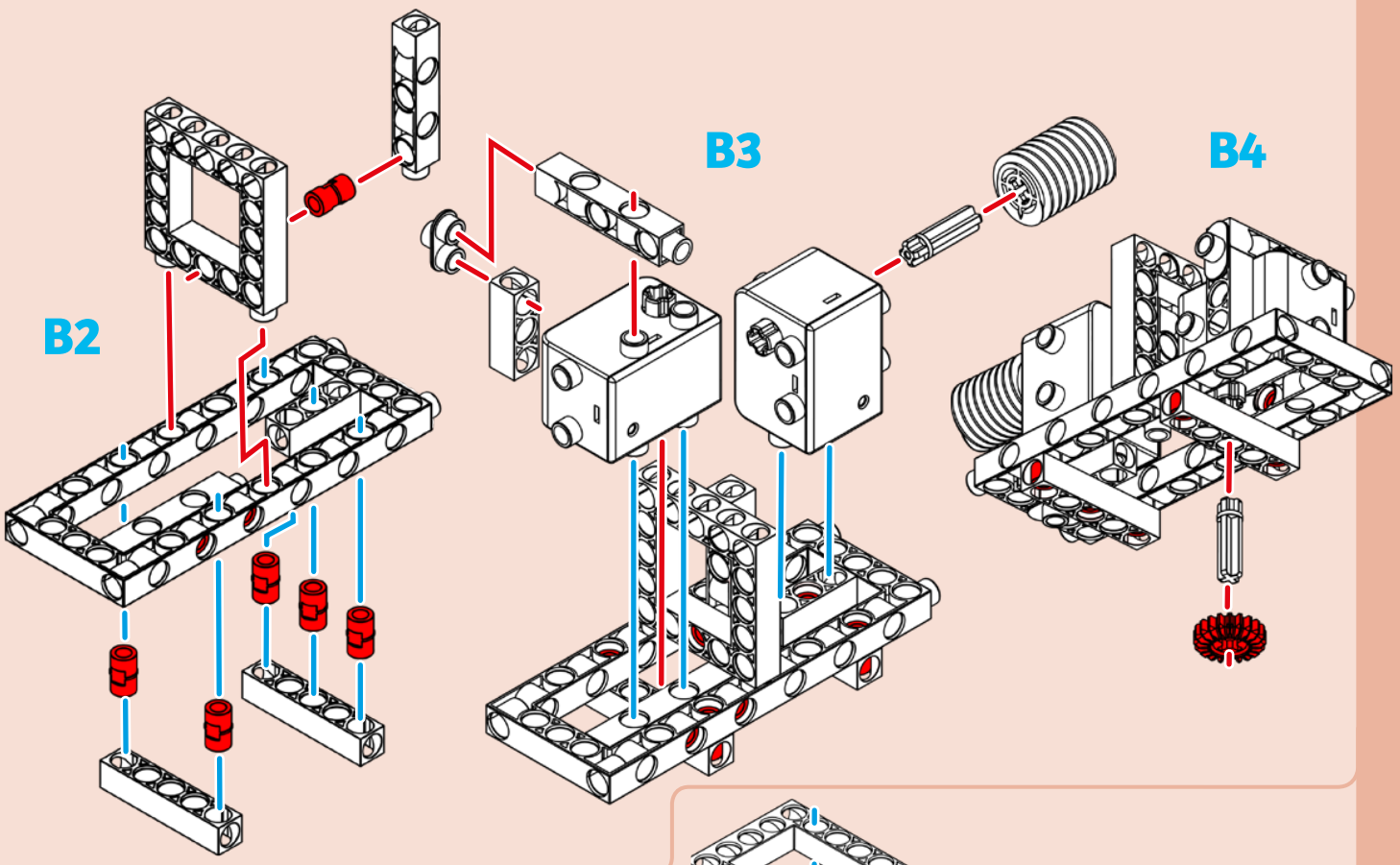

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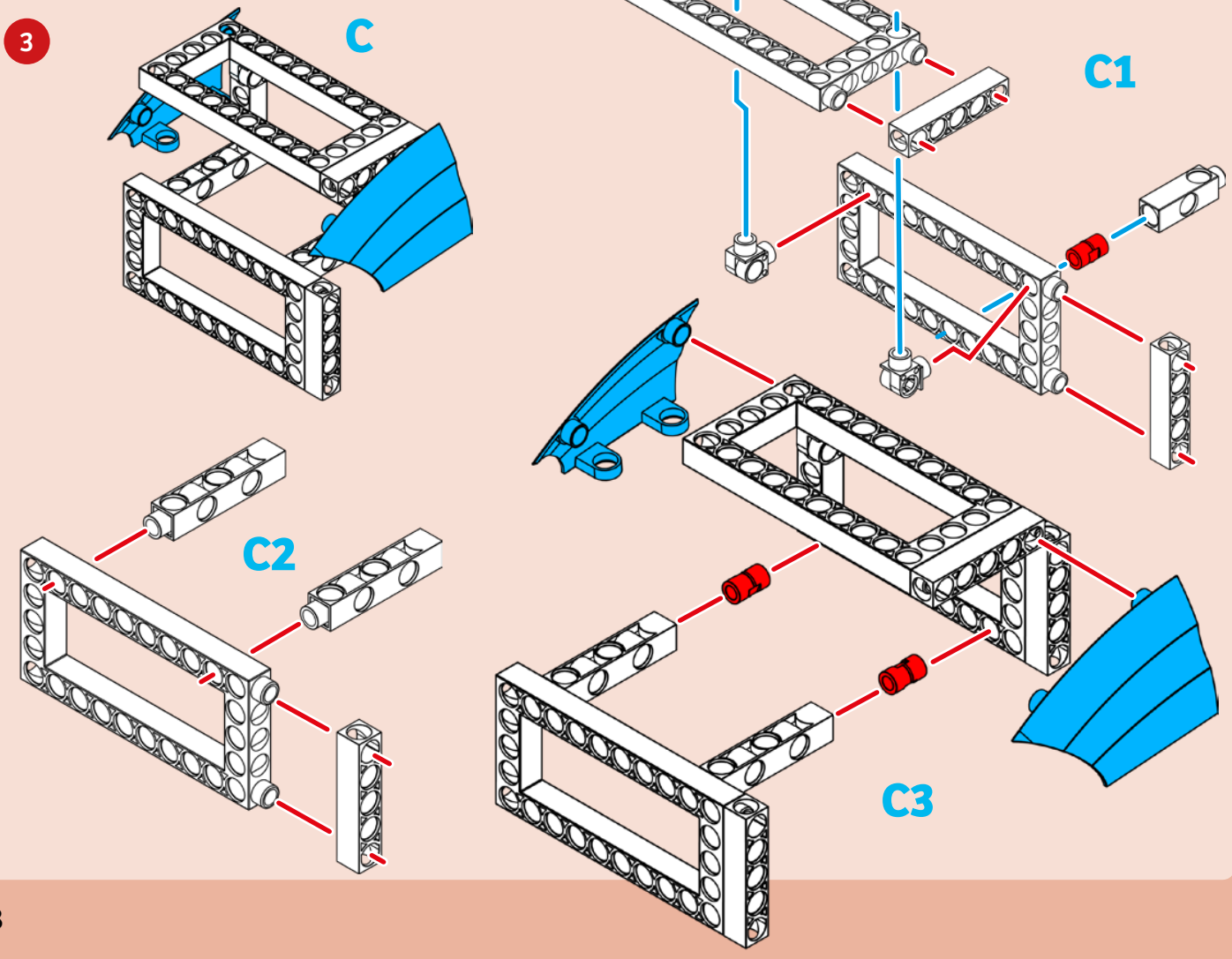

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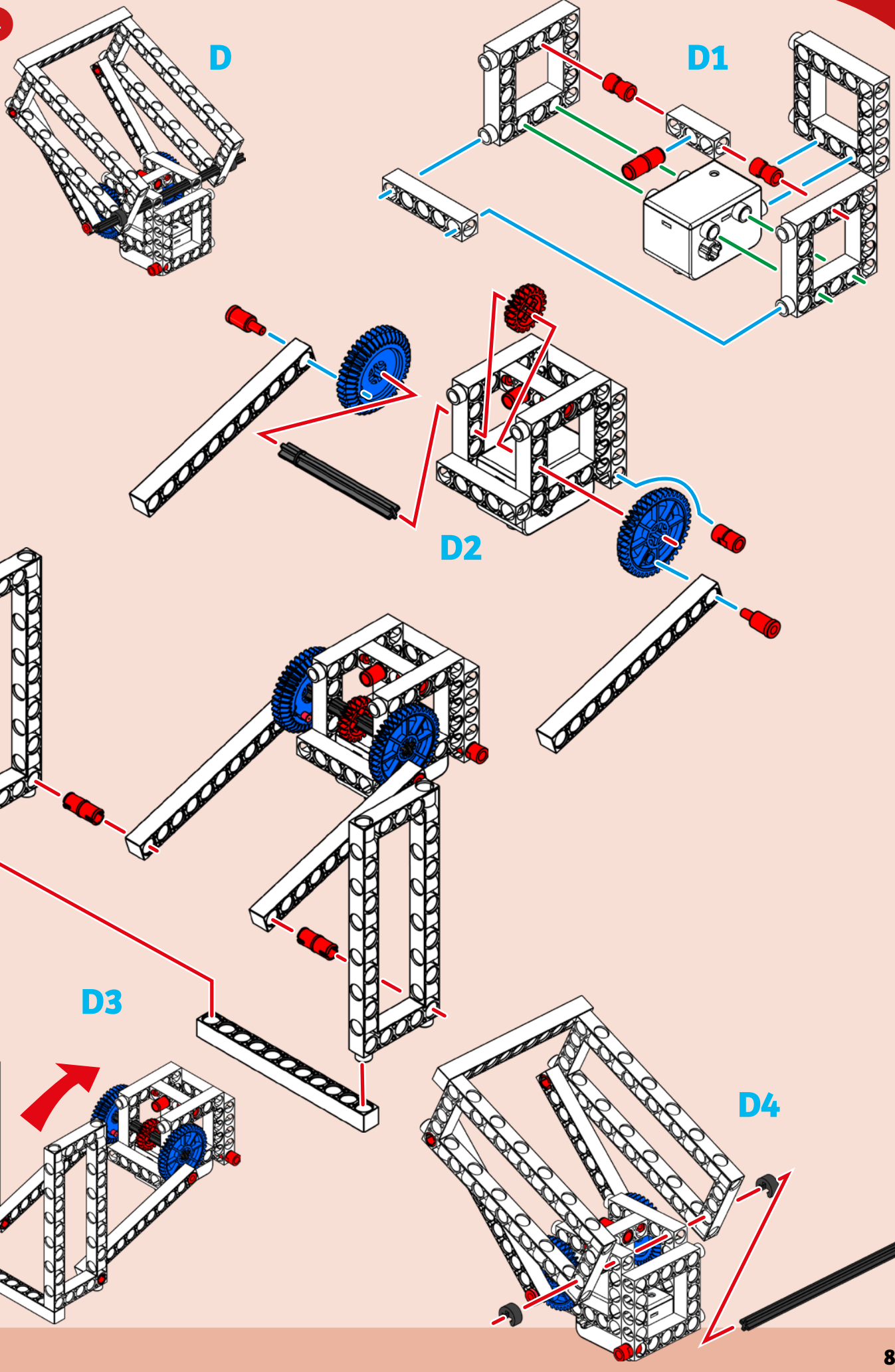

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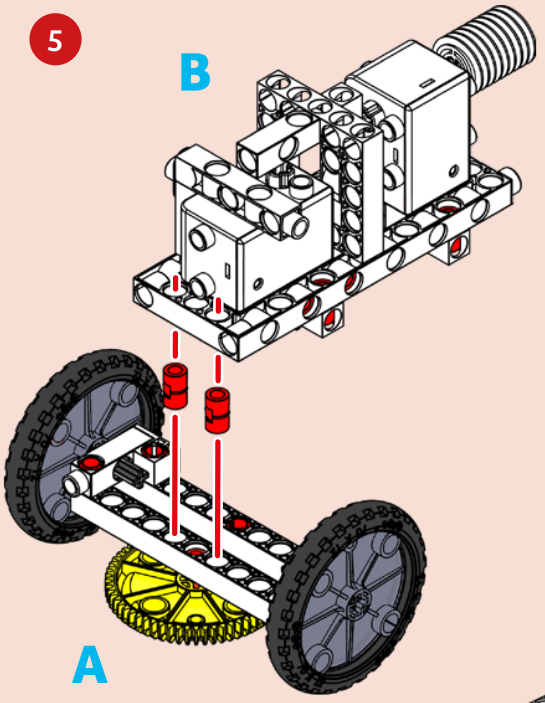

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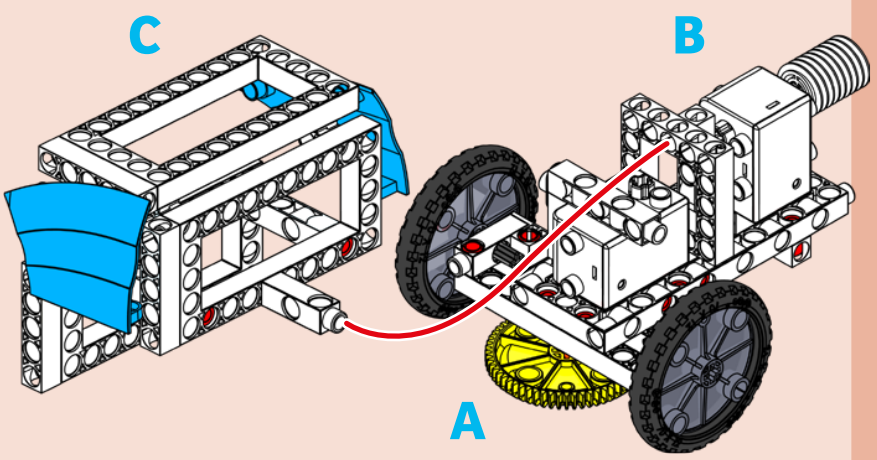

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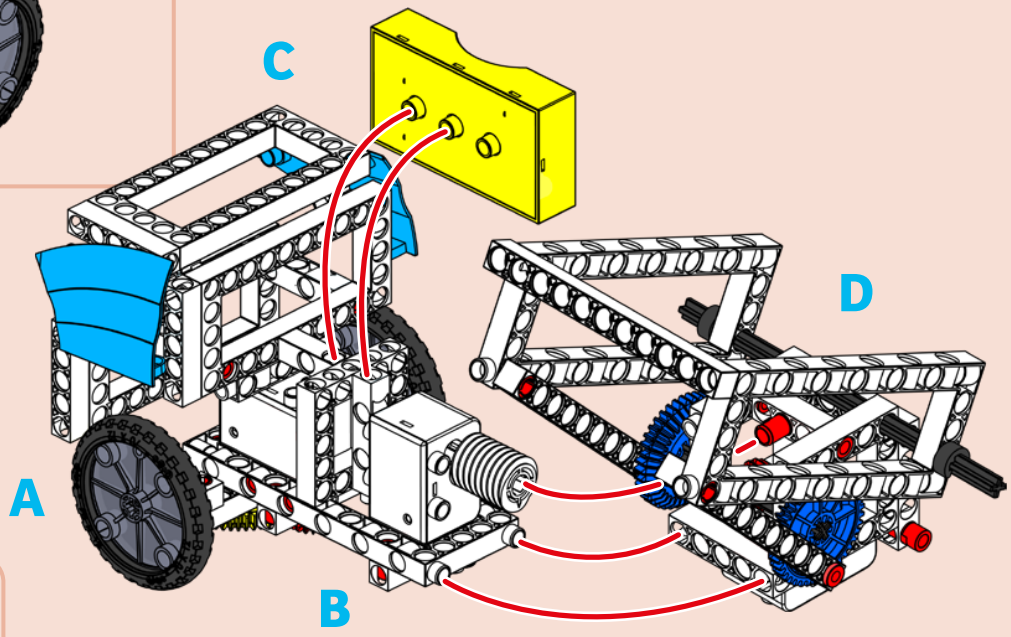

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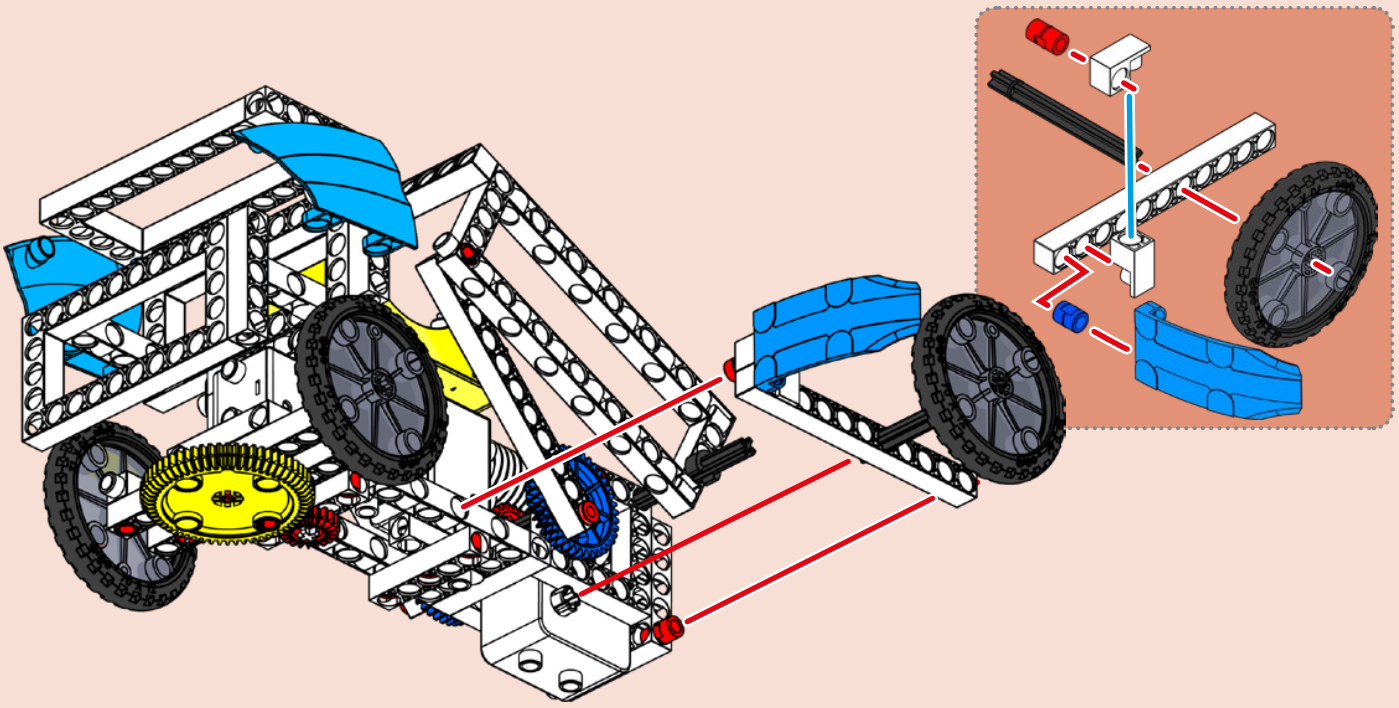

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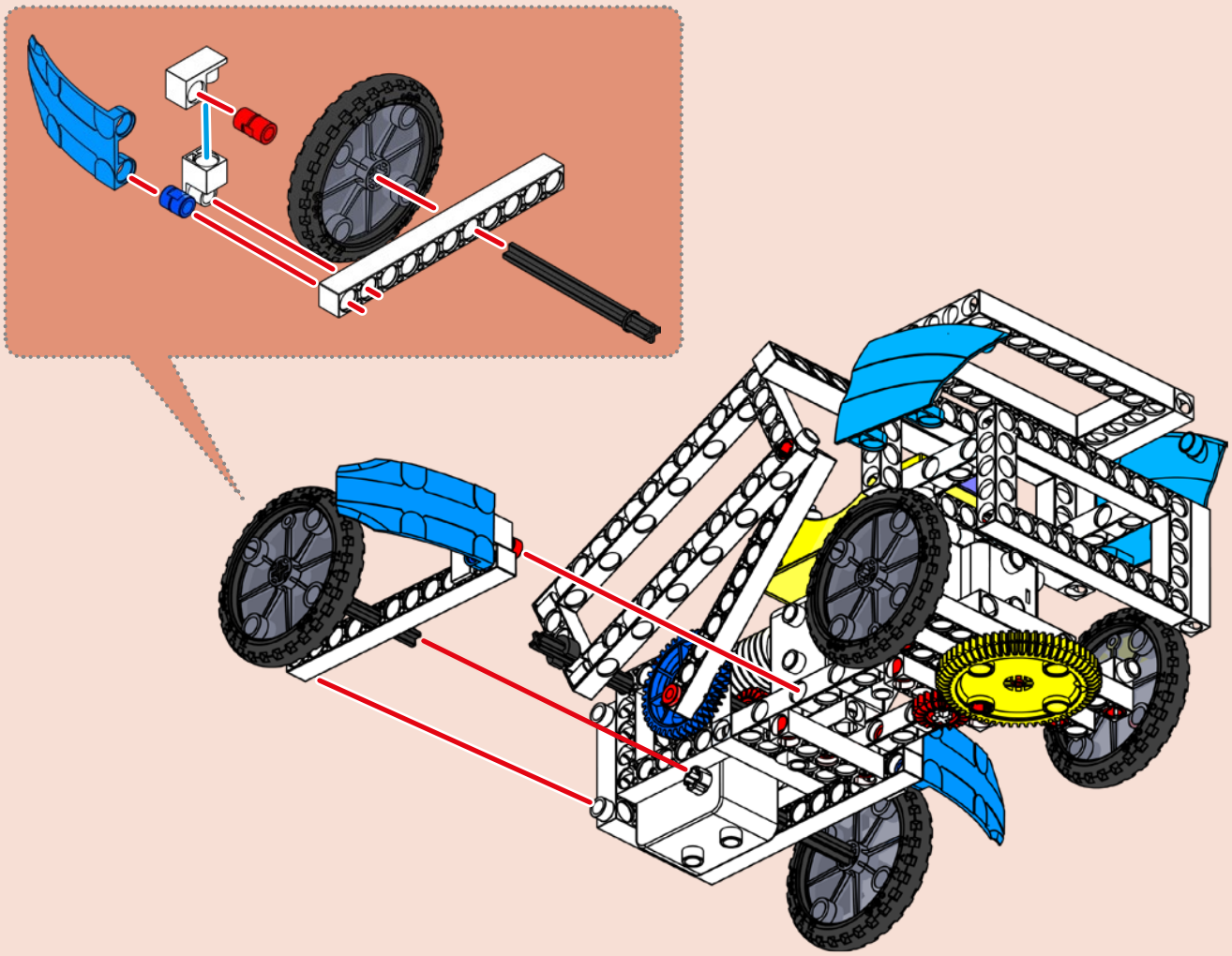

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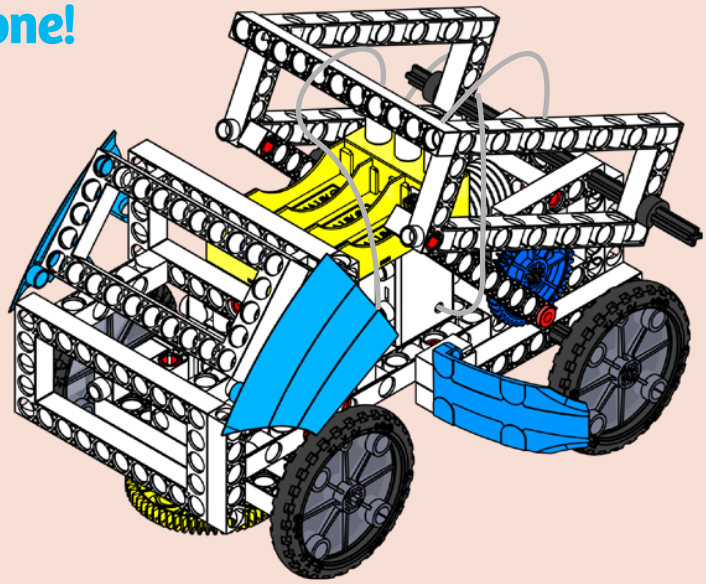
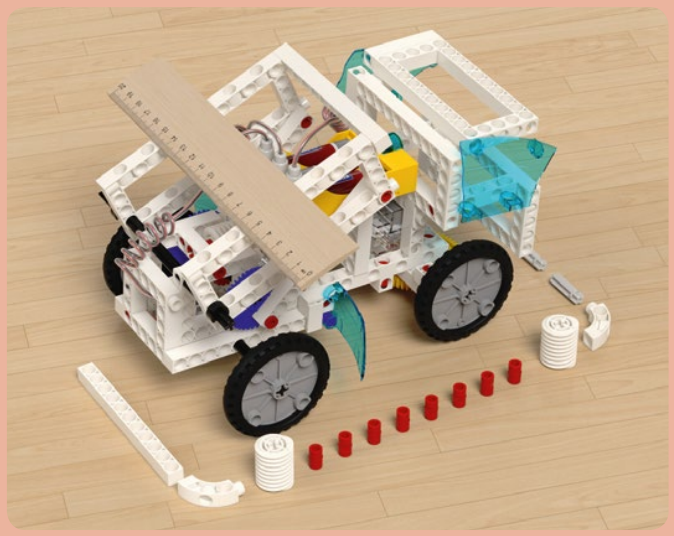


How a dump truck works



YOU WILL NEED

- **The assembled dump truck**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Pieces from the experiment kit to serve as boundary markers*
- *Ruler*
- *Masking tape*

HERE'S HOW

1. Use extra pieces from your experiment kit to make a parking space into which your dump truck can fit lengthwise.
2. Lay a ruler across the cargo bed. The ruler has to be long enough to extend beyond the bed to the left and right.
3. Drive toward the parking space from a far-away starting spot and back into it.
4. Tip up the cargo bed so the ruler slides off it.
5. The experiment will be harder if you specify a small marked area as a "landing zone" for the ruler. Use masking tape to mark a landing zone behind the parking space.
6. The better you get at unloading, the smaller you can make the landing zone.

WANT MORE?

You have probably noticed how easy the dump truck is to drive. Why not try using it as a replacement vehicle in other experiments? Experiment 12 or 15, for example.

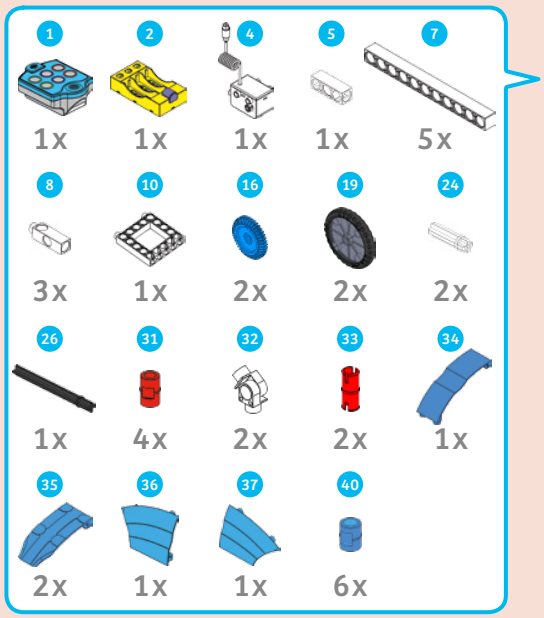
KEYWORD: INCLINED PLANE

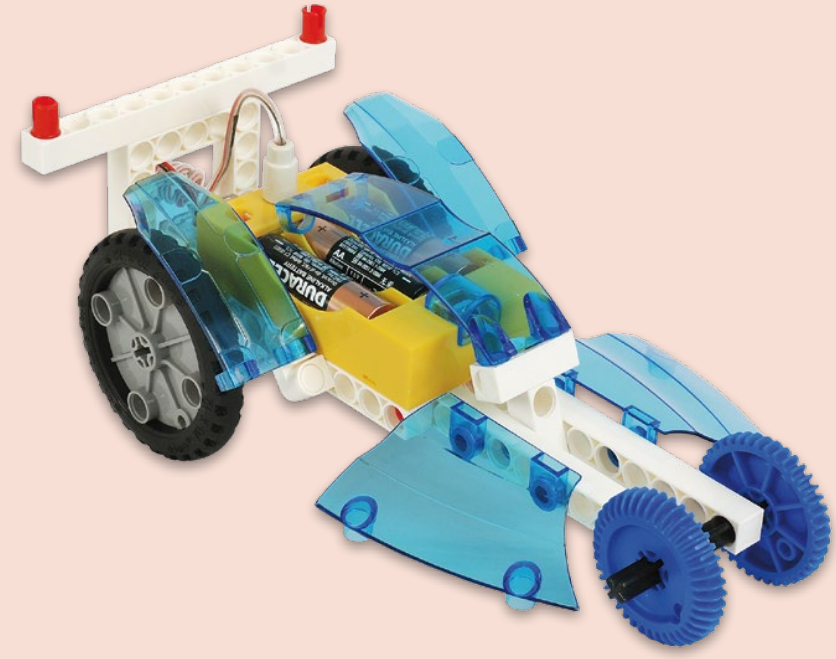
An **inclined plane** is always used when an object (or person) is to be transported upward with relatively little expenditure of force. Examples might be a ramp or an uphill-climbing road with switchbacks. Slides and peaked roofs are inclined planes too.

WHAT'S HAPPENING?

A dump truck is a special construction truck with an open-box bed on it. It is ideal for loose, pourable material such as soil or sand. Since the dumping bed — just like an inclined plane — can be tilted, the material can just slide off the cargo bed all by itself if the bed is tilted enough. That makes unloading very easy.

SPORTS CAR





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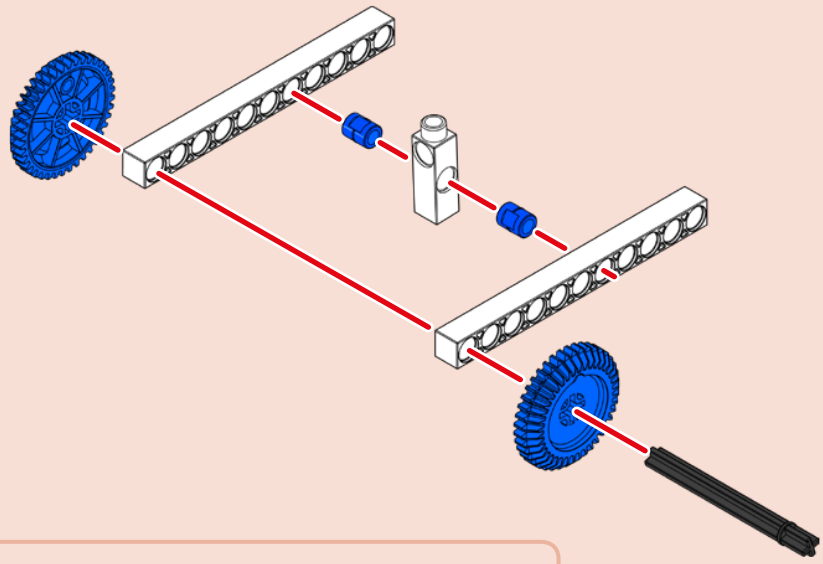

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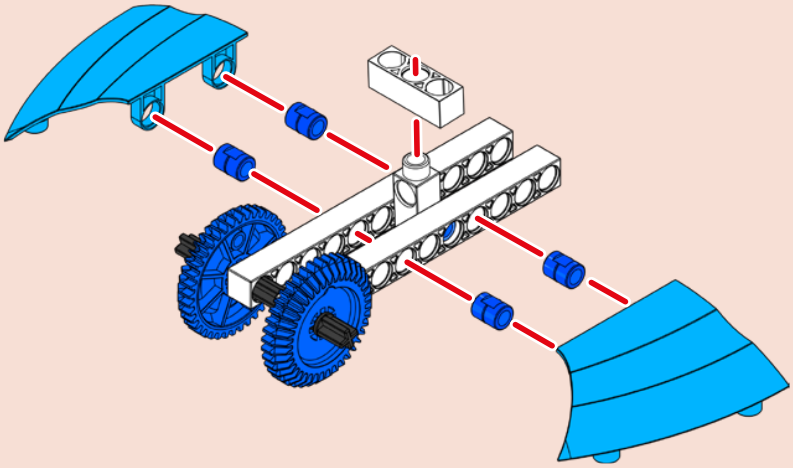

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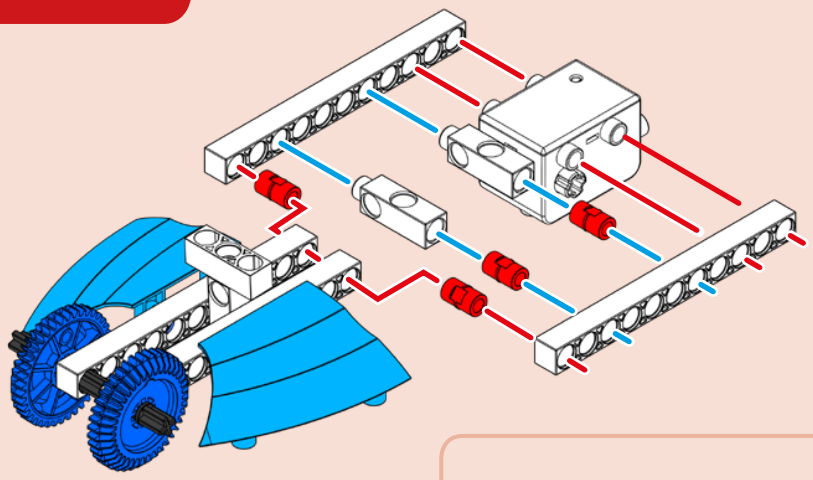

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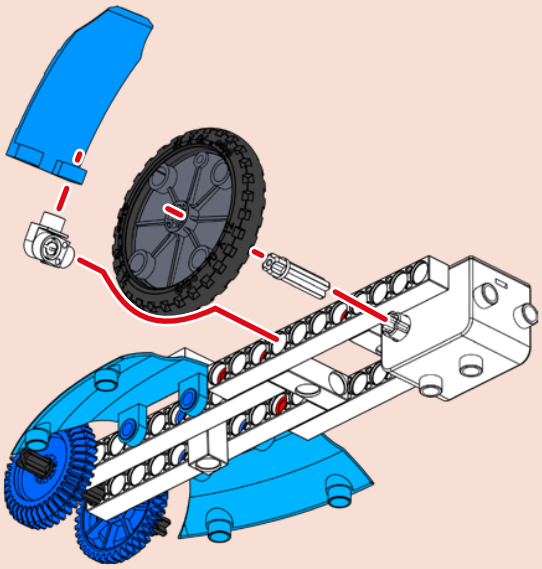

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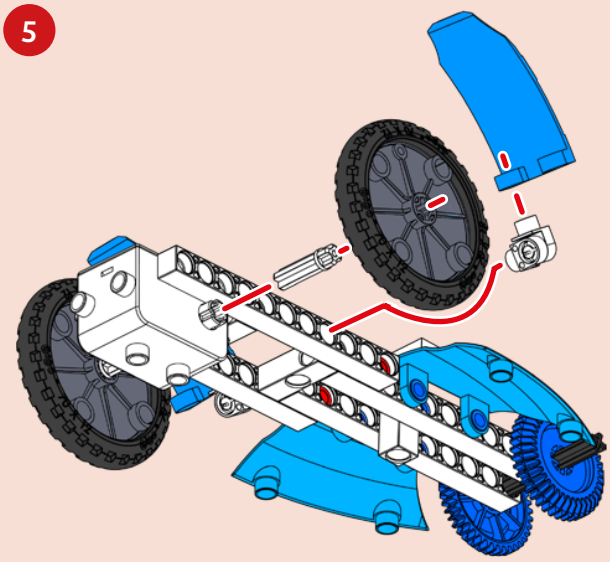

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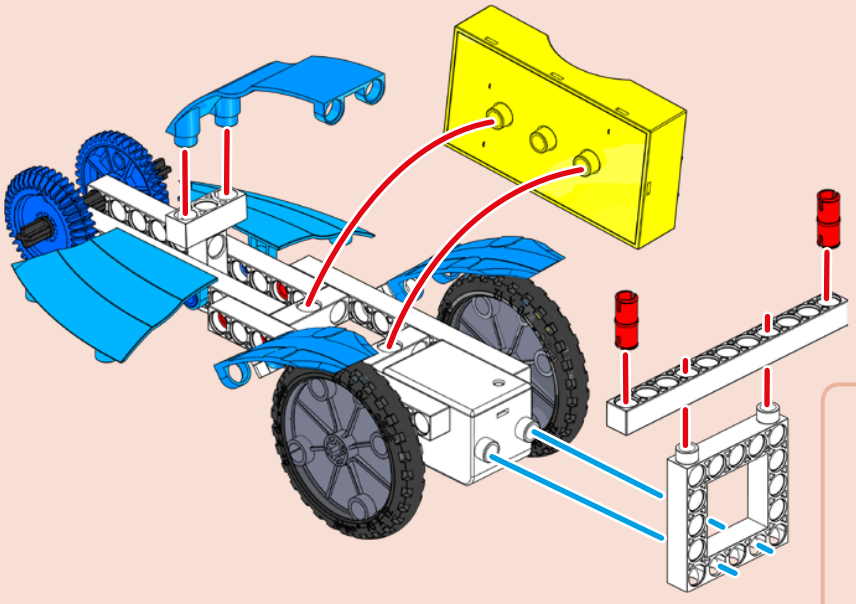

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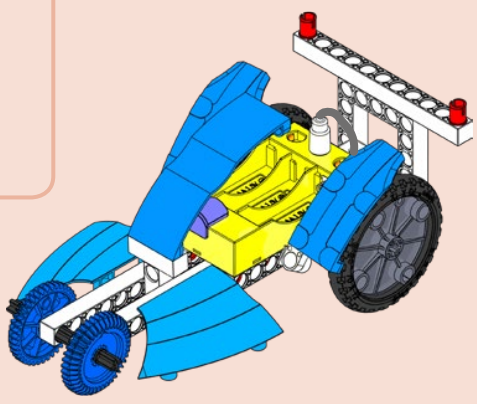


EXPERIMENT 15

Pedal to the metal with the sports car

YOU WILL NEED

- **The assembled sports car**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Masking tape*
- *Measuring tape*
- *Stop watch, note pad, and pen*

HERE'S HOW

1. For this experiment, you will need a large room, because your "race track" should be as long and straight as possible. A hallway or corridor is perfect.
2. Use masking tape to mark a starting line at one end of the track and a finish line at the other. Make sure to leave a safety zone beyond the finish line so your car doesn't crash into the wall.
3. Precisely measure the distance from the starting line to the finish line, down to the millimeter. The track should be as long as possible so as to reduce the effects of inaccuracy in your time measurements.
4. Drive your sports car right up to the starting line. Ask someone to operate the stop watch. Ready, set, go!
5. As soon as your sports car has completely crossed the finish line, note the time. Write it down in your note pad and repeat the procedure 10 times for each driver.
6. Repeat the series of experiments on different surfaces. This will help you figure out whether a surface with more "grip" or traction allows you to make faster times.

WHAT'S HAPPENING ?

In this experiment, you repeated the same experiment several times under the same conditions. Scientists often perform a series of tests or experiments in exactly this same way. This is because in a single experiment, it's easy to do something wrong — press the stopwatch too soon or too late, for example.

This kind of error can be prevented by performing a series of experiments. In our case, performing it ten times gave us ten sets of results. You add these together and divide by the number of experiments (that is, 10). The final result is the **average** of all of them.

WANT MORE?

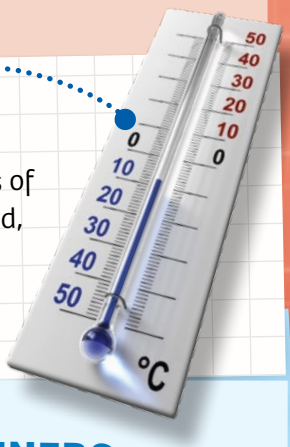
A longer track has the advantage of reducing the impact of any measurement error. For example, if you were too react just a tenth of a second too late with the stop watch at the start of the race, it would inevitably result in a measurement error by that amount. If your car needs, say, three seconds to run the entire track, the impact of this error (0.1 seconds out of 3 seconds = 3.33%) is much less than with a track that your car runs in just 0.5 seconds (0.1 seconds out of 0.5 seconds = 20%). See Experiment 12 to find out how to convert speed to the familiar km/h unit.

How robots orient themselves to their surroundings

Things get really exciting with robots when they are able to move around in their surroundings all by themselves. To do that, though, they have to orient themselves. They have to know where they are and what's going on around them, where their goal is, and where and how to keep moving. **Below, we present a few important kinds of technology for autonomous robots.**

SENSORS

A **sensor** is something that takes measurements of the physical or chemical properties of its environment. Some such properties might be temperature, humidity, pressure, sound, brightness, or acceleration. This way, a robot can know how cold or loud it is, or even just whether it is already moving.



CAMERAS AND LASER SCANNERS

By using cameras, a robot can create an image of its surroundings. Sometimes the robot has to know more precisely how even or uneven the ground is, for example. Here's where the **laser scanner** comes in. During laser scanning, a surface is covered with a grid of laser beams, each of which take measurements of the surface. A computer connected to the scanner creates a picture out of those measurements. Then the robot applies special sensors to recognize whether the ground surface is squishy, granular, or soft.

BARCODES

A barcode is a type of image consisting of lots of parallel lines and spaces. The data in a barcode is read with optical readers such as barcode scanners and then processed electronically to convert it into numbers. The numbers represented by the barcode are usually printed at the bottom of the barcode.

Global Positioning System (GPS)

You probably know about GPS from car navigation systems and smartphones. This is a kind of technology that draws on information from around 30 space-based satellites that constantly transmit their current position along with the exact time. That information can be used to help you determine your location within 10 meters. GPS signals can also be used to calculate your speed and direction and thus serve as an artificial compass.

WIRELESS LOCAL AREA NETWORK (WLAN)

In buildings, you often can't get a good GPS signal, or any signal at all. That's because GPS signals travel in practically straight lines, just like light, and anything that gets in their way can affect their quality. A robot inside a building that relies completely on GPS would therefore get completely disoriented and lost. This is where wireless LAN technology comes in handy — the same type of technology you know from your PC, laptop, or tablet computer, or smartphone. WLAN can also be used to establish a wireless connection between a robot and a central computer.

UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM (UMTS)

A robot is even more flexible, of course, if it doesn't have to rely on a WLAN access point. This can be accomplished through a mobile communication connection, ideally a cellular network based on third-generation digital mobile communications phone technology.

Appearing today in a home near you: robotic vacuum cleaners

Some of these technologies are already being used by robotic vacuum cleaners. Simple models use just a single sensor to size up their surroundings. If the robot runs into an obstacle, it changes its direction. More expensive models use infrared light or lasers to calculate their distance from an object by reflecting a beam off of it.

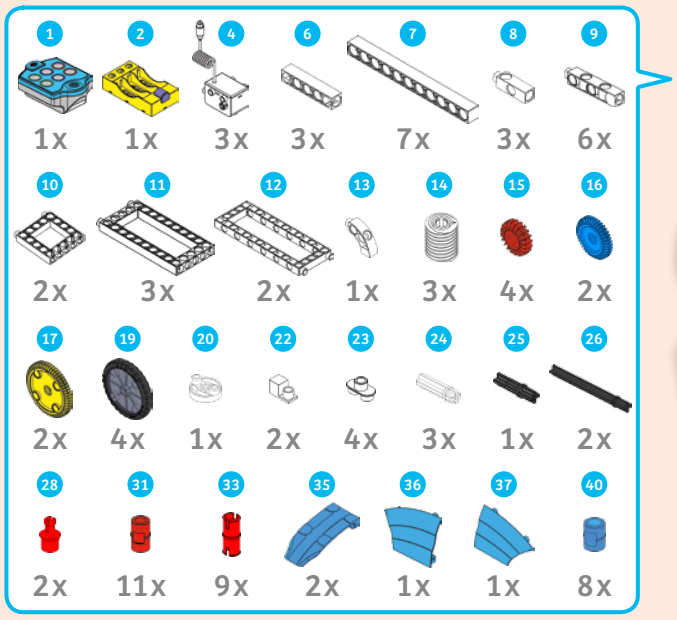
CARS AS ROBOTIC TECHNOLOGY PIONEERS

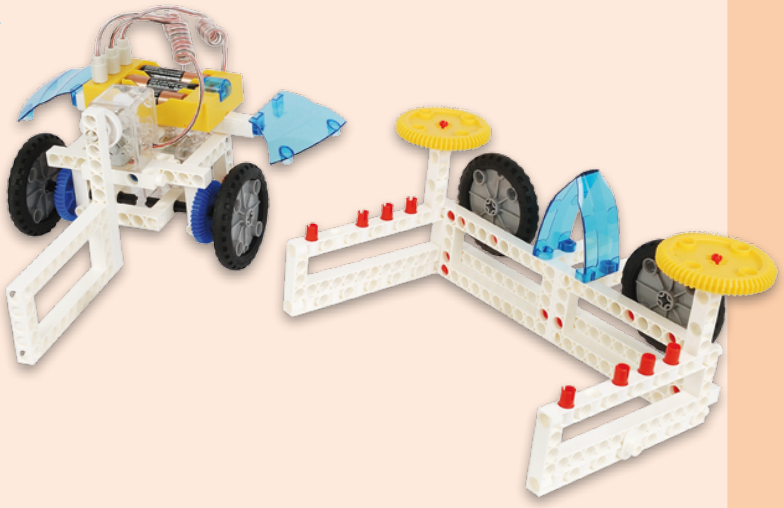
Automobile company engineers already have a lot to show us about what's possible in the realm of **autonomous driving**. Even today, autonomous driving works well in bumper-to-bumper traffic, given the low speeds involved and the relatively predictable traffic conditions. Different states and countries are adopting their own new laws regarding driverless vehicles, with many more changes to be expected as the technology improves.

GOOOOAL!

And now for some fun games! Let's play soccer! That's right. You can actually use a remote-controlled robot to play soccer. You can take penalty kicks, practice dribbling, and even play a match against an opponent. Or how about a match against several opponents? And how long do you guess it might take before world-class soccer players no longer stand a chance against robotic players? Roboticists have already set their own goals to ensure that such a day will indeed come.

SOCCER GAME





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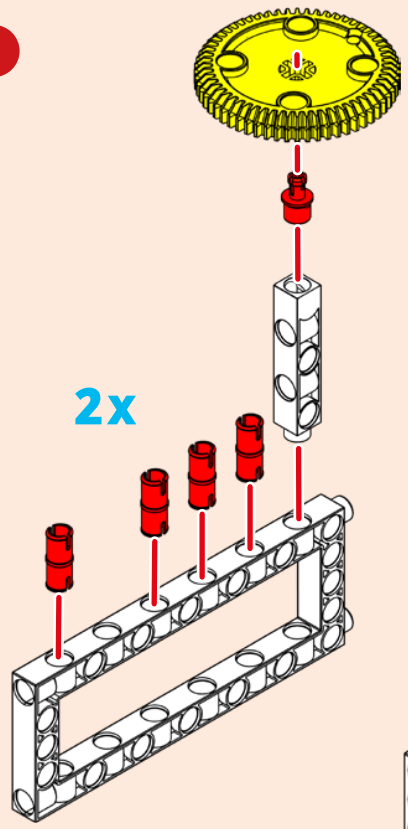

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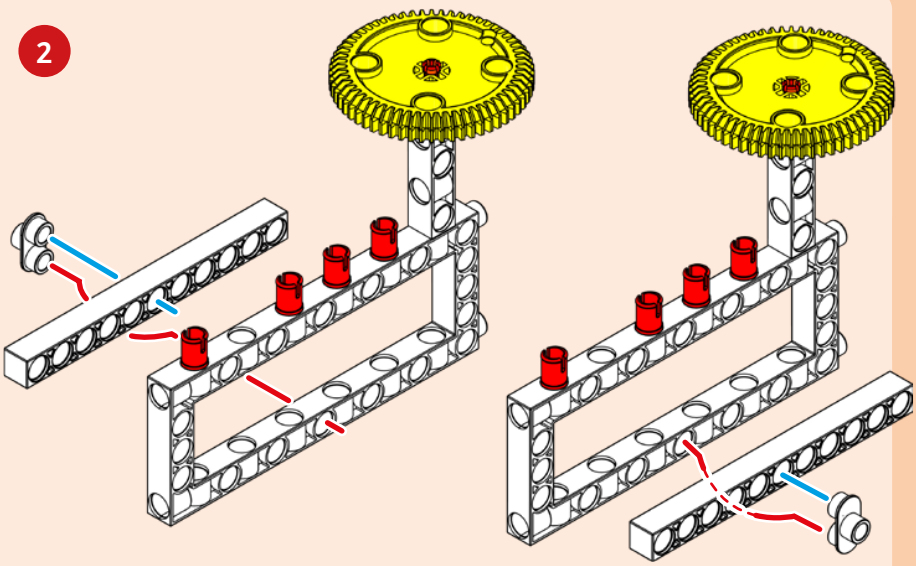

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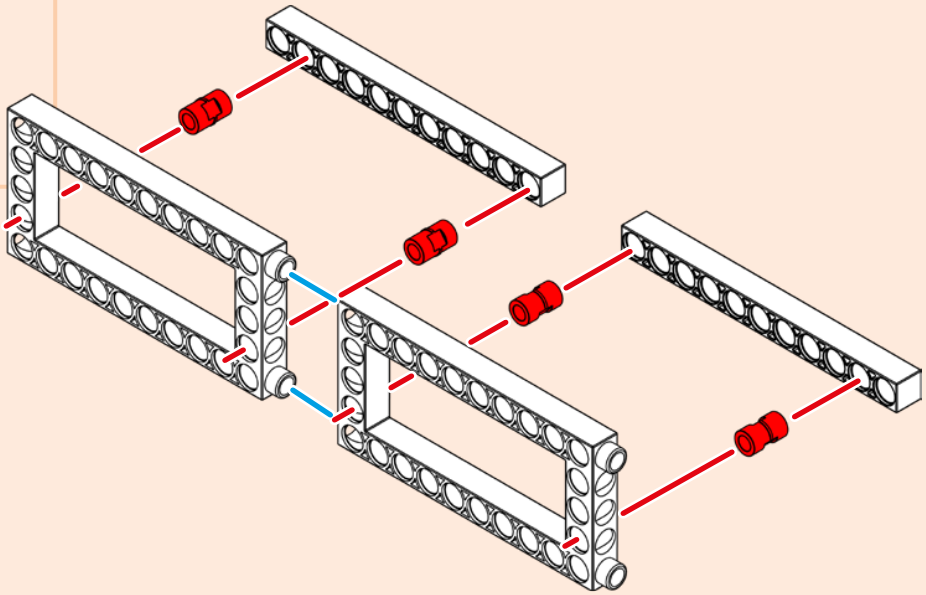

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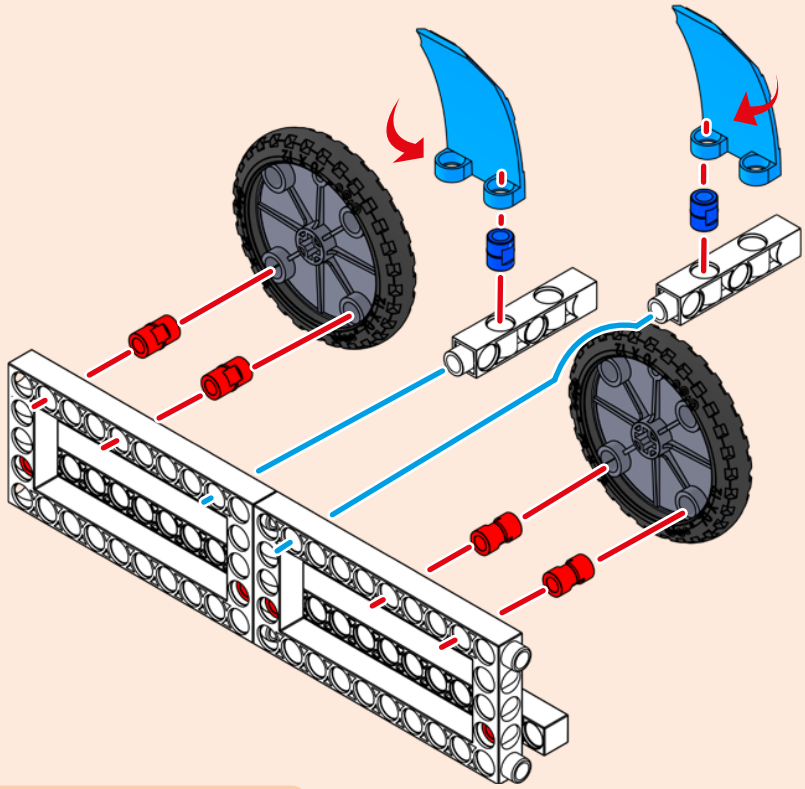

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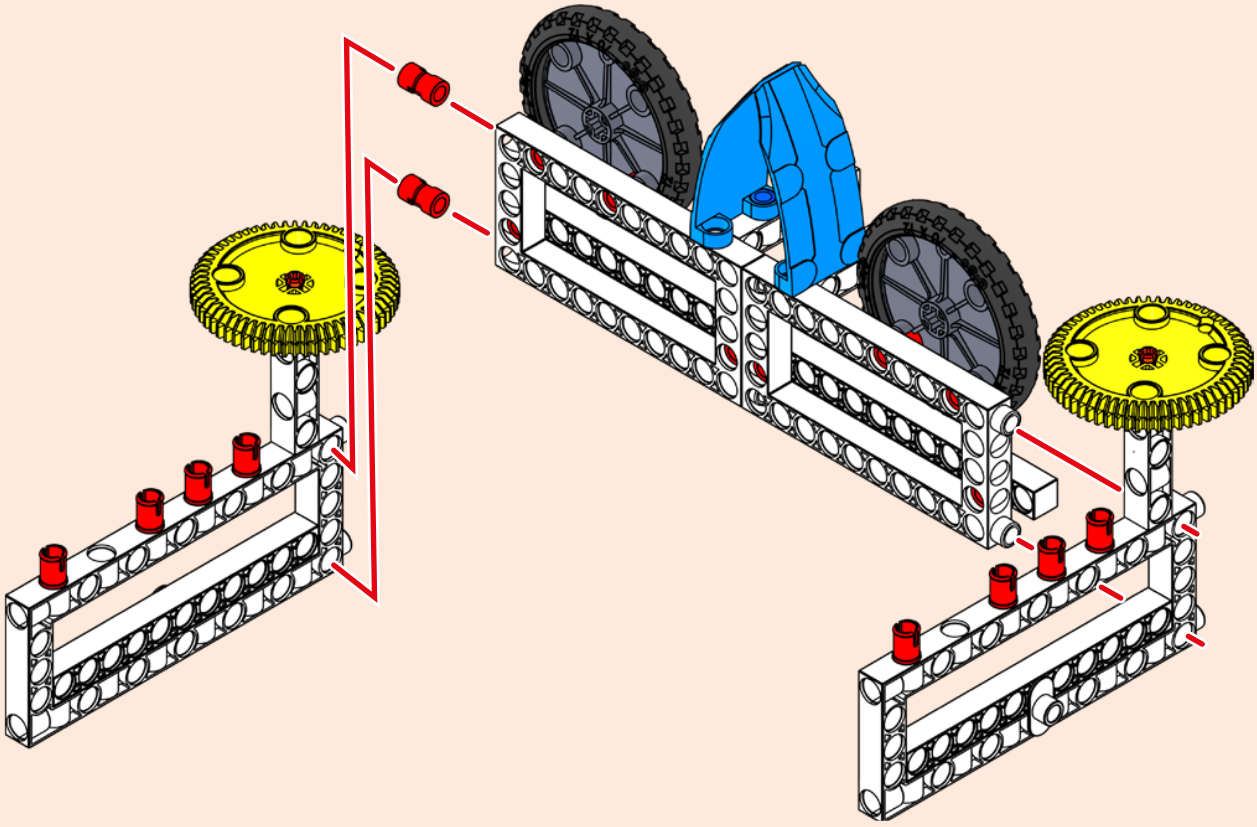

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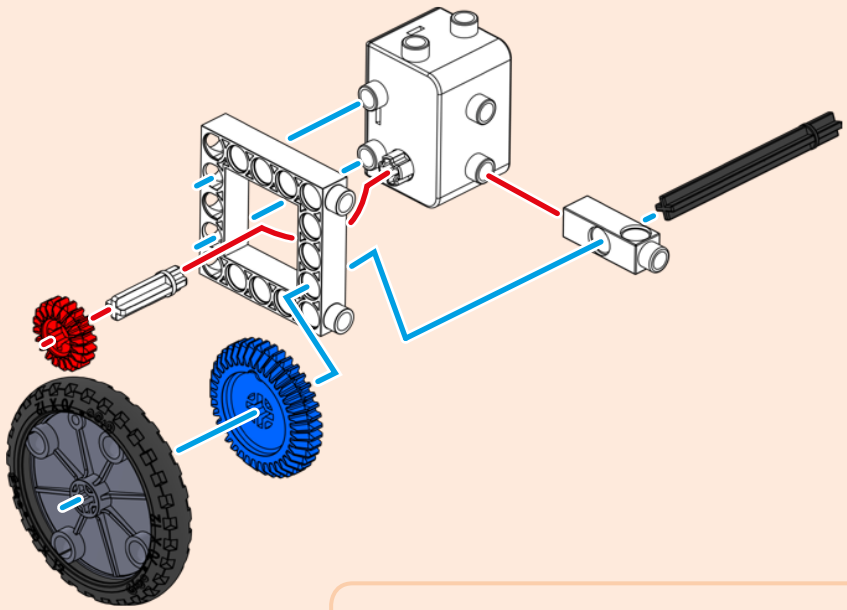

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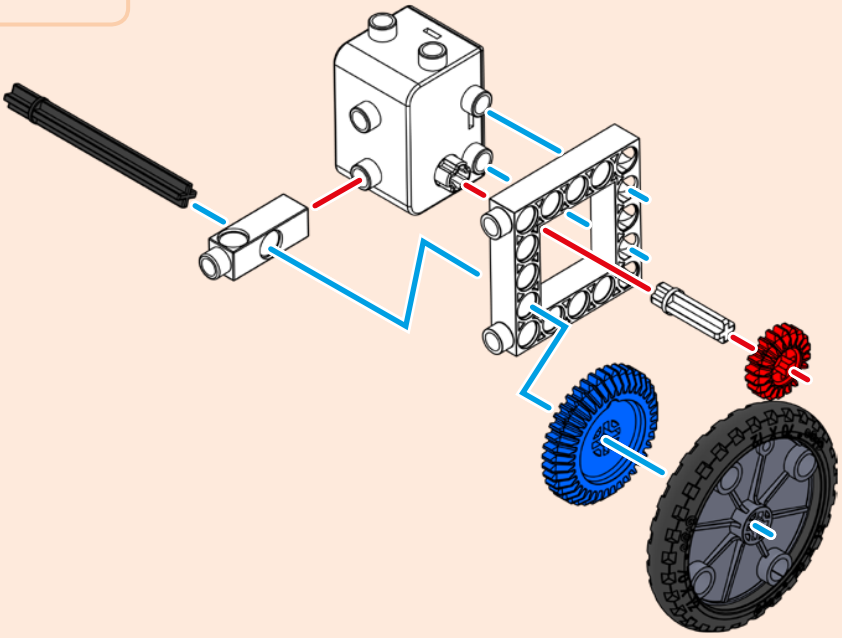

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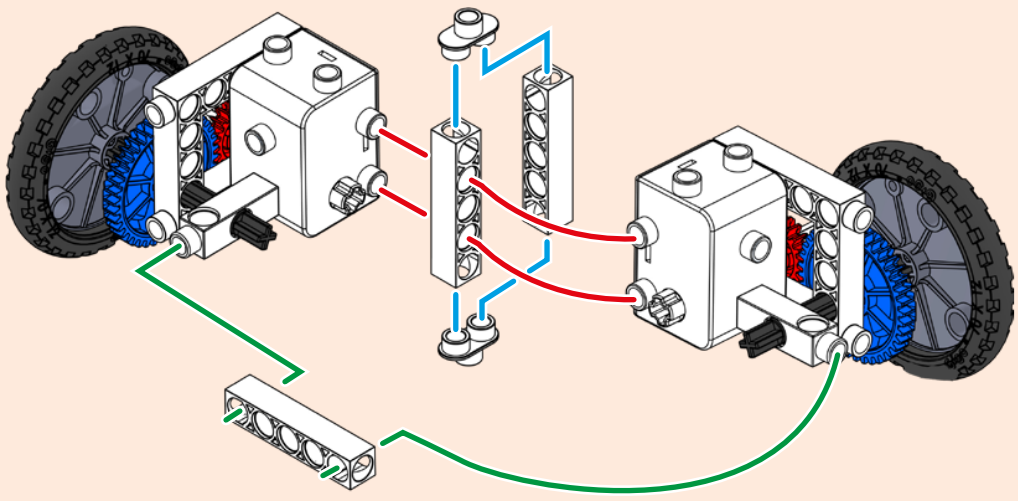

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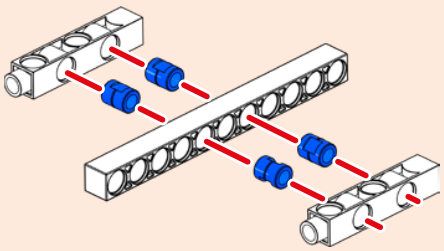

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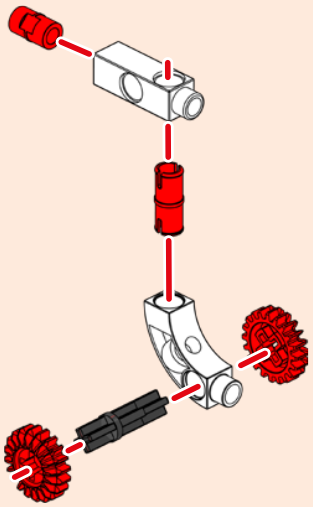

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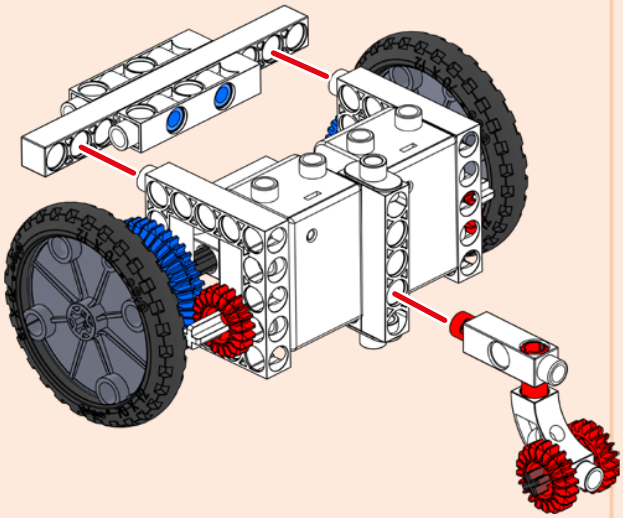

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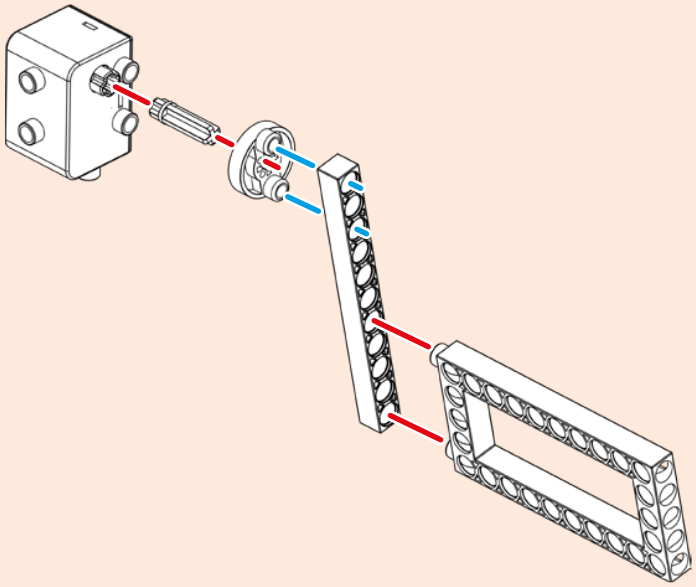

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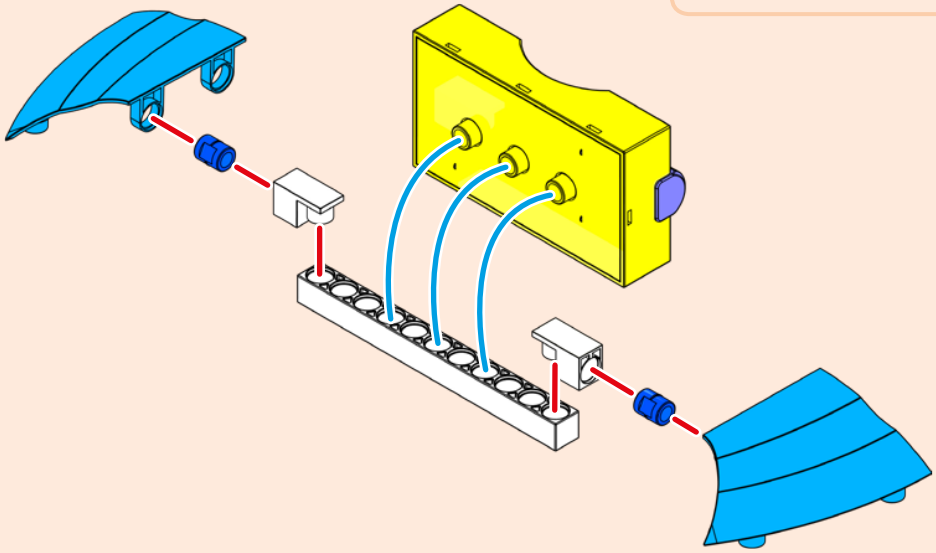

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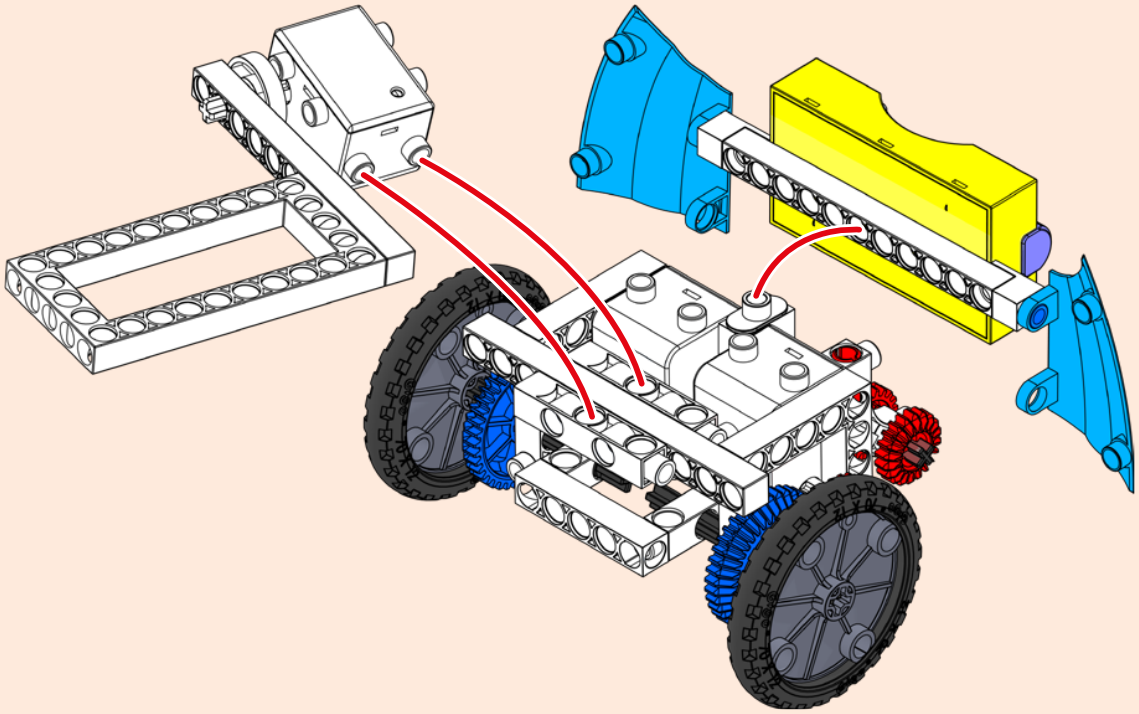

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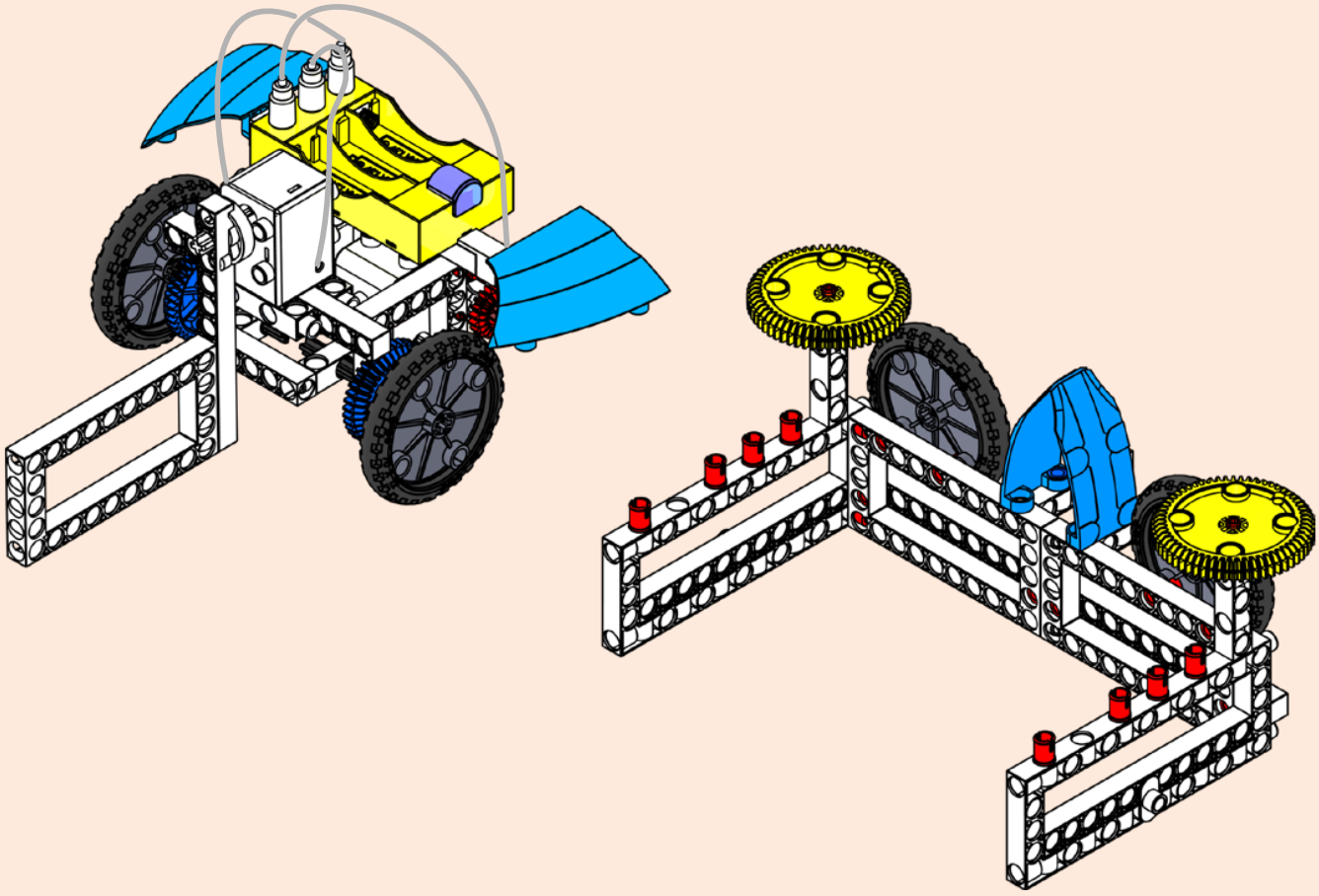
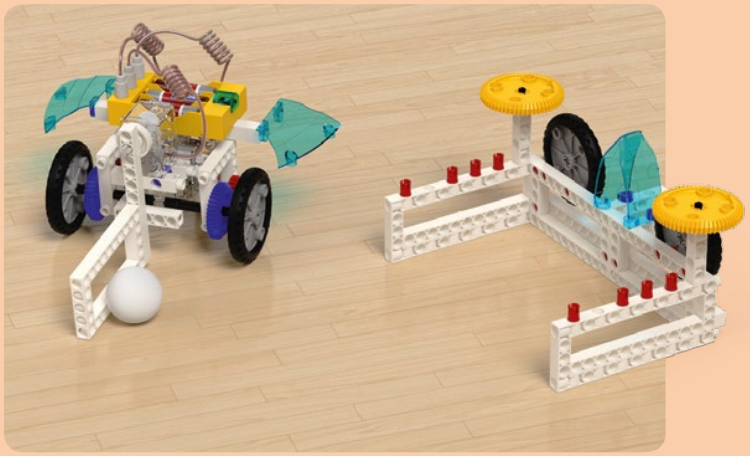


EXPERIMENT 16

Penalty shoot-out in the soccer game



YOU WILL NEED

- **The assembled soccer game**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Ping-pong ball (table tennis ball)*

HERE'S HOW

1. Familiarize yourself with the soccer game controls.
2. Set up the goal in the frame.
3. Place the table tennis ball about 50 centimeters away from the goal
4. Approach the ball with the robot to try to kick the ball into the goal. The ball will have to be positioned directly in front of the robot's rotating "foot."
5. Experiment with other distances between the ball and the goal.

WHAT'S HAPPENING?

When your robot strikes the ball, **momentum** is transferred from the movement of the foot's rotation to the direction in which the ball rolls or flies. Momentum is a physical quantity also known as kinetic momentum or quantity of motion. Any moving object can either fully or partly transfer its momentum to another object or have the other object's momentum transferred to itself, such as when one of them strikes the other. Another example of momentum is the impact of the force of a boxer's fist transferred to a boxing bag.

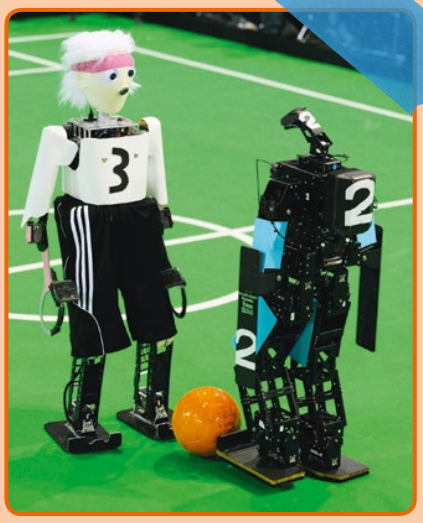
DID YOU KNOW?

Robots are sometimes used to play soccer in actual leagues or competitions. This was the idea behind the RoboCup (see "Check it out" on page 107).

And just for students up to 20 years of age, there is also the RoboCup Junior league, which helps inspire kids and teens to take an interest in the fields of robotics and information technology.

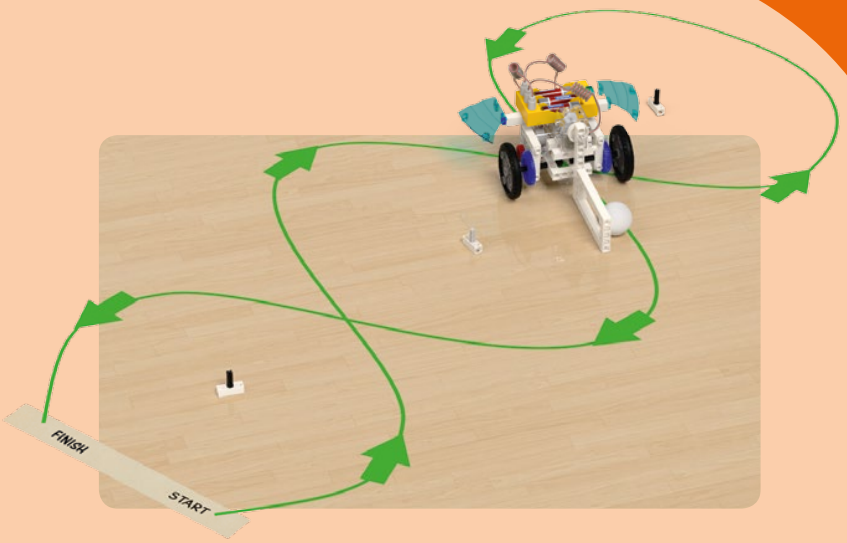
In addition to soccer, RoboCup Junior includes Dance and Rescue sub-leagues, each divided into under-15 and older age groups.

You can read more about the Dance and Rescue leagues in Experiment 17. Experiment 18 has more information on the Soccer league.



EXPERIMENT 17

Dribbling



YOU WILL NEED

- **The assembled soccer game**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Goal posts (made of short rods and axles)*
- *Masking tape*
- *Ping-pong ball (table tennis ball)*
- *Stop watch, note pad, and pen*

HERE'S HOW

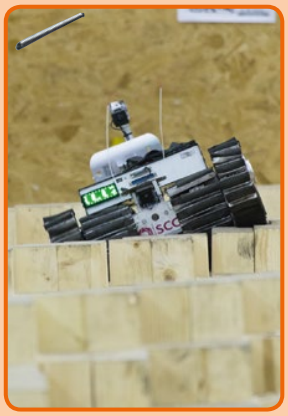
1. Assemble a slalom course like you did in Experiment 12. You can use axles inserted into short rods, and space these about 50 centimeters apart in a straight line.
2. Mark the start and finish lines with masking tape. The starting point is just to the right of the first gate, and the finish point is just to the left of it.
3. Have you familiarized yourself with the controls? If so, drive your robot up to the starting point
4. Place the ball directly in front of the robot, ideally between the foot and one of the wheels.
5. Ask someone to operate the stop watch. On your mark, get set, go!
6. Now try pushing the ball through the gates while the stop watch is running. At the last gate, turn the model back toward the starting point.
7. Finally, cross the finish line with the ball to the left of the first gate. It isn't as easy as you might think. But you'll soon get the hang of it with a little practice!

WHAT'S HAPPENING?

The robot in this experiment (as well as Experiments 16 and 18) has special steering controls. Unlike the dump truck in Experiment 14, this robot is not controlled by an Ackerman steering mechanism, which is common in cars and trucks. The robots in the three soccer experiments (16 through 18) are steered like a bulldozer — with the motors moving independently on the two sides.

DID YOU KNOW?

In the RoboCup's Dance league, students have robots perform and dance to music. A jury evaluates the performances by various criteria including creativity. If you can dribble well, you will probably have a good touch for remote-controlled dance movements too.

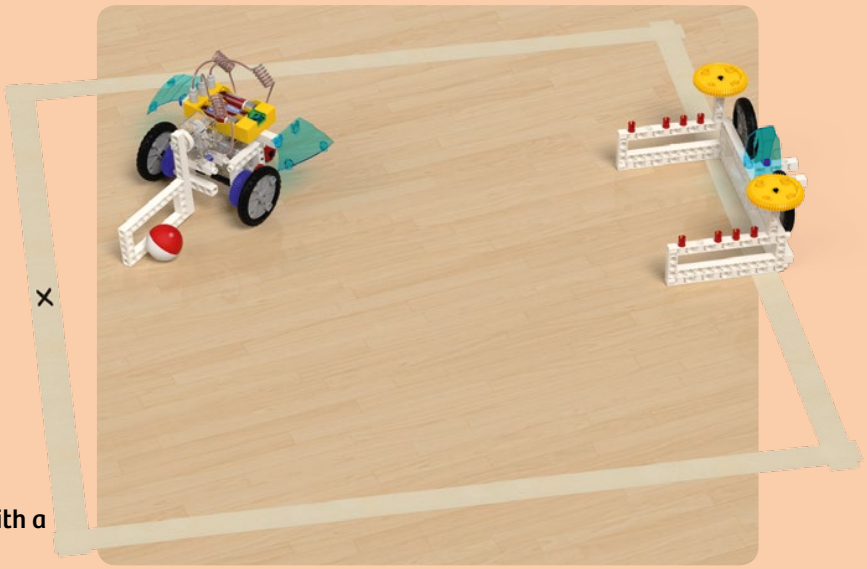


In the Rescue league, the robots have to follow a specified path and recognize, recover, and rescue an "injured person" at the end of it. The task is made harder by ramps, gaps, and obstacles placed on and next to the path (see "Check it out," page 43).

WANT MORE?

Who can dribble the longest around the gates without making a mistake?

The great soccer match



YOU WILL NEED

- **The assembled soccer game**
- **IR remote control**
- *5 AA batteries or 5 AA rechargeable batteries*
- *Ping-pong ball (table tennis ball) and felt-tip pen*
- *Masking tape*
- *Measuring tape and coin*

HERE'S HOW

1. Take a new table tennis ball and color one half with a felt-tip pen.
2. Decide where on the floor you want your soccer field to be. It should be an area about one meter by one meter. Mark the boundaries with masking tape. Place the goal on one of the boundary lines.
3. Decide on the location of the kickoff point. It could be at the edge opposite the goal, for example.
4. Now, you and your opponent should flip a coin to decide who starts. The winner of the coin toss should also pick a color — white or the color you drew on one half of the table tennis ball.
5. Time to start. Kickoff! Each player gets to use the robot to kick the ball when that player's color is on the top. Whoever is the first to get three goals is the winner.

DID YOU KNOW?

In the RoboCup Junior league, the soccer league is arguably the most exciting of the three challenges. One of the soccer league's classes used to have contests in which two autonomous robots competed against each other. In the other class, each team is composed of two robots with a maximum height of 22 centimeters. The teams play with a ball about the size of a ping-pong ball. The ball emits infrared light, which lets the robots track it.

WHAT'S HAPPENING?

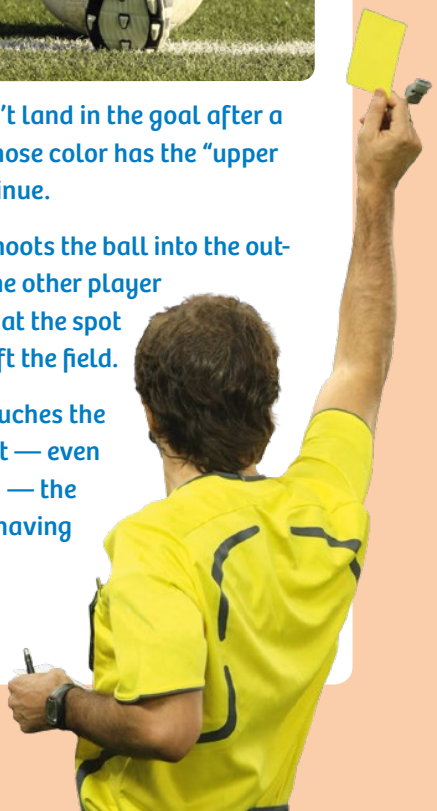
This experiment is all about having fun playing. So let's cut right to the chase and sum up the most important rules:

››› If the ball lands in the goal, the shooter gets a point and the other player gets to kick off.

››› If the ball doesn't land in the goal after a shot, the player whose color has the "upper hand" gets to continue.

››› If one player shoots the ball into the out-of-bounds area, the other player gets a "throw-in" at the spot where the ball left the field.

››› If a player touches the ball with a robot — even just by mistake! — the ball counts as having been played.



CHECK IT OUT

Off to the World Cup for robots!

Even if shooting at a goal just looks like fun and games, robot soccer involves **artificial intelligence**, or **AI**, which means the creation of human-like intelligence. A computer has to accomplish tasks and solve problems all by itself. As a standard problem for artificial intelligence, soccer is actually quite challenging. In addition to intelligent programming to handle the planning and learning of moves, the robots also have to be able to handle:

- the recognition of teammates, opponents, and objects such as the ball, the corner flag, etc.
- motor functions such as locomotion and shooting
- quick responses to changes in playing conditions
- cooperation with teammates
- determination of the robot's own position and the positions of the other players
- knowledge of the paths of the ball and the players.

The researchers and developers are very ambitious: By 2050, they want their robots to win the actual soccer World Cup! That is what inspired the creation of the RoboCup world championships, which are played in different locations every year and in various different leagues.

SOMETHING FOR EVERYONE:

A SELECTION OF ROBOCUP LEAGUES

- **Small Size:** Two teams compete against each other with teams of five robots each. The robots are controlled remotely by a computer.

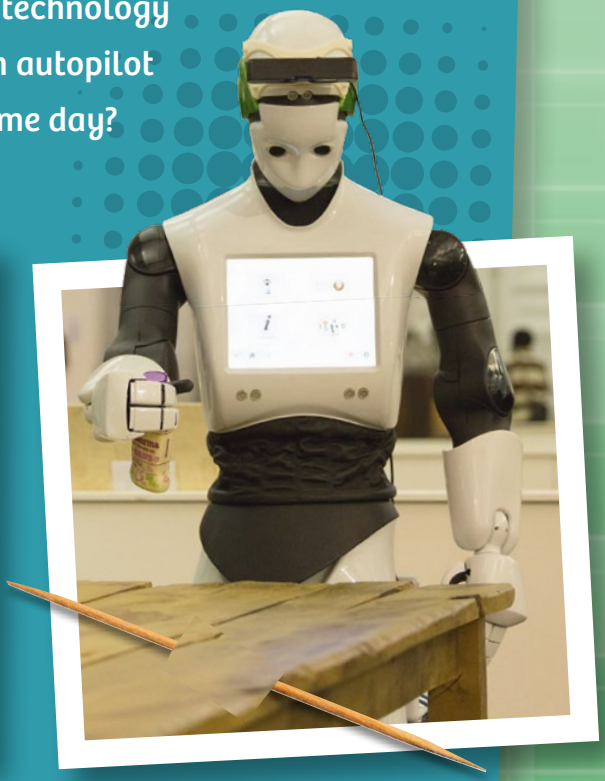
- **Middle Size:** The robots in this league are autonomous, featuring cameras and other sensors.

- **Standard Platform League:** This league originally used Aibos, robotic dogs made by Sony. Now the games are played with Naos by Aldebaran Robotics. These robots are 57.3 centimeters tall and weigh 5.2 kilograms.

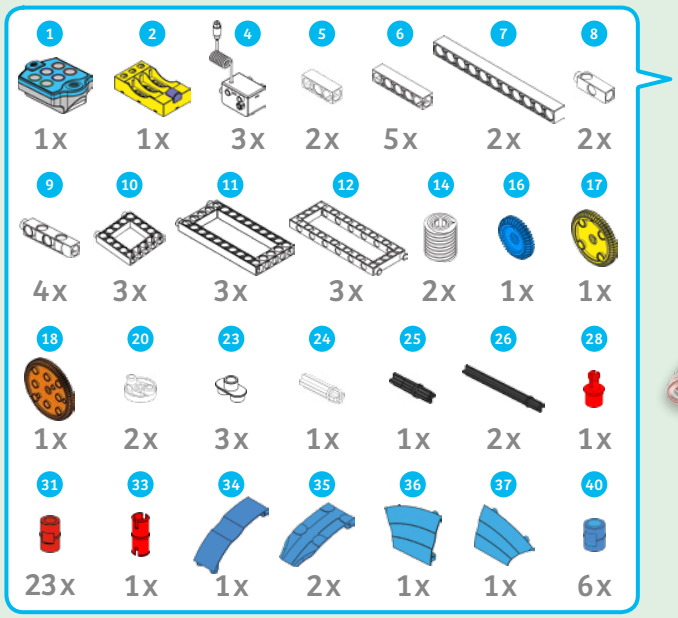
- **Humanoid:** In the Humanoid League — as the name implies — robots with human-like bodies compete against each other. The robots have to be fully autonomous, and are equipped with sensors accordingly. There are three size classes with competitions in skills such as penalty kicks and playing.

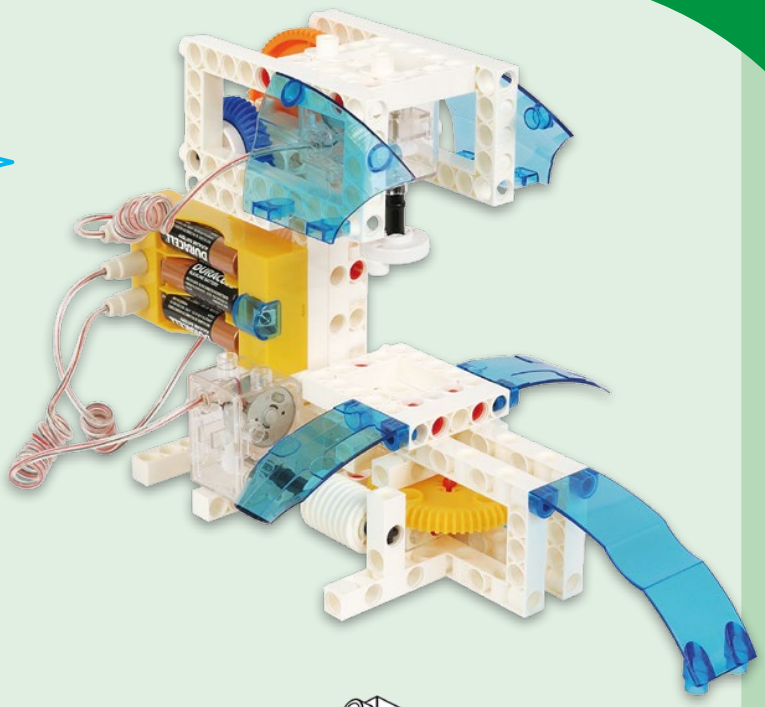
A Look into the Future

In the future, will we go to a robotic dentist instead of a human dentist? Even though that might sound like something from a science fiction movie, a robot — with its high-precision sensors and controls — might be able to drill much more accurately than a human. Who knows where robotic technology may take us? Even today, every large airplane has an autopilot on board. Could planes fly entirely without pilots some day? Unimaginable! Or is it?



DRILLING ROBOT





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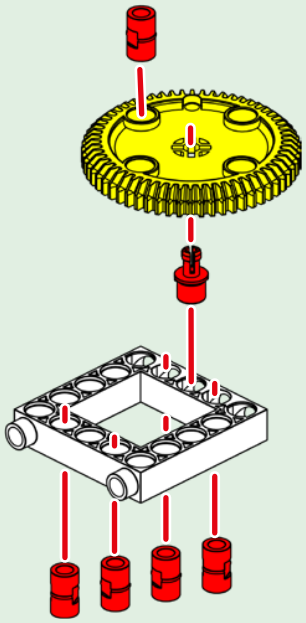

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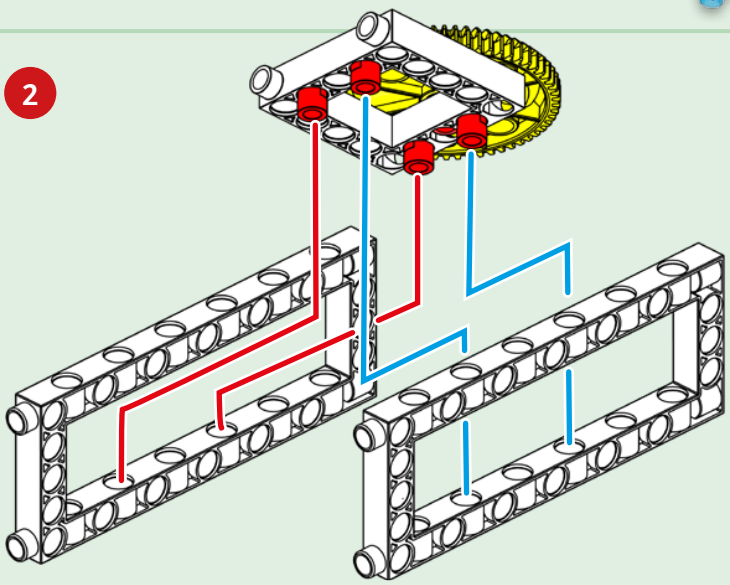

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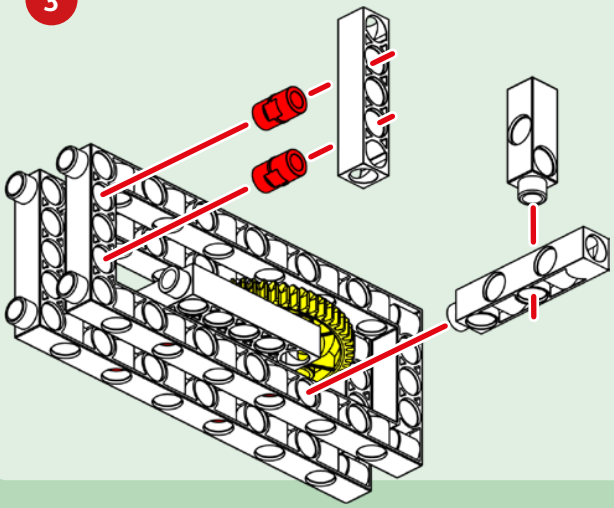

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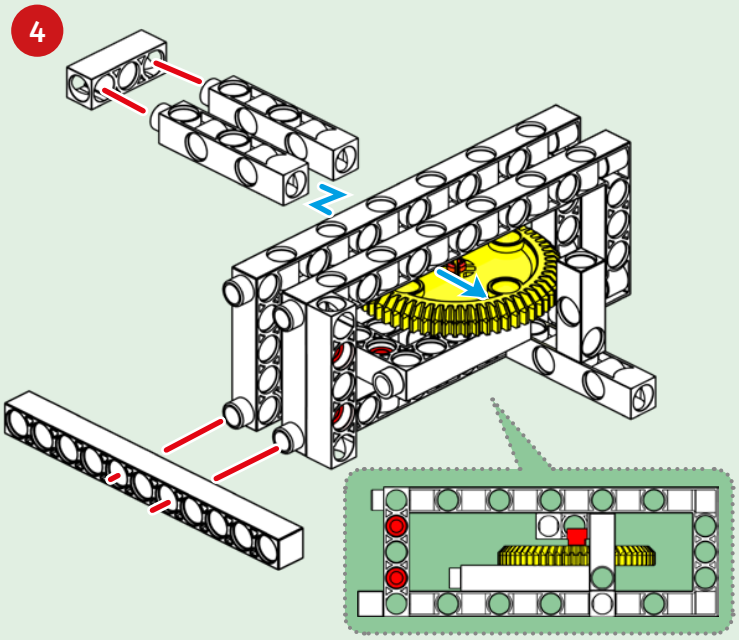

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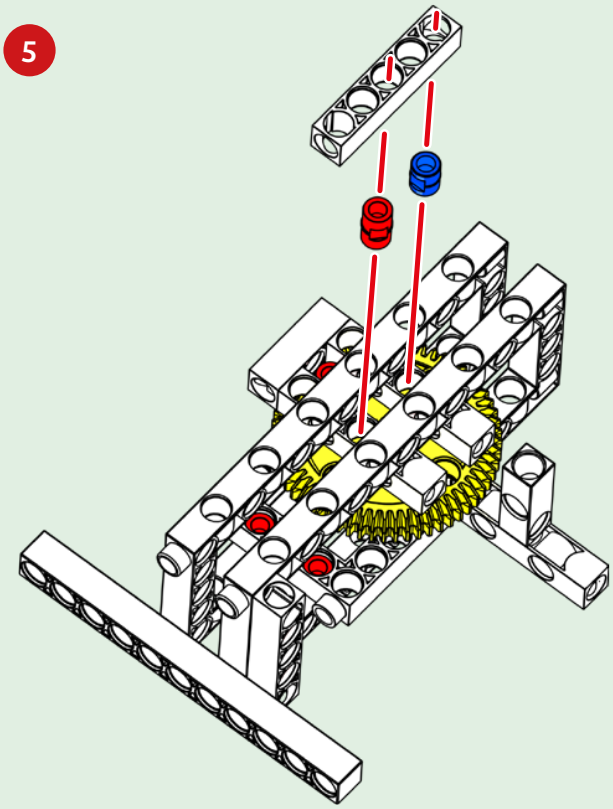

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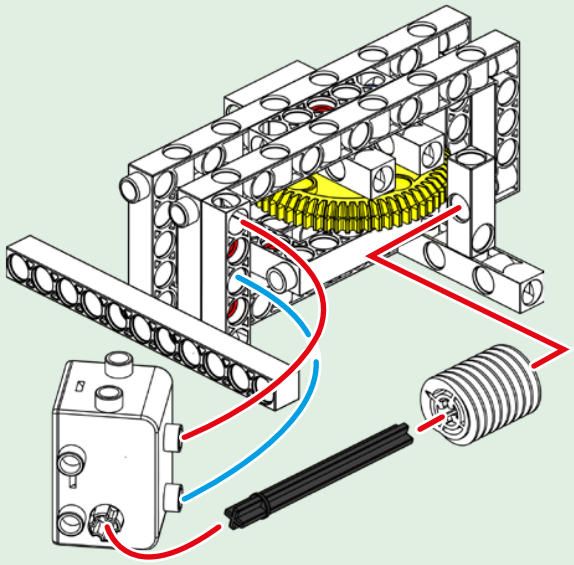

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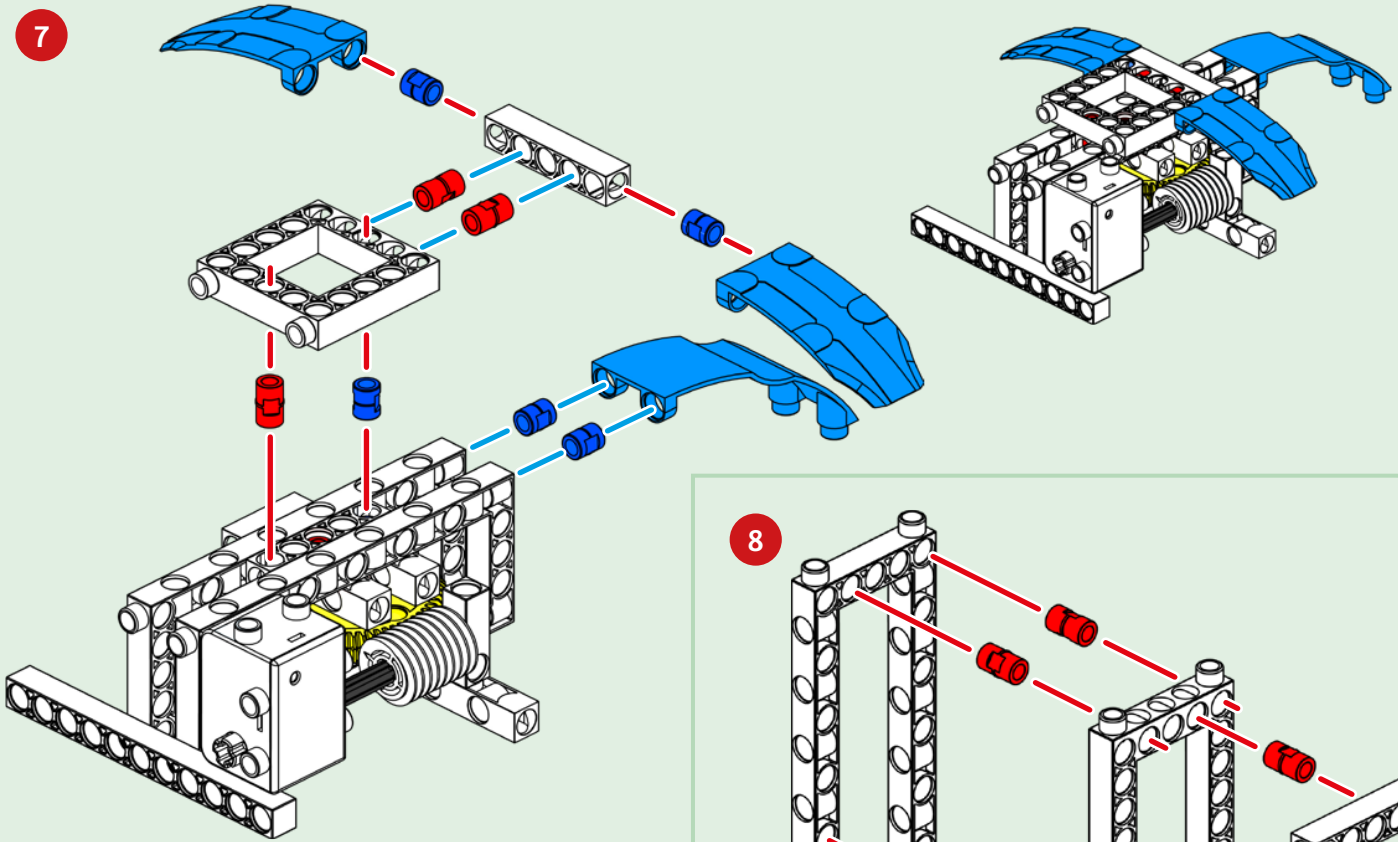

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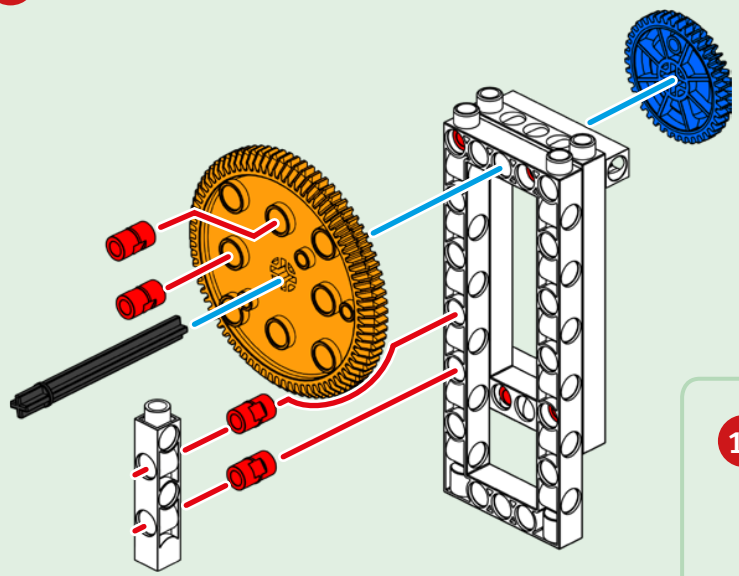

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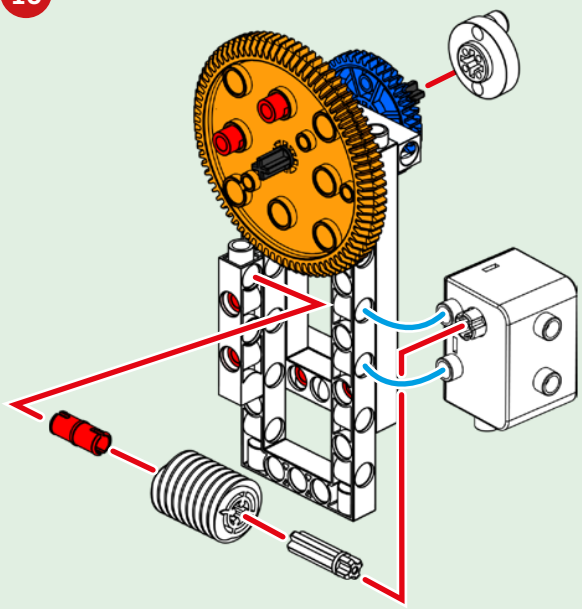

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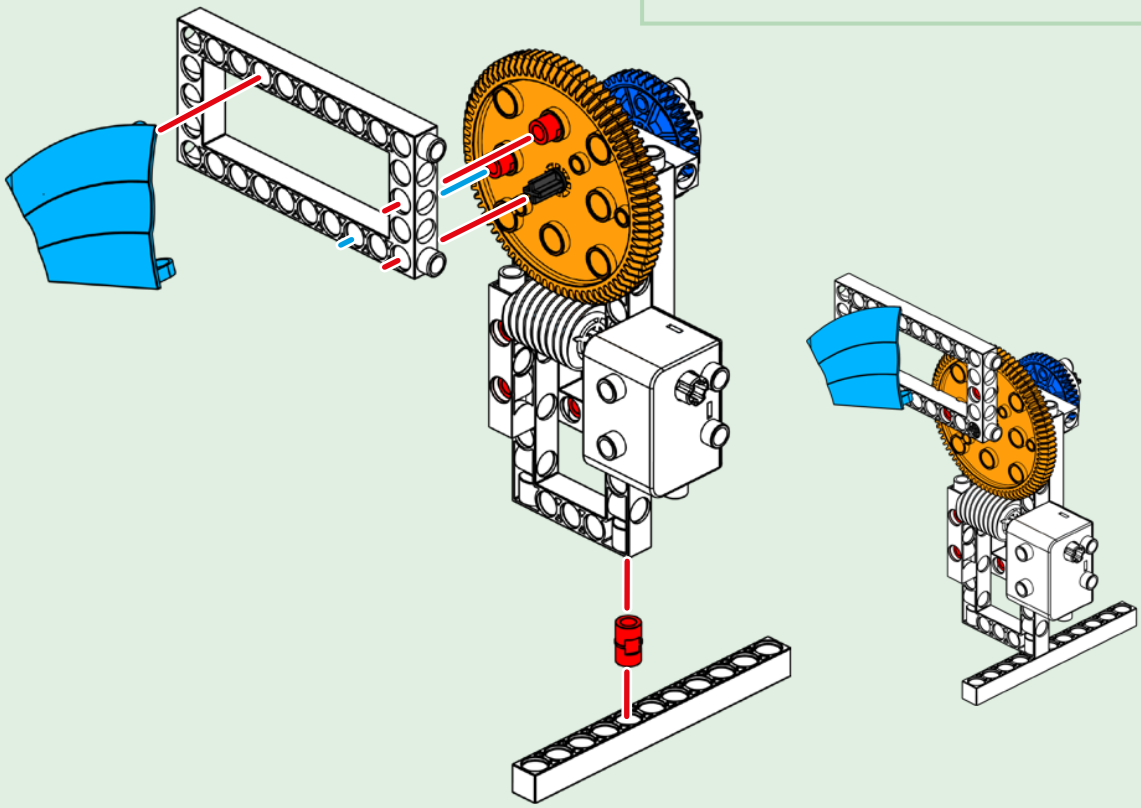

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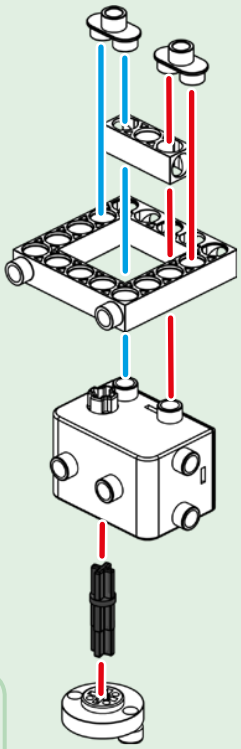

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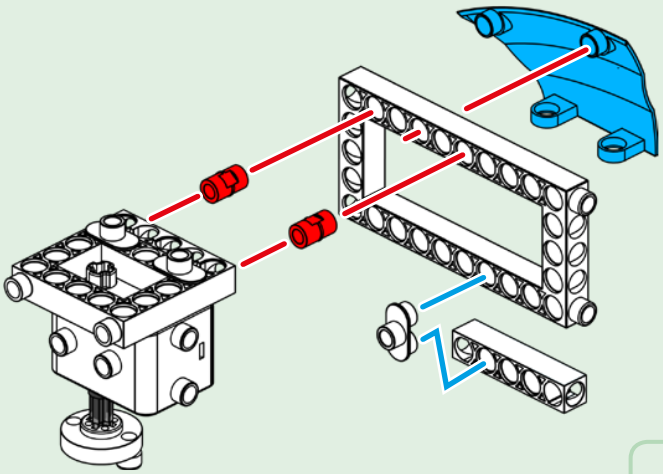

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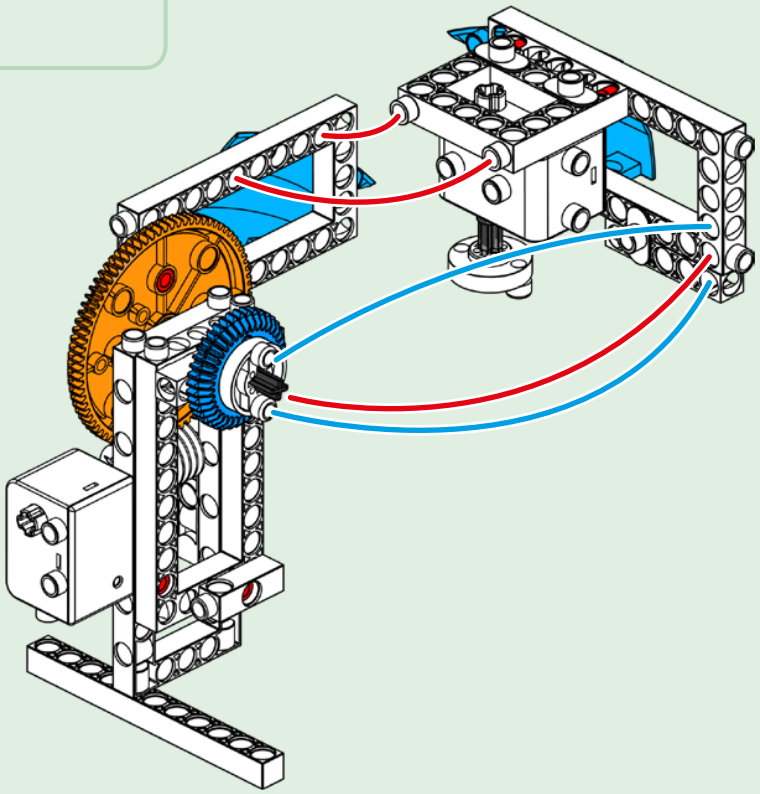

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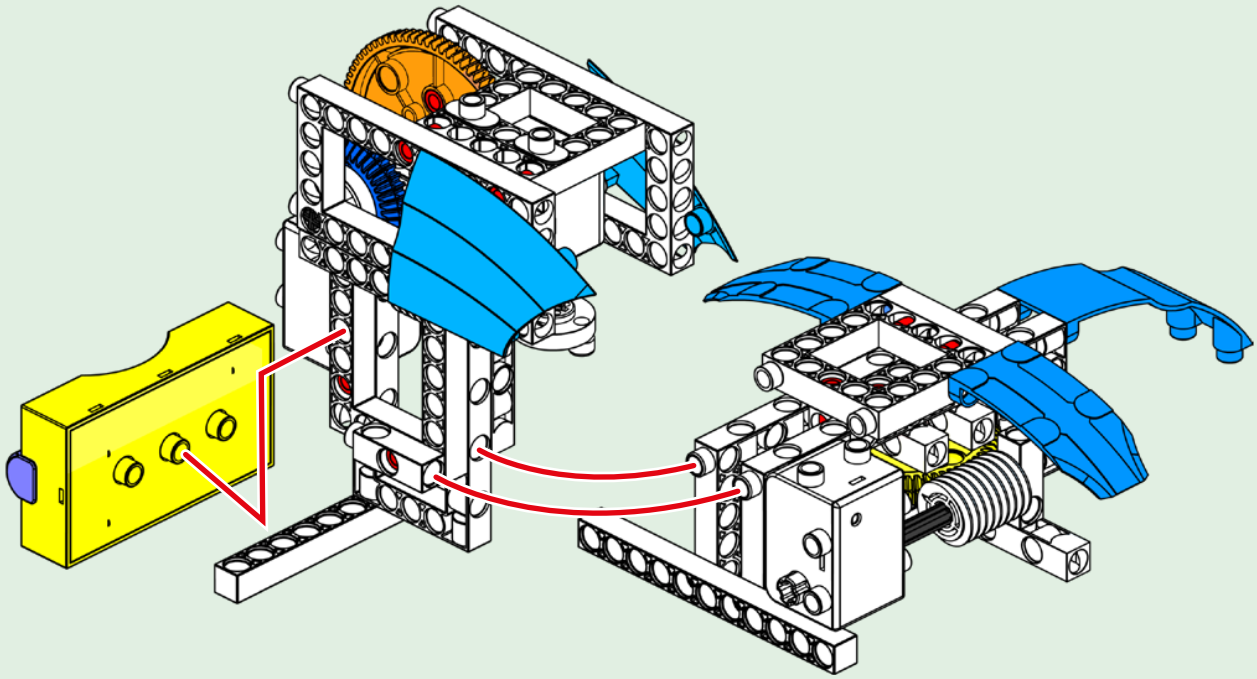

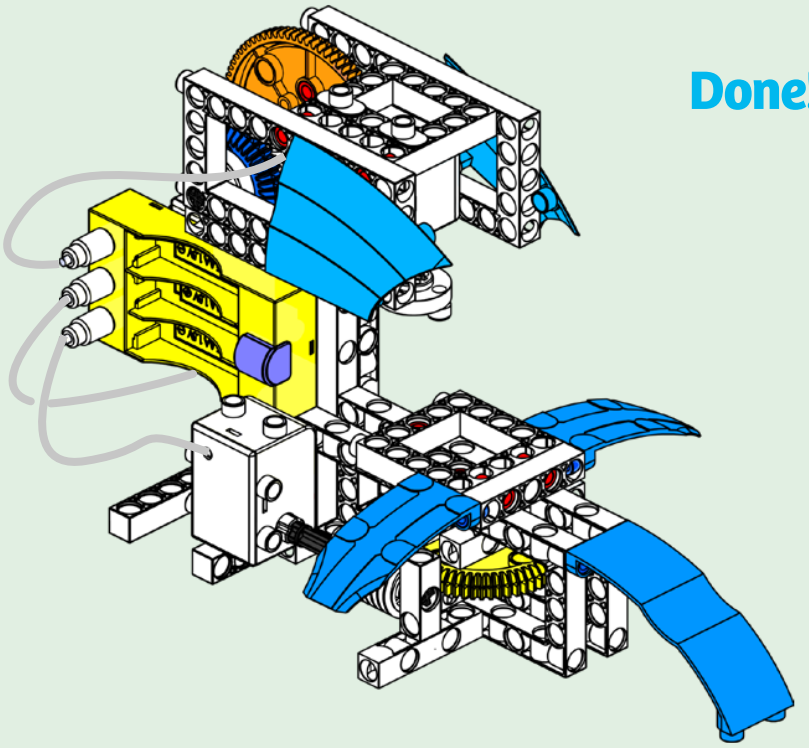

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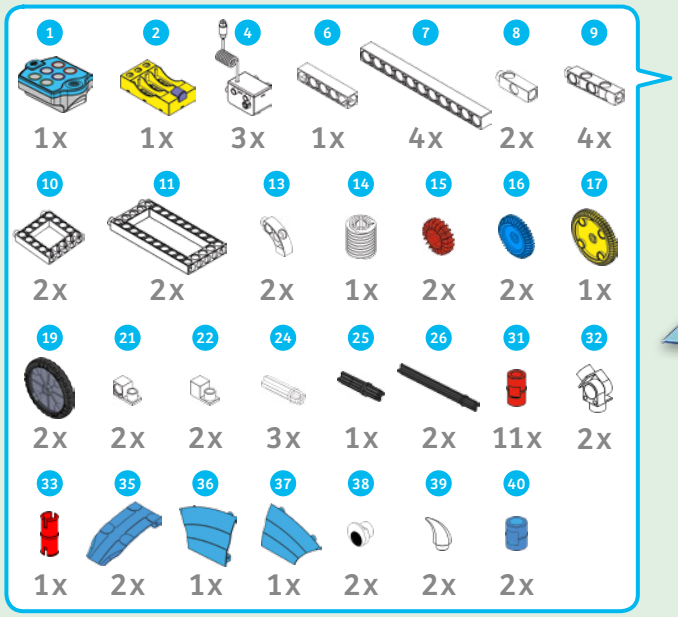

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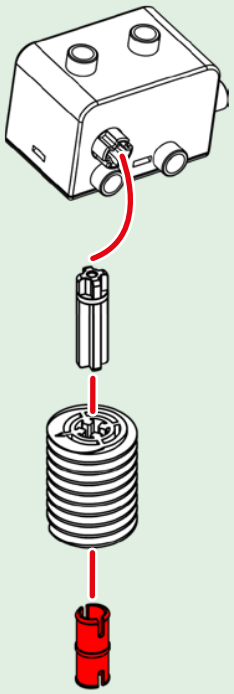

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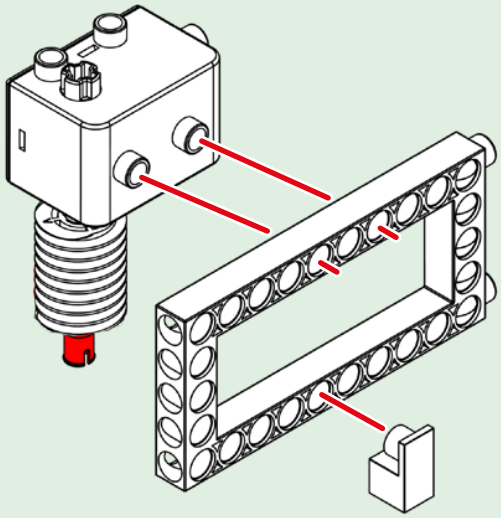

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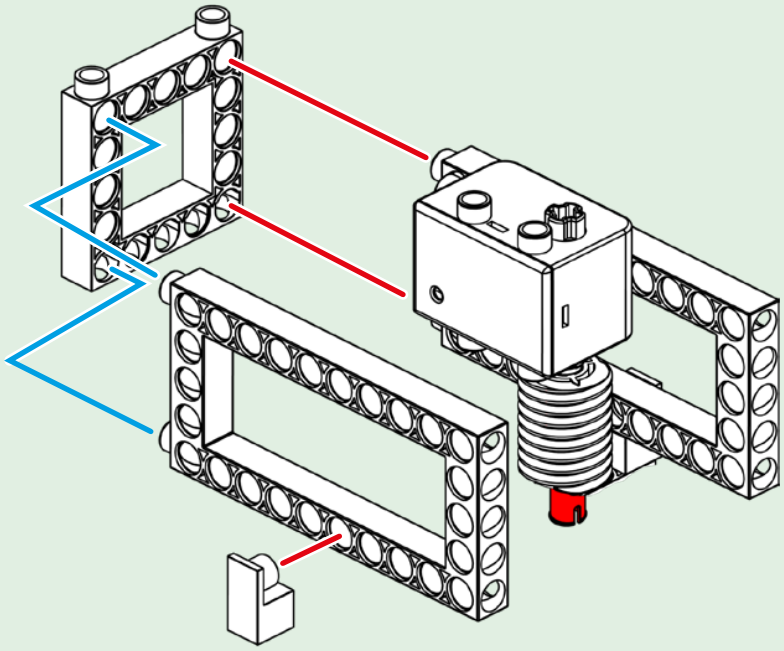

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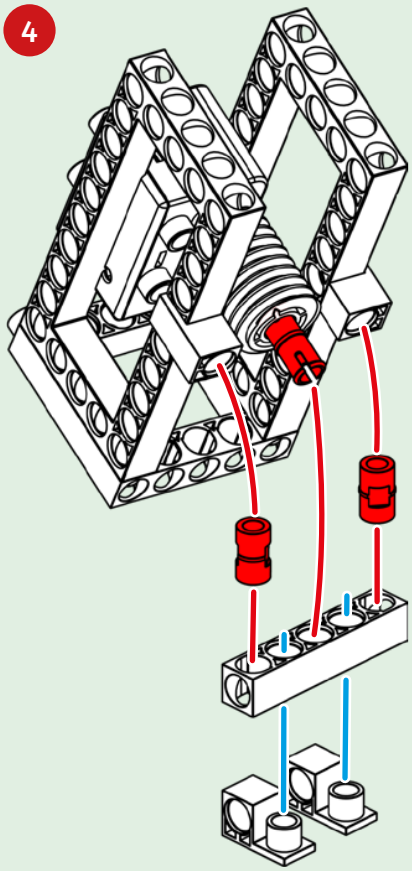

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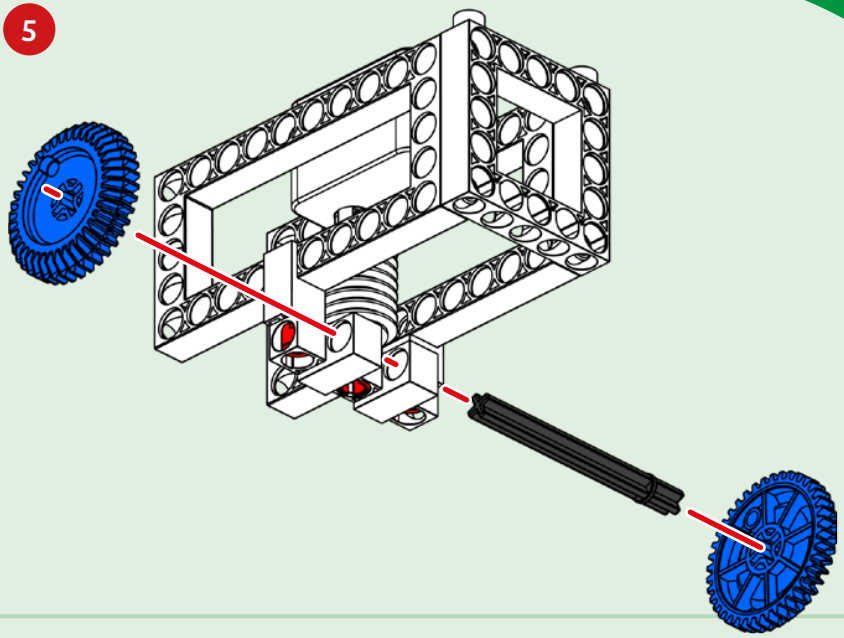

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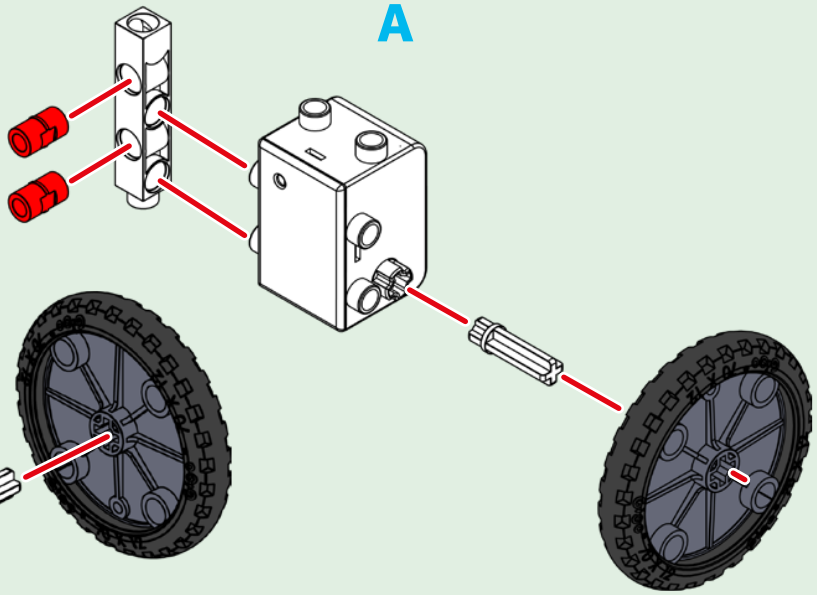

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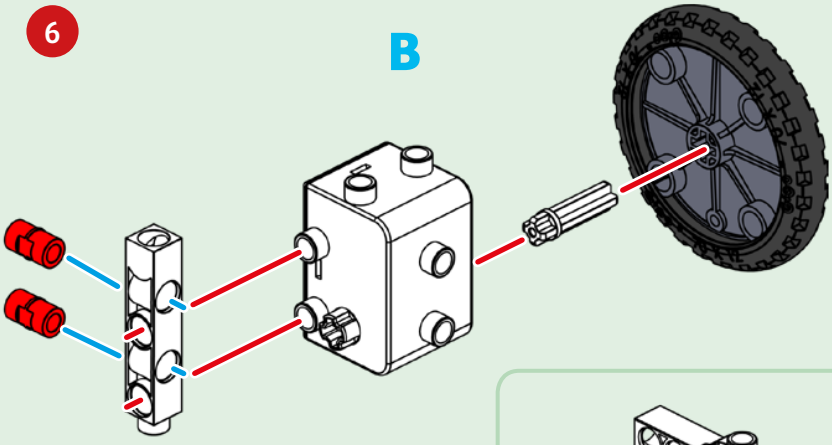

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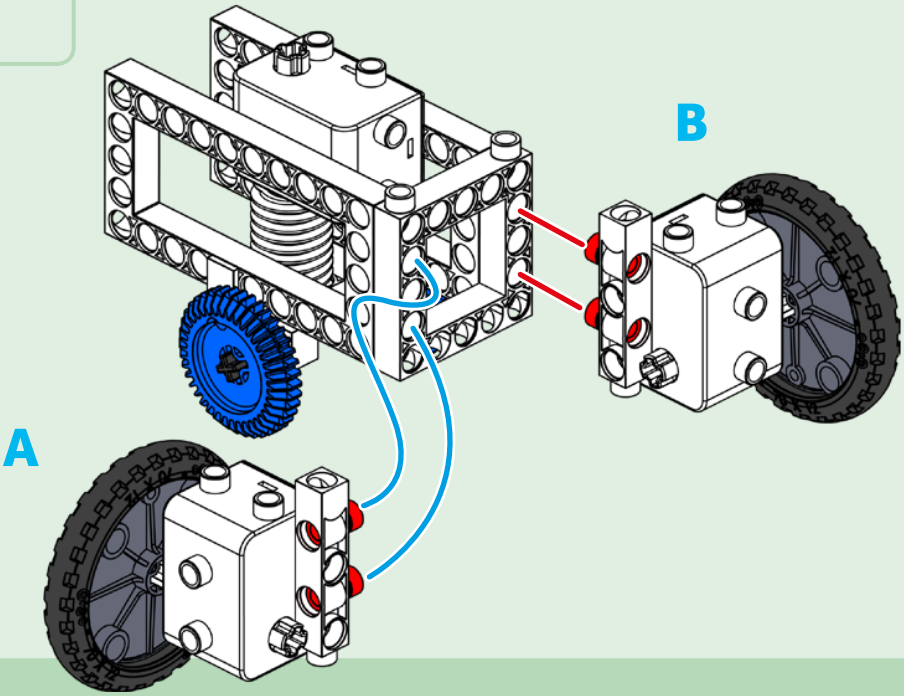

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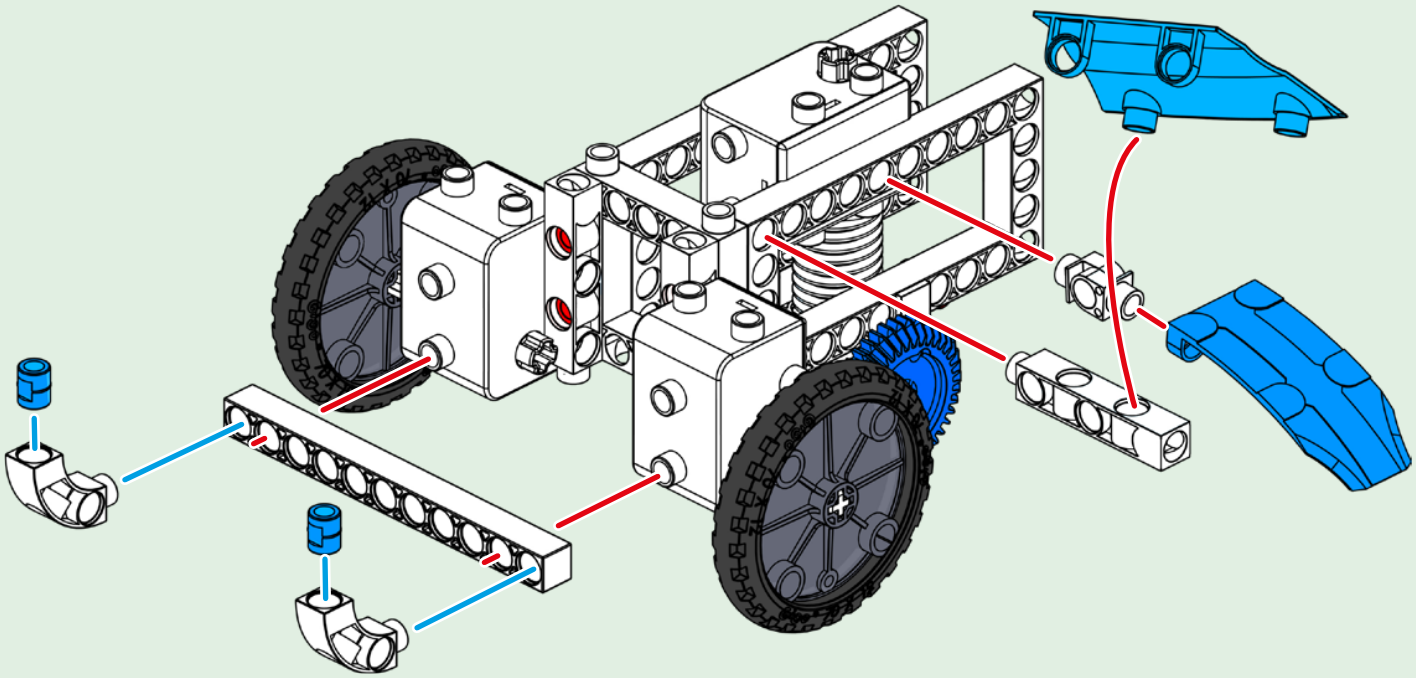

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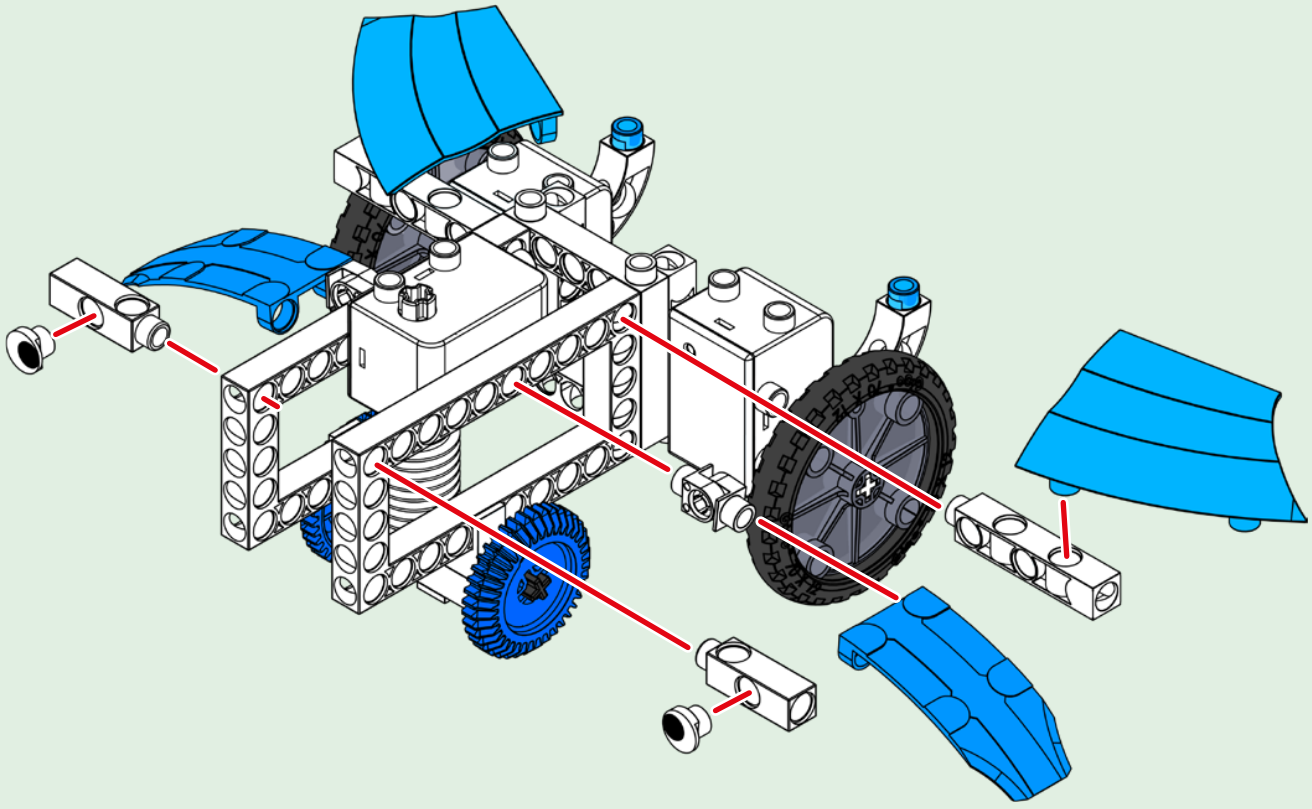

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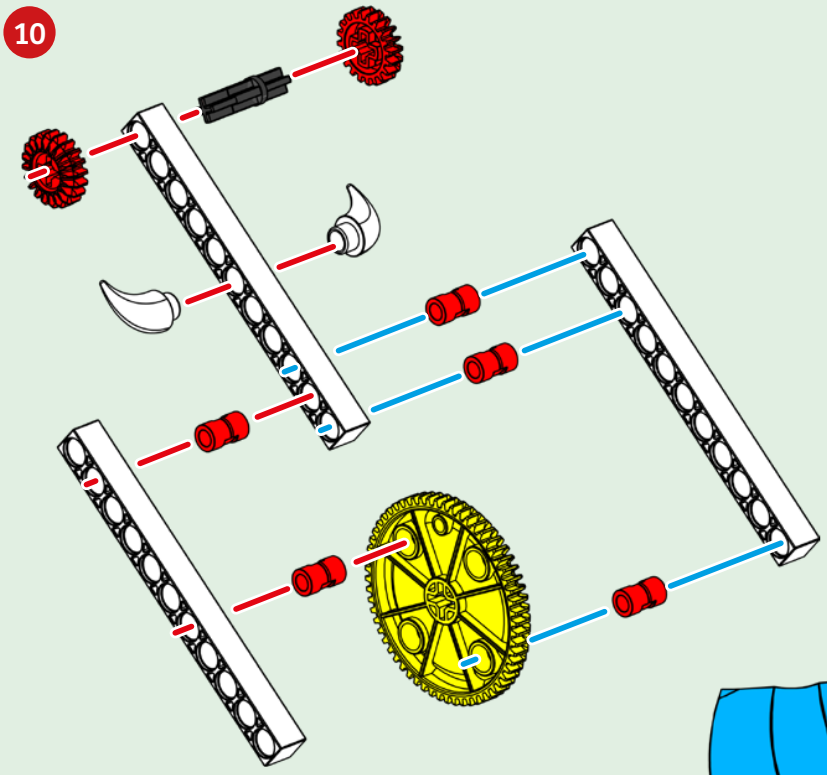

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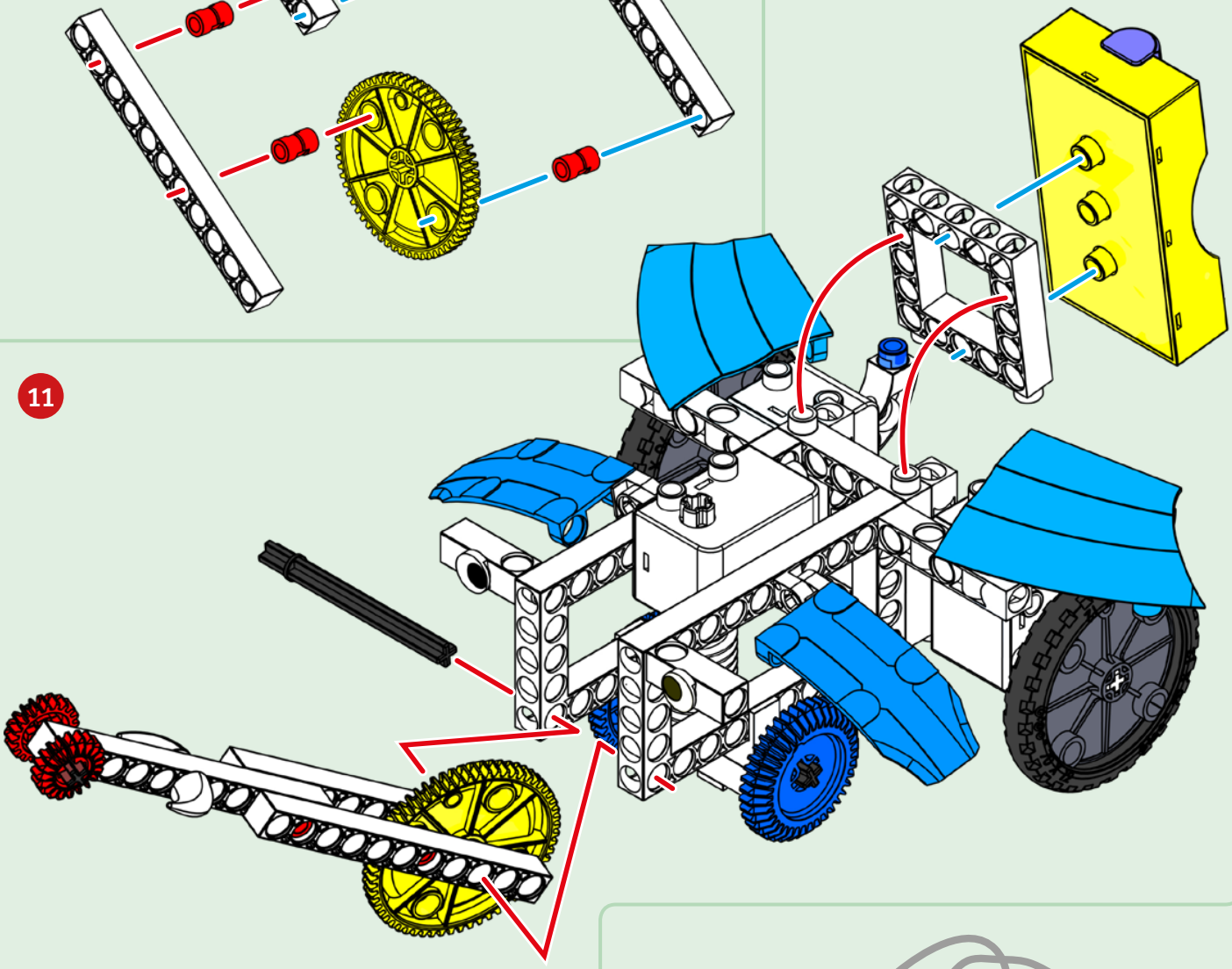

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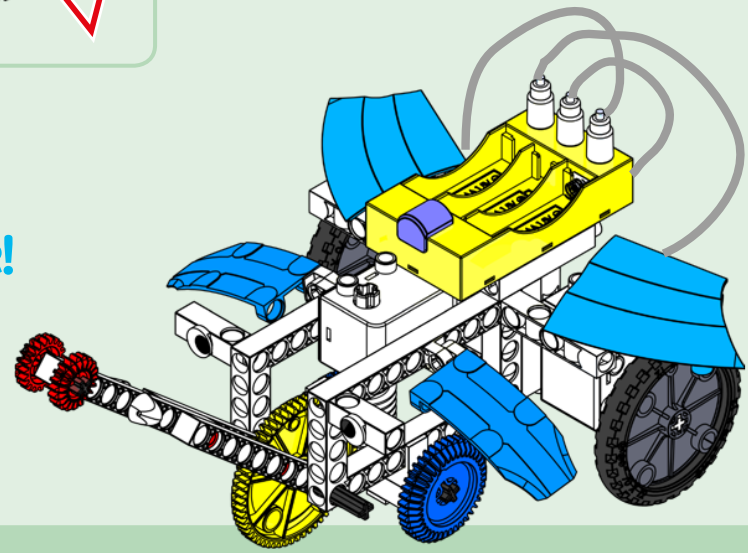
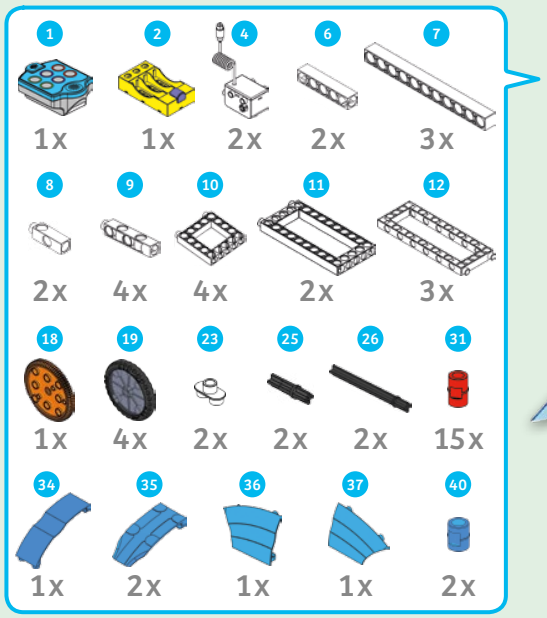
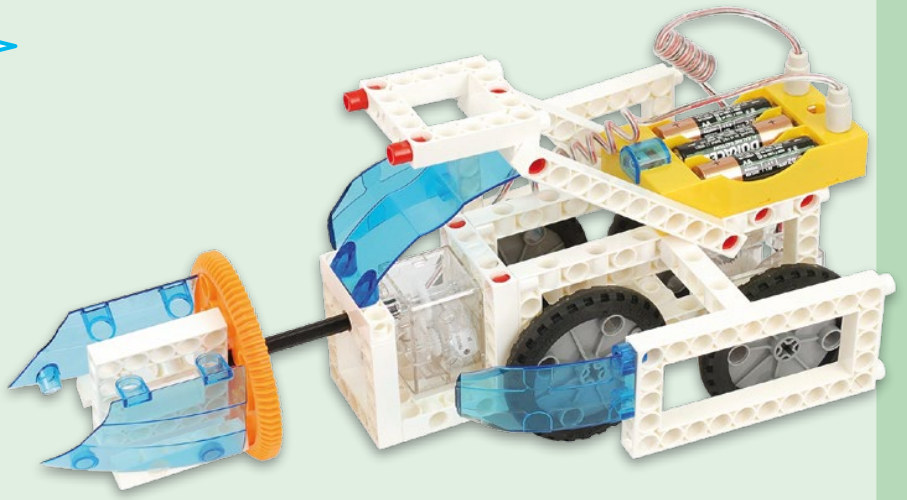


TUNNEL DRILLING MACHINE





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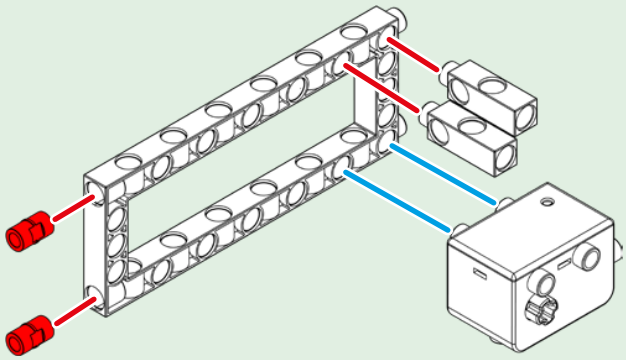

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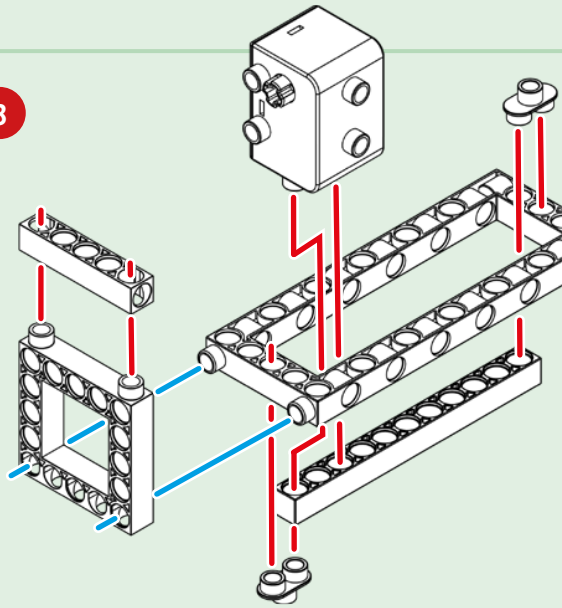

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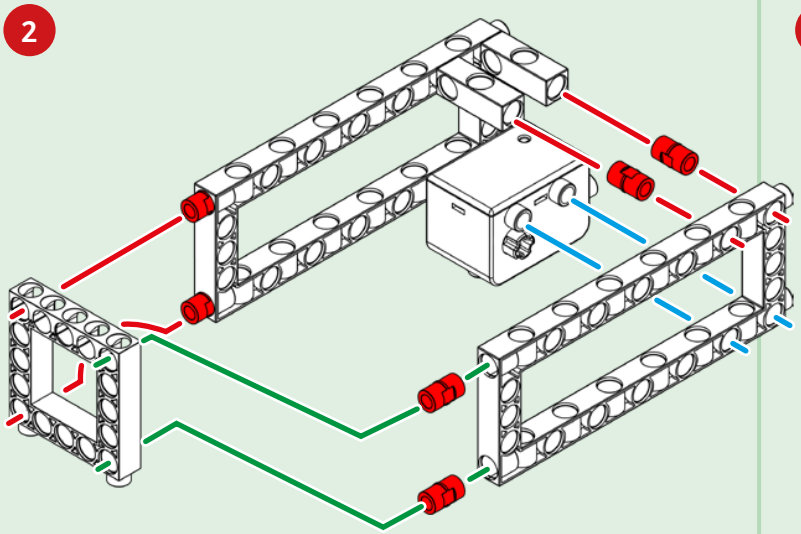

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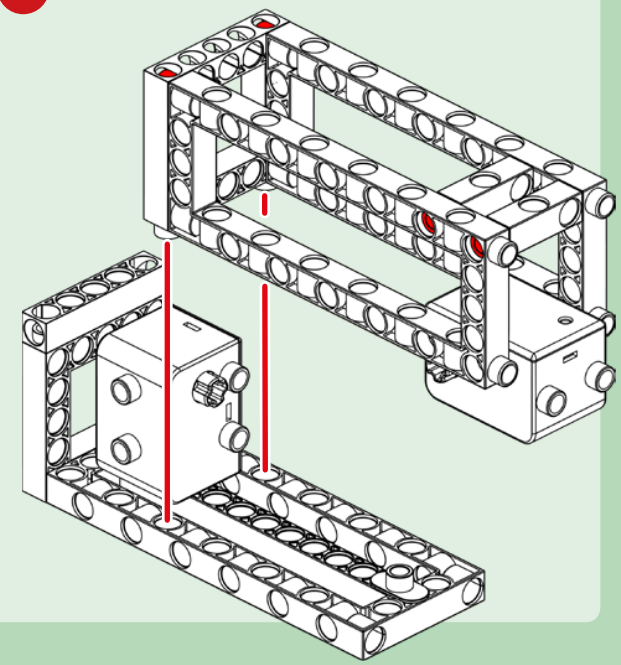

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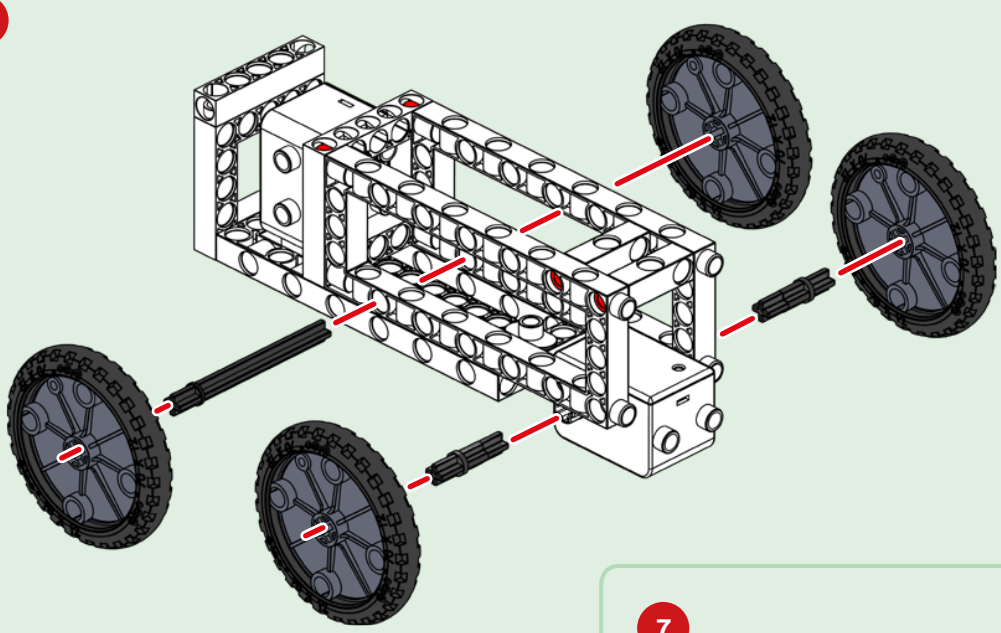

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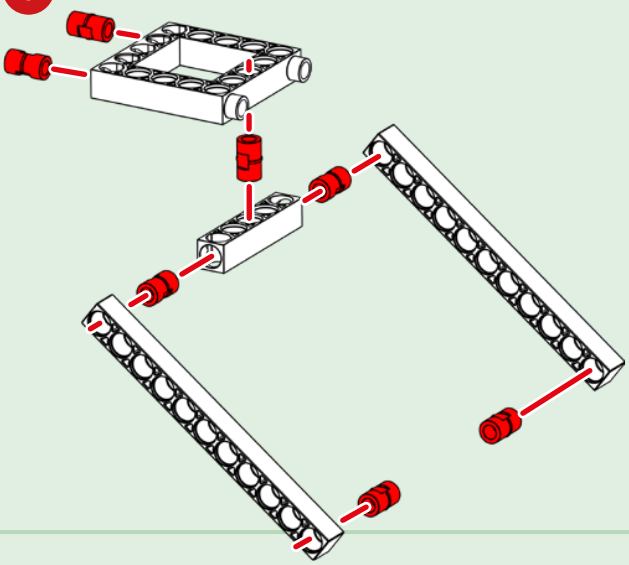

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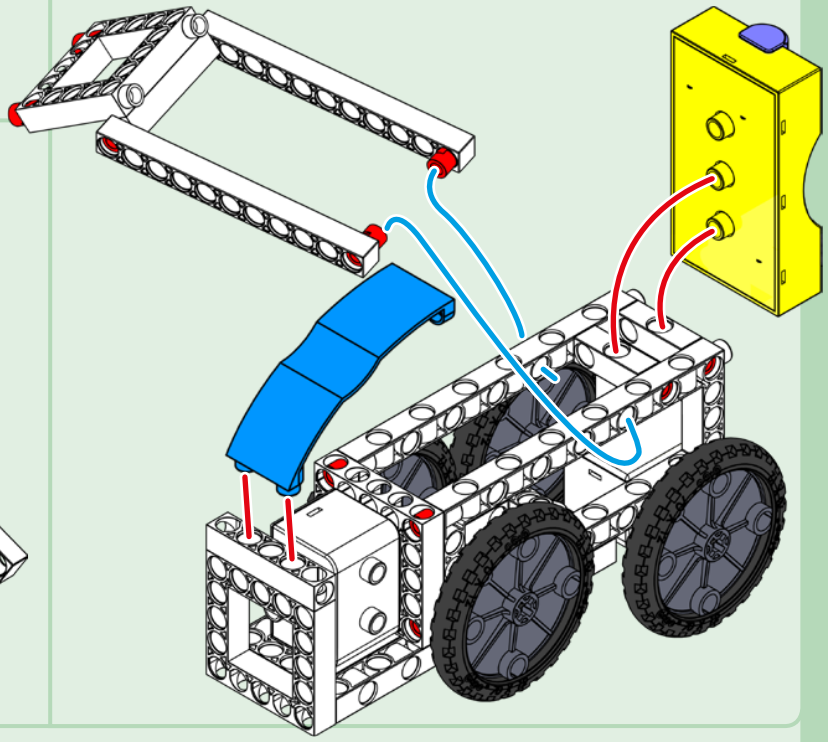

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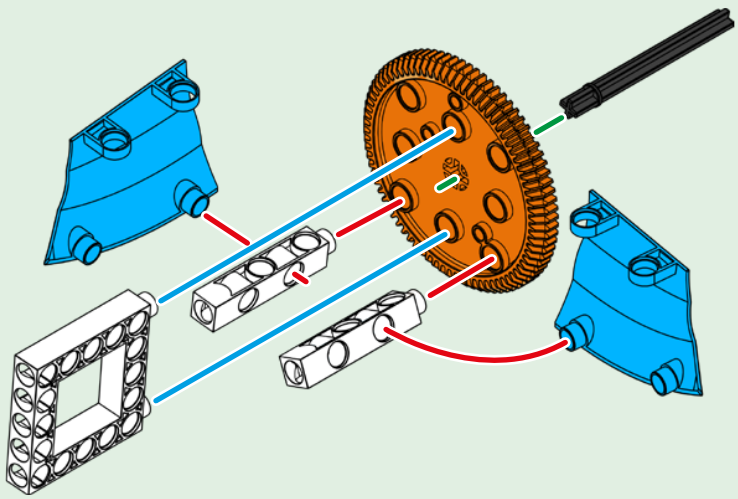

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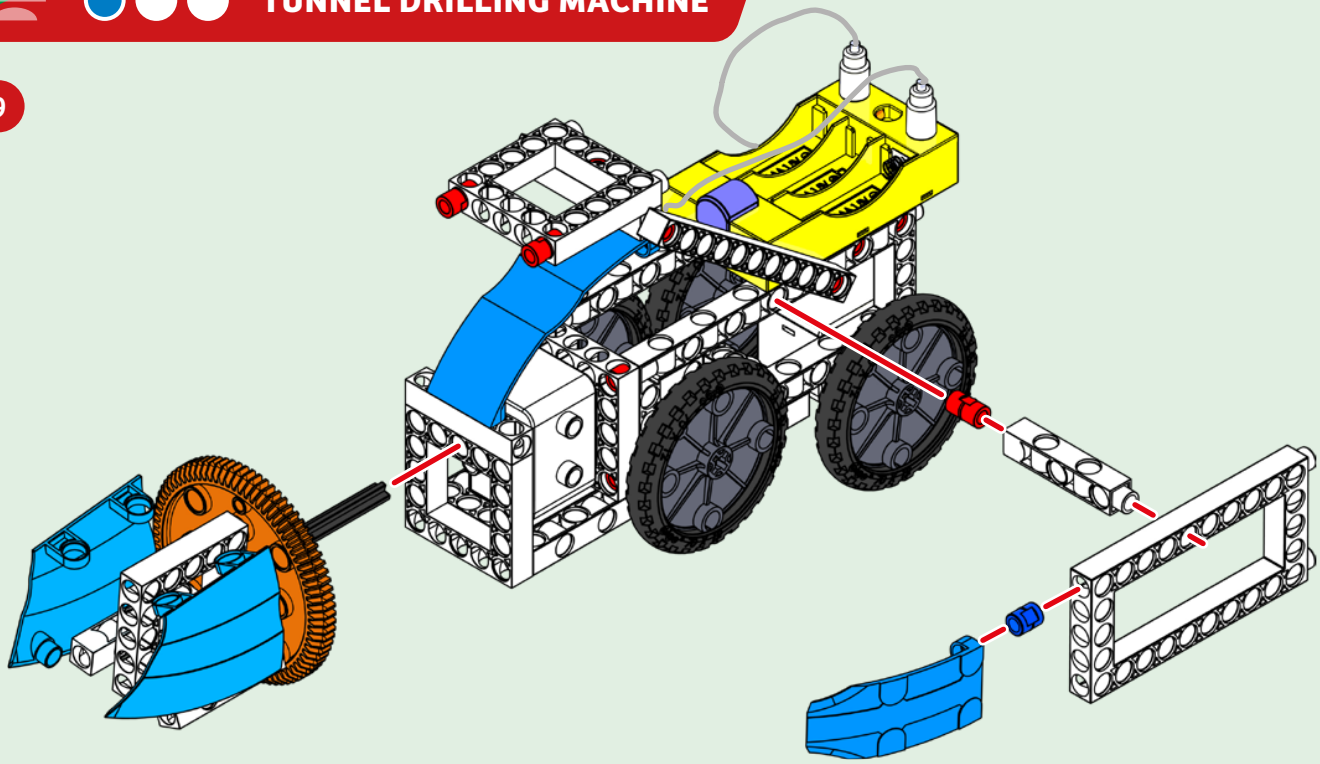

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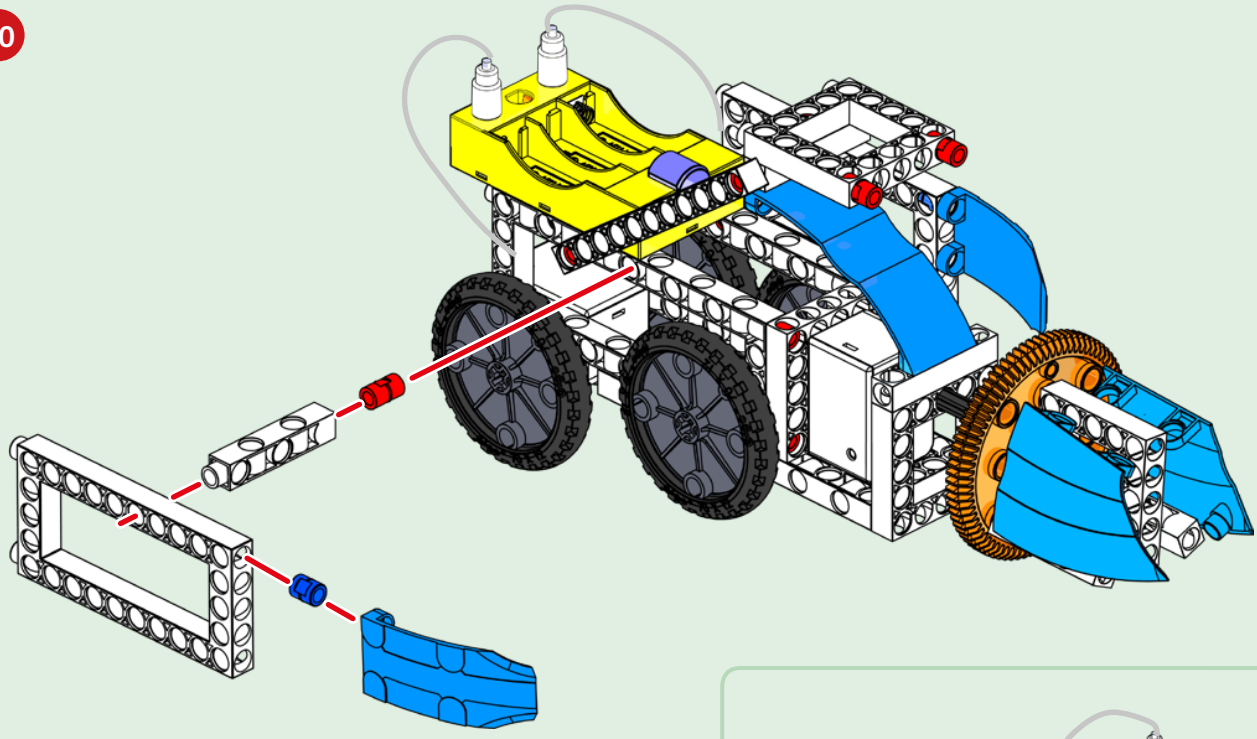

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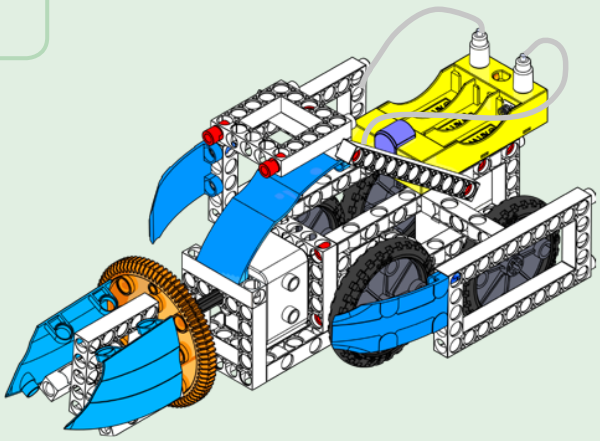

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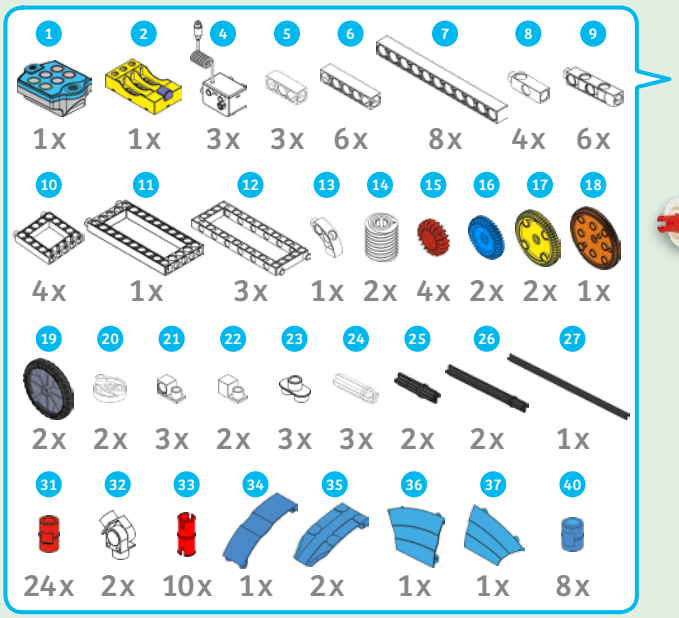
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15 4x
16 2x
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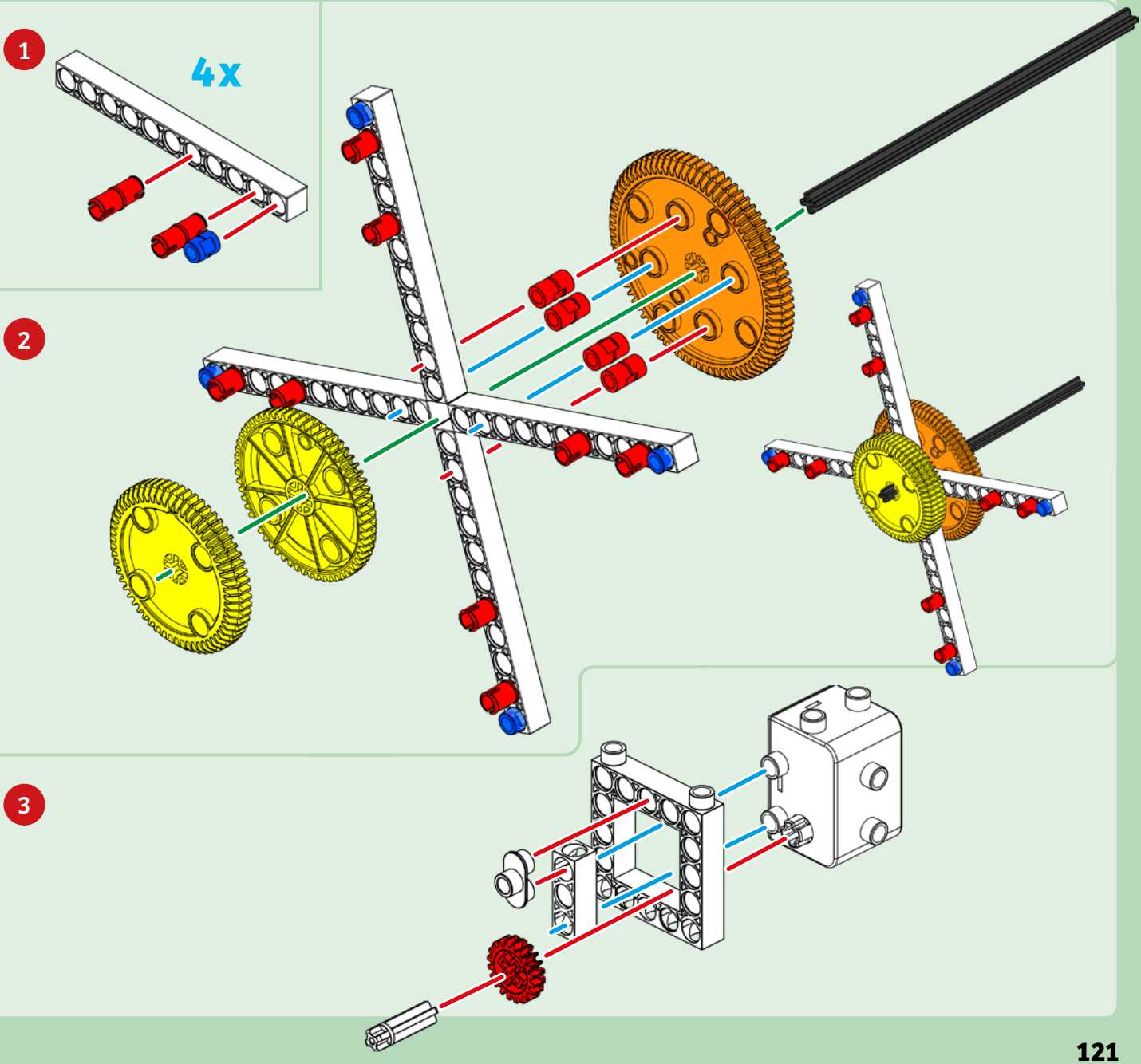
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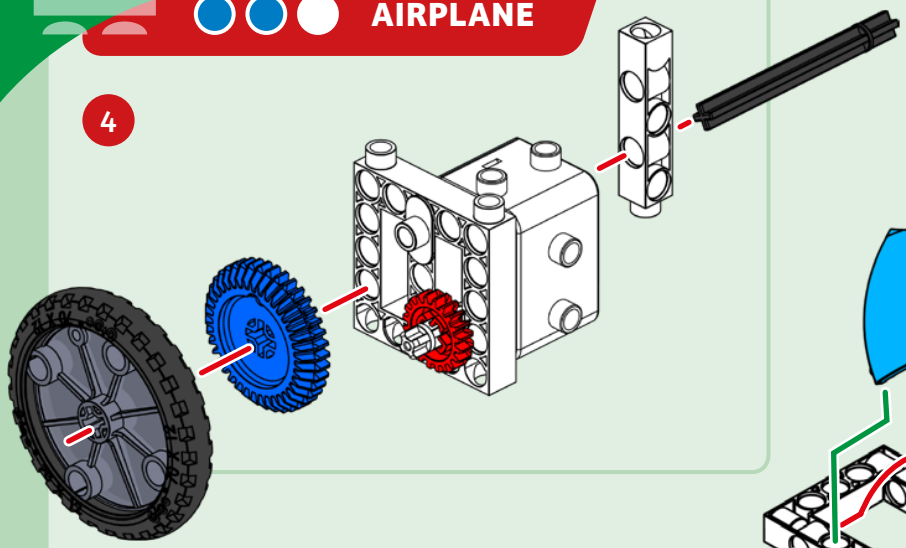

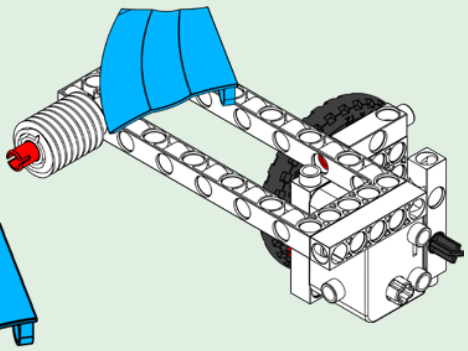

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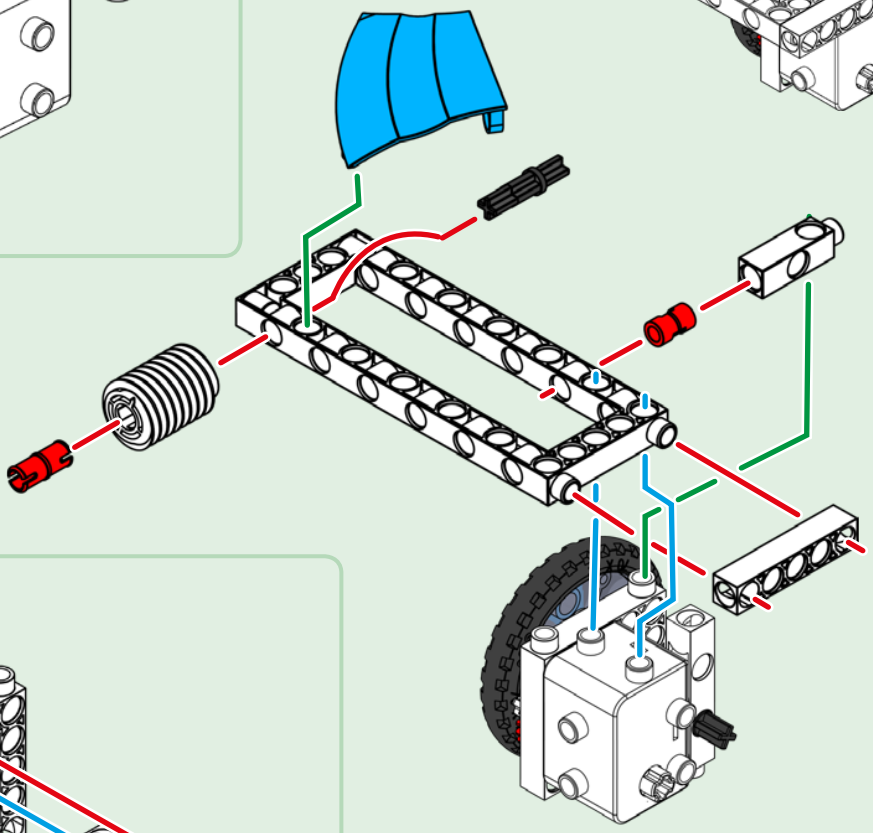

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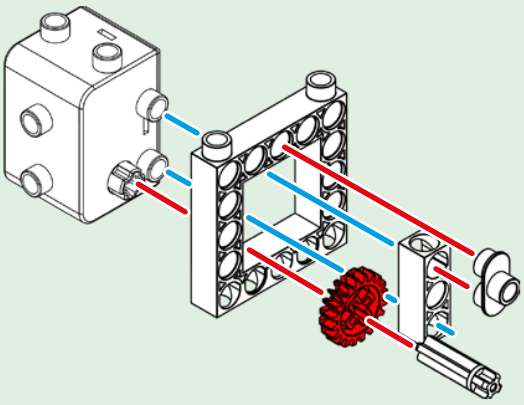

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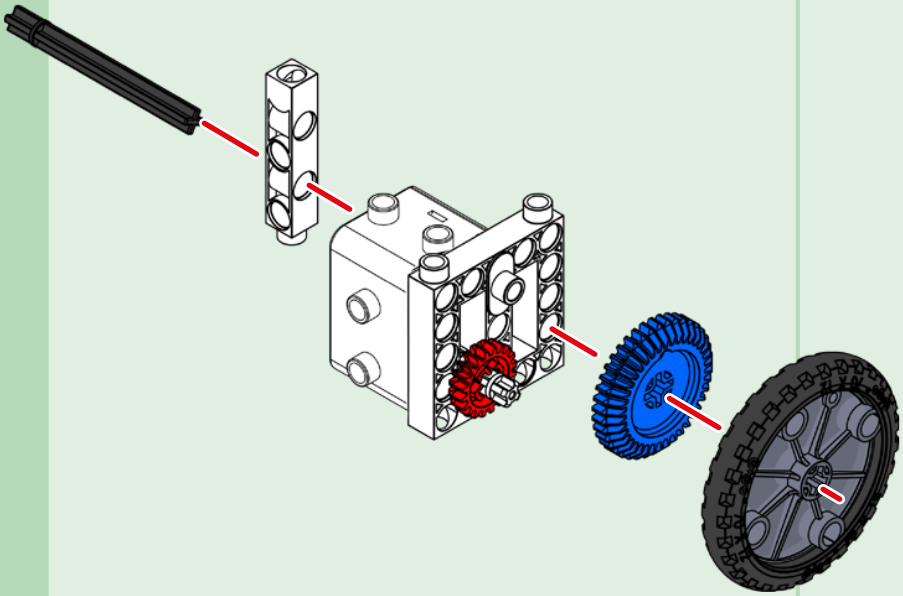

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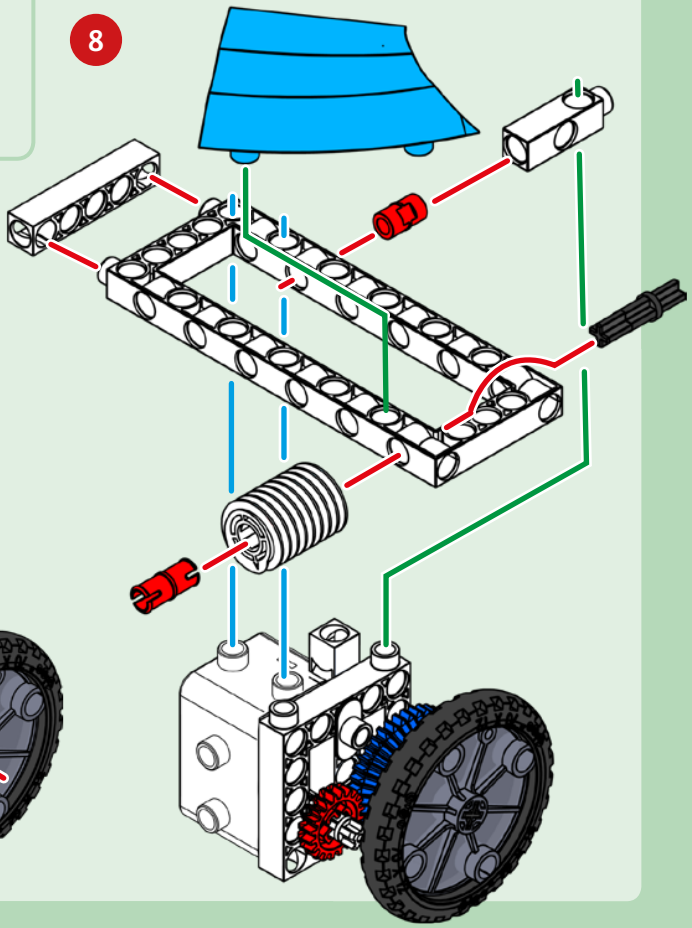

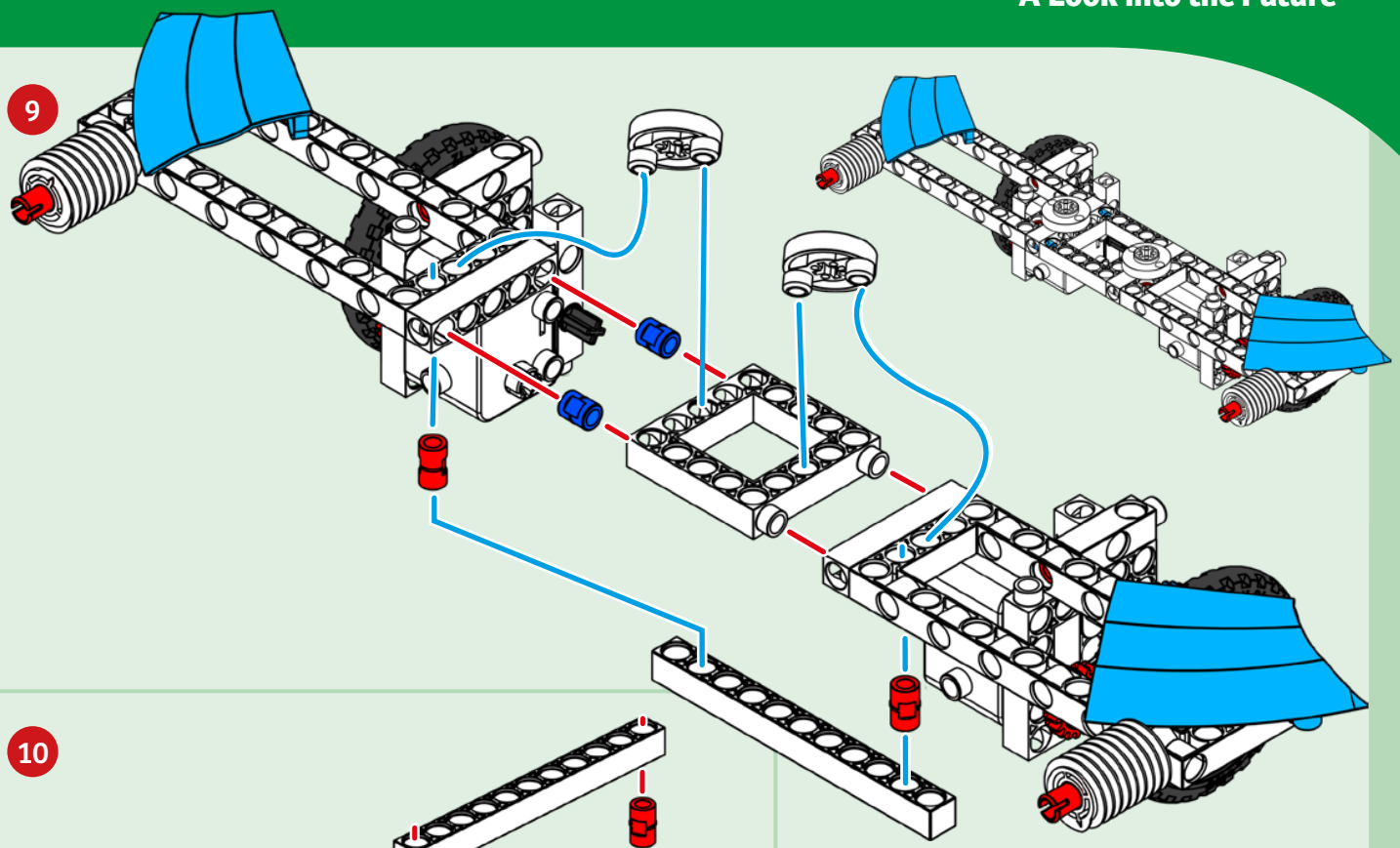
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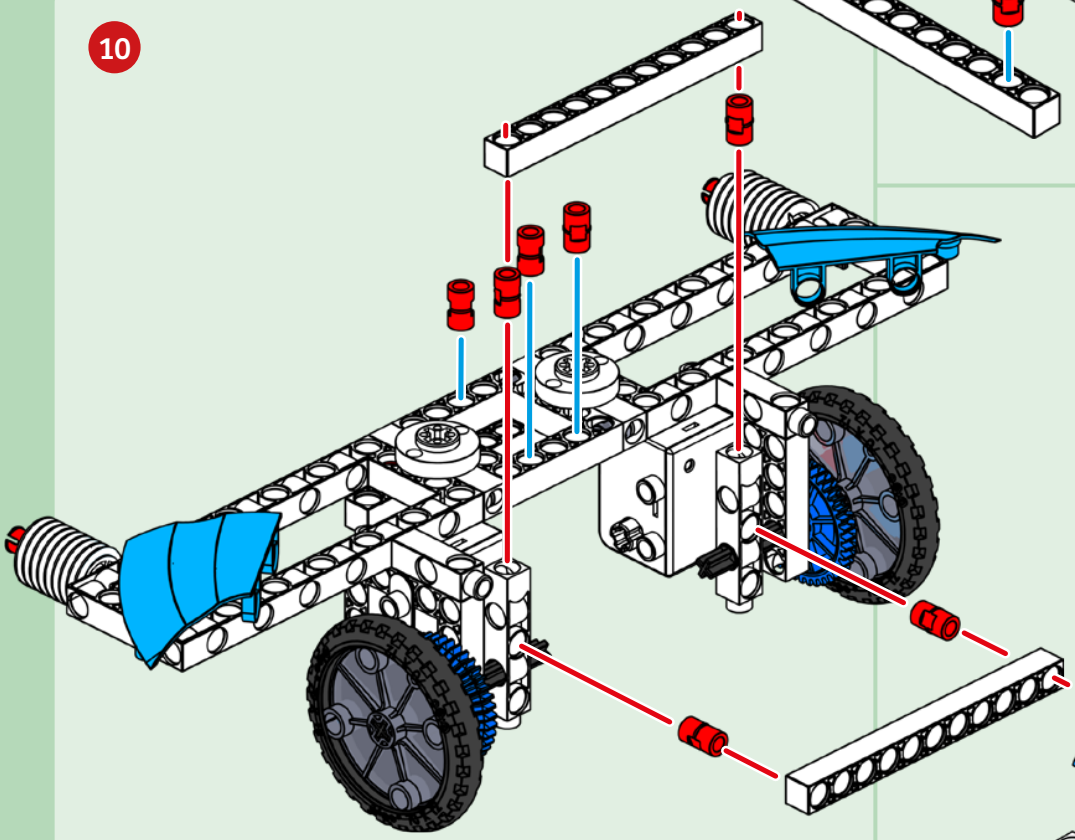
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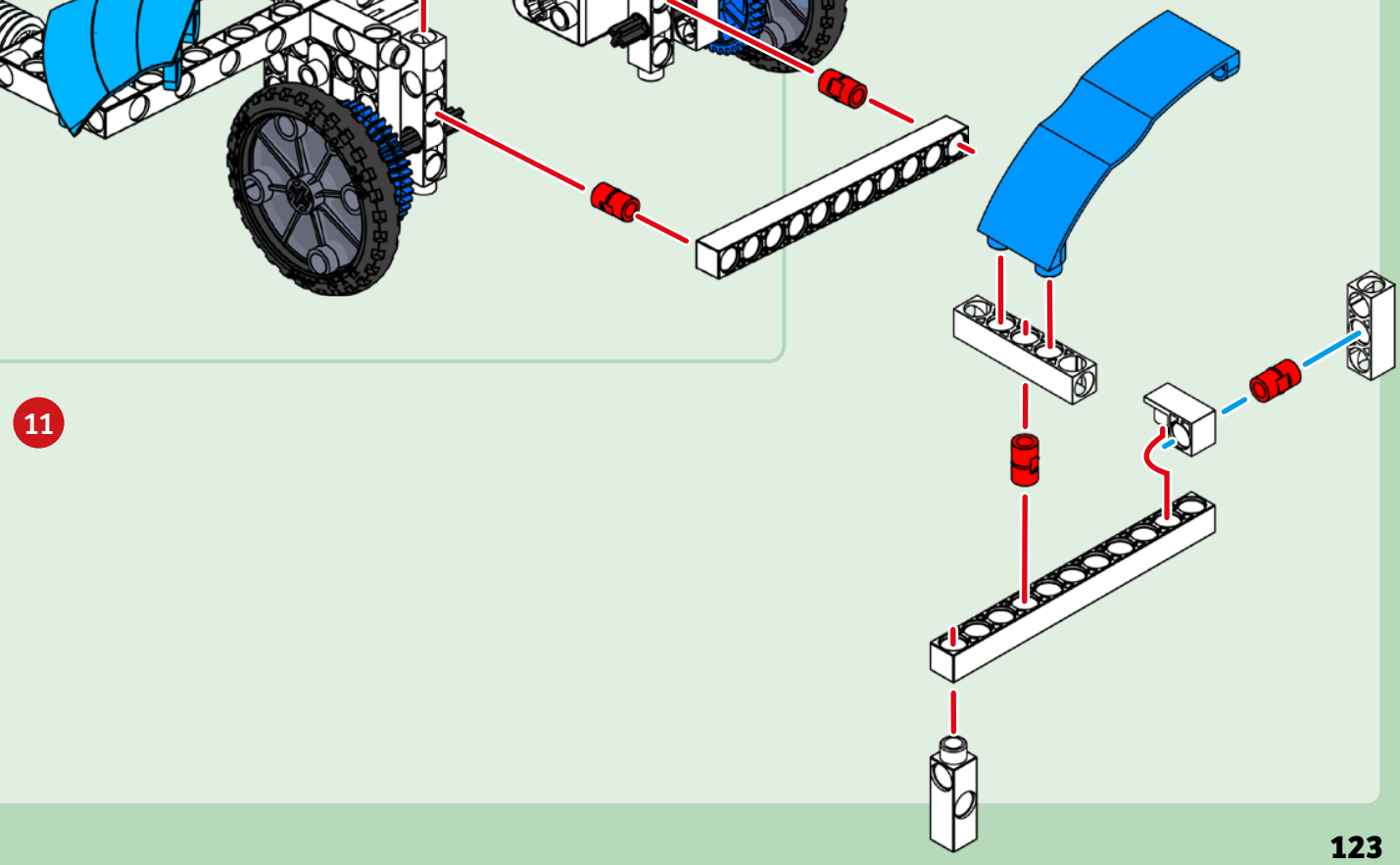
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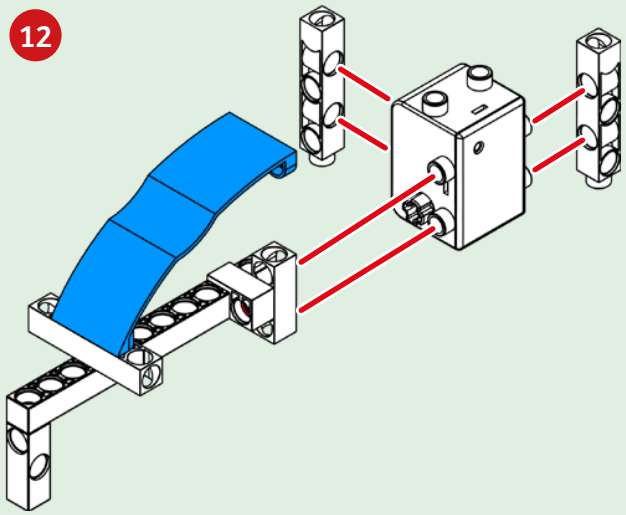

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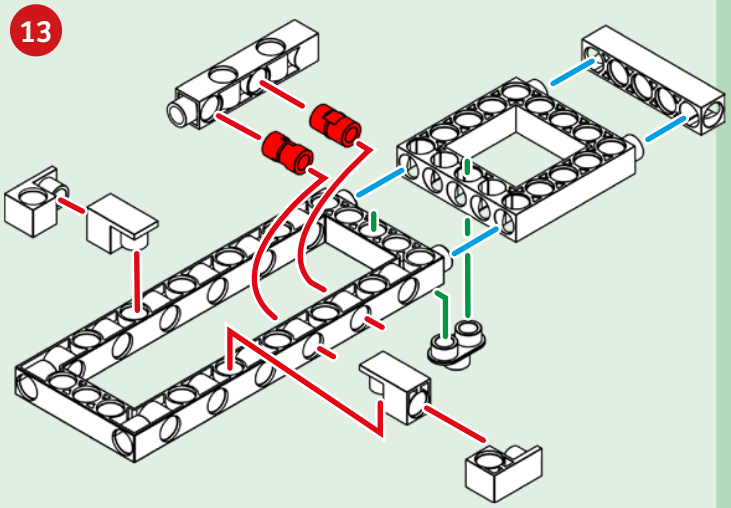

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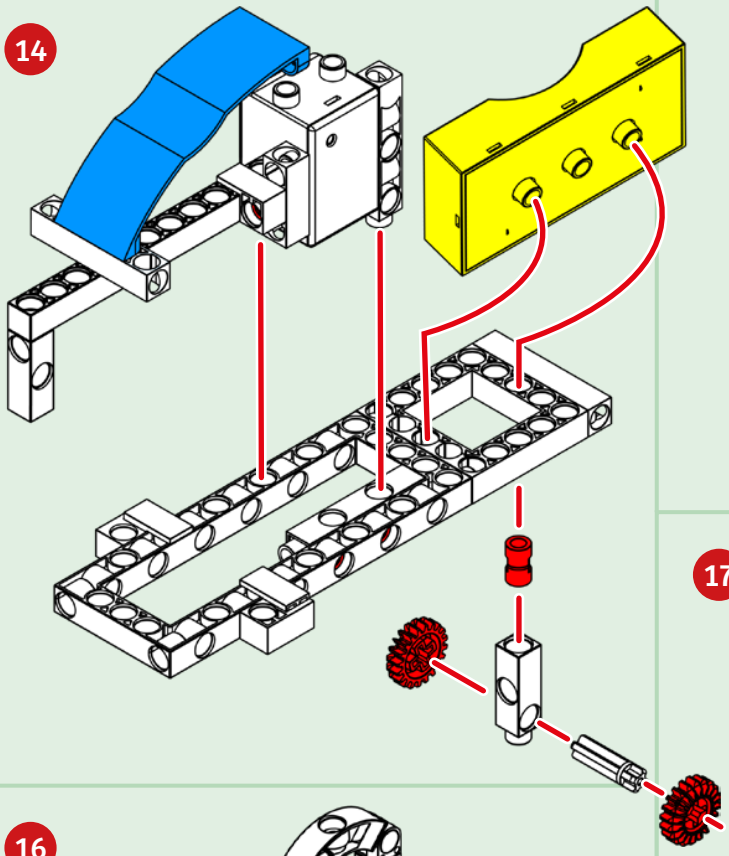

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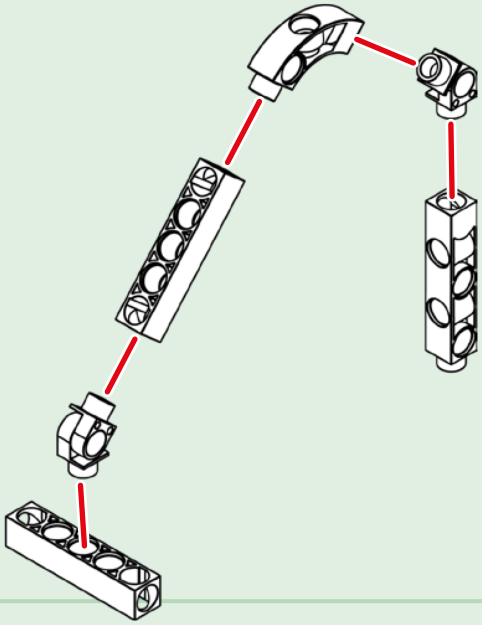

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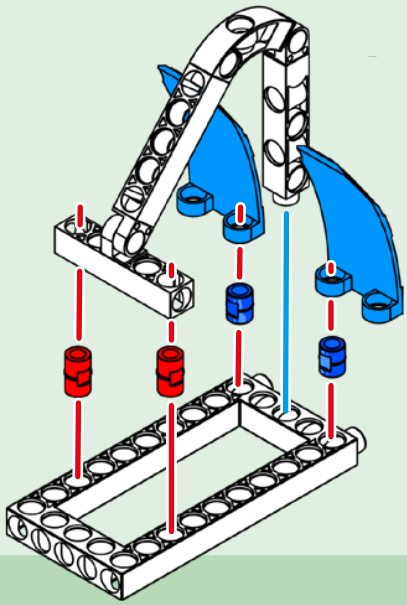

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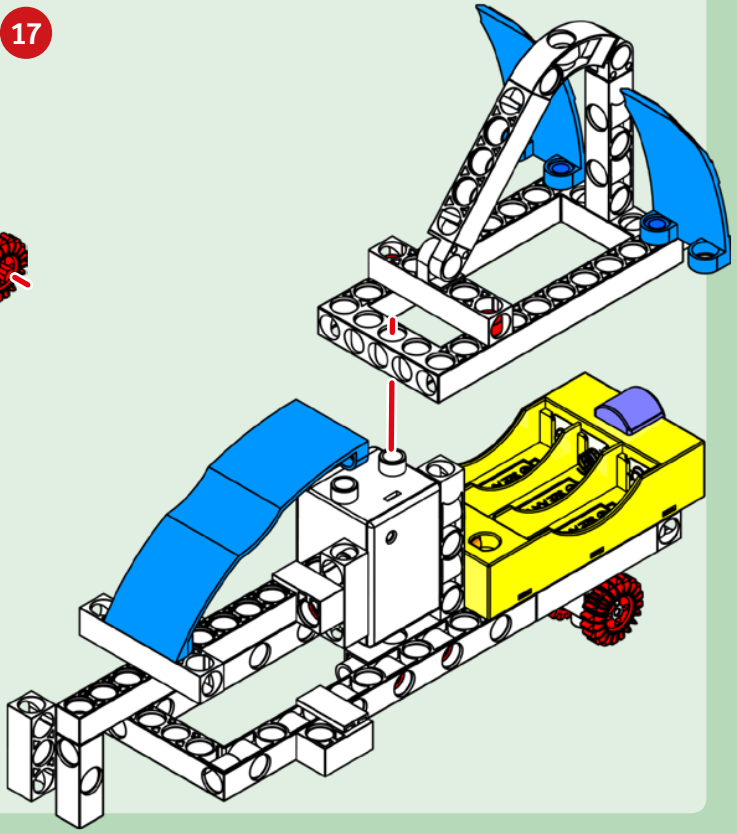

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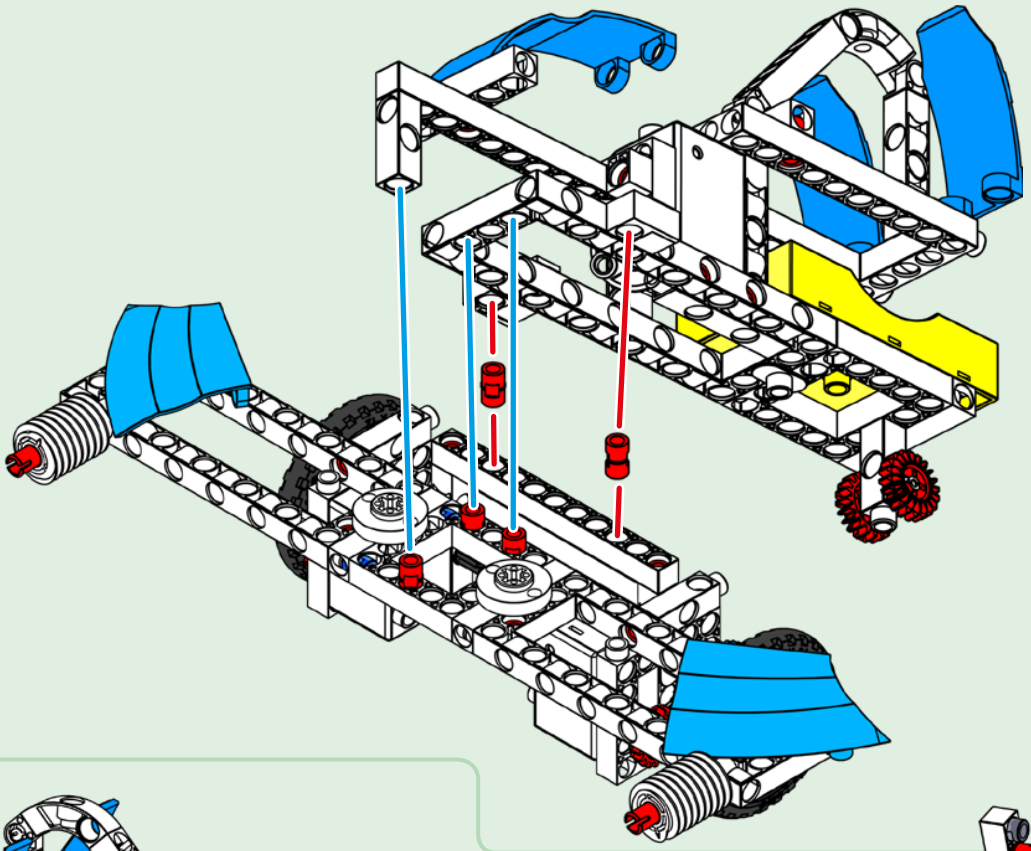

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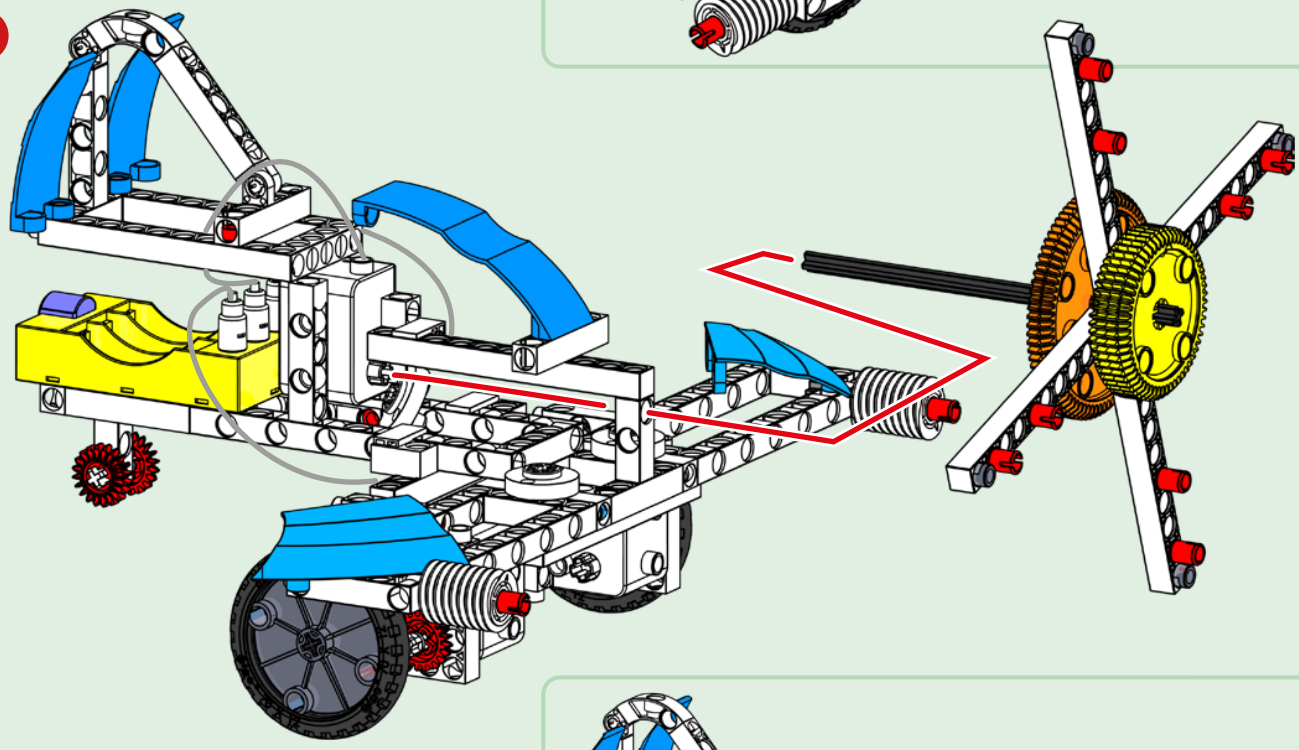
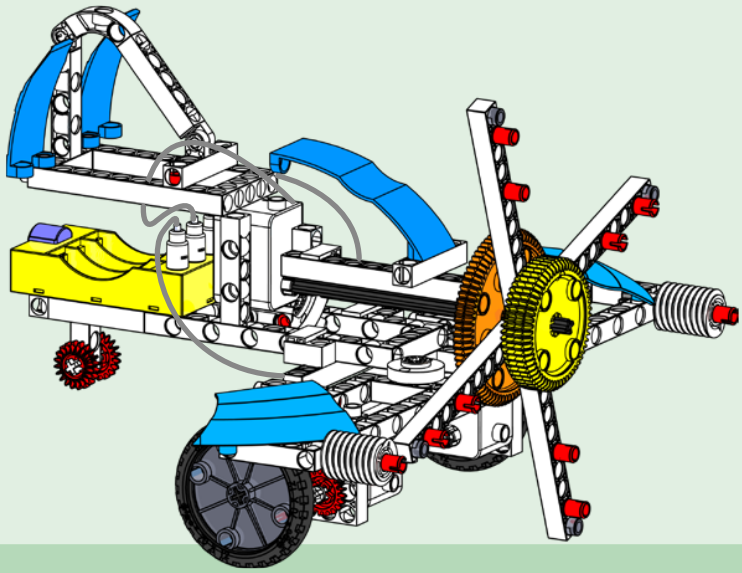


Done!



Flying mail robots and other visions of the future

What sorts of things will robots be able to do in the future? Here are a few examples of the things that researchers are already working on.

Drones weaving webs by themselves

In the future, robots will be able to spin webs, just like spiders. They can already do this in the lab. Specialized drones, or pilotless flying machines, work like spiders that fly through the air instead of jumping.

ROBOTS IN SPACE

A robot has even managed to go into space. His name is "Kirobo," and he comes from Japan. This little robot, 34 centimeters tall and weighing just one kilogram, is an "astronaut" on board the International Space Station, or ISS. His job? To keep the human astronauts entertained.

AIRPLANES WITHOUT PILOTS AND PACKAGES SENT BY FLYING ROBOTS

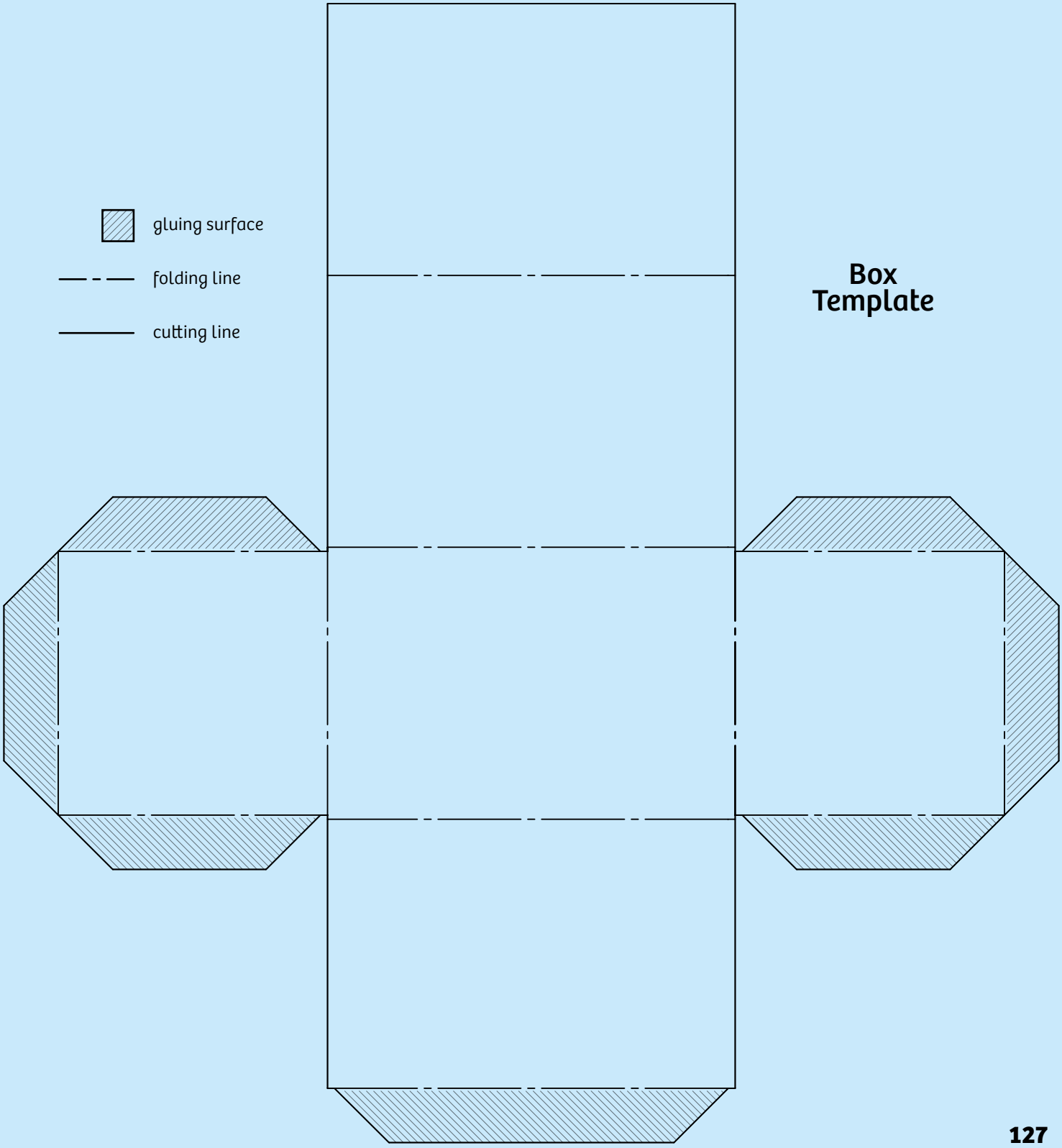
Will airplanes soon be zooming through the clouds without a pilot? Right now, airplane engineers are designing pilotless flying machines such as drones, which are controlled remotely by an expert. Fully autonomous airplanes have not left the drawing board. But who knows? Experts have already planned test flights to monitor borders or search for victims of air or sea crashes.

The future also holds the promise of flying packages — or, more precisely, delivery drones. Amazon, UPS, and DHL have already tested drones that fly about 50 meters high and deliver packages to specific locations. These are controlled by remote operators. But it should also be possible for the flying robots to be guided to their destinations by GPS.

For some of the experiments, you will need boxes and pallets. Use the patterns on this and the following page to make them quickly. See page 2 to find out what else you will need.

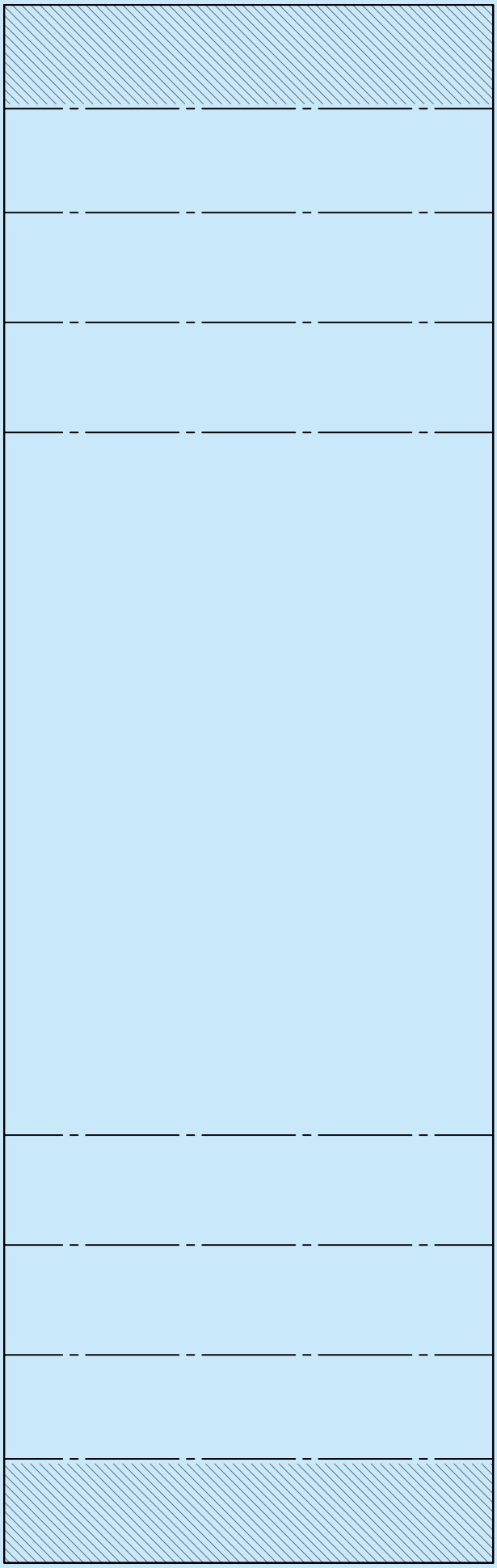
Lay wax paper or tracing paper over the pattern and trace all the lines onto the paper with ruler and pen. (Taping the paper to the page with a couple strips of masking tape will keep it from slipping.) Then cut your template out along the cutting lines.

Next, lay the template onto some colored card stock or thick construction paper and trace all around its edge with a pen. Also mark the areas where the dashed lines are. Cut out the box or pallet and fold it along the dashed lines. Then apply glue to the shaded surfaces, fold together, and you're done!



Box Template

Pallet Template



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