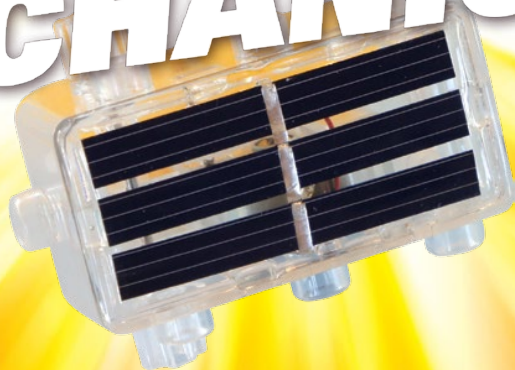


EXPERIMENT MANUAL

# SOLAR MECHANICS



 THAMES & KOSMOS

**GENERAL ADVICE AND WARNINGS**

1. Please read these instructions, follow the safety rules, and keep them for reference. We recommend you build the models in the order given. You will then be able to understand the way the parts connect together, and go on to create many more different models.
2. This kit has been designed for children over 8 years of age. It aims to help children discover solar power and how it works while creating a variety of models.
3. Discuss the safety warnings and possible risks involved with the children before allowing them to build these models.
4. In order to prevent a short circuit and damage to the solar motor unit, do not expose the solar panel to a high temperature light bulb for a long period of time.
5. While activating the solar powered models with a light bulb, please keep your hands away from the light bulb and fixture to avoid burning yourself.
6. Please experiment with at least a 60 watt light bulb or outdoor sunshine. A normal electric flashlight is too weak to activate the solar vehicles.



## Dear Parents,

Solar power is an exciting, cutting-edge technology, and it isn't really all that hard to understand. This kit makes the science of solar power — generating electricity from light — tangible and fun for young scientists.

This experiment kit is designed to help bring the fascinating world of mechanics and solar power a little bit closer to your child. With its multipurpose materials and easy-to-grasp examples, it will provide a first look into the world of physical measurements and laws — and thus also contribute to a better understanding of what your child will be learning in school.

The individual experimental setups are assembled step by step out of pieces with variably interconnecting parts. The assembly will take a little patience and practice at first. It will be ideal if you can help your child until he or she is familiar with all the connection methods.

We wish your child a lot of fun discovering and learning!

**WARNING!** Not appropriate for use by children under 3 years of age. There is a danger of suffocation due to the possibility of swallowing or inhaling small parts. The kit contains some small parts, such as anchor pins, gears, and axles, so it is absolutely essential that you keep it out of the reach of young children.

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

### Checklist: Find – Inspect – Check off

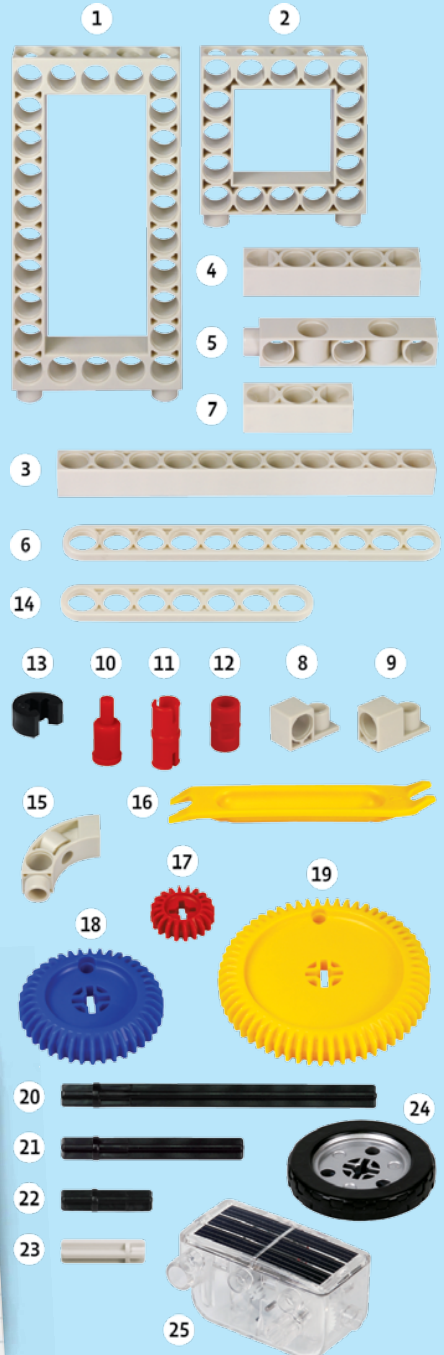
✓	No.	Name	Qty.
<input type="checkbox"/>	1	Large frame	1
<input type="checkbox"/>	2	Square frame	1
<input type="checkbox"/>	3	Long rod	2
<input type="checkbox"/>	4	5-hole rod	2
<input type="checkbox"/>	5	3-hole dual rod	4
<input type="checkbox"/>	6	11-hole flat rod	2
<input type="checkbox"/>	7	3-hole rod	1
<input type="checkbox"/>	8	90 degree converter - L	2
<input type="checkbox"/>	9	90 degree converter - R	2
<input type="checkbox"/>	10	Shaft pin	2
<input type="checkbox"/>	11	Joint pin	2
<input type="checkbox"/>	12	Anchor pin	14
<input type="checkbox"/>	13	Axle lock	2
<input type="checkbox"/>	14	7-hole flat rod	2
<input type="checkbox"/>	15	Curved elbow rod	4
<input type="checkbox"/>	16	Part separator tool	1
<input type="checkbox"/>	17	Small gear wheel	3
<input type="checkbox"/>	18	Medium gear wheel	2
<input type="checkbox"/>	19	Large gear wheel	1
<input type="checkbox"/>	20	Long axle	2
<input type="checkbox"/>	21	Medium axle	1
<input type="checkbox"/>	22	Short axle	2
<input type="checkbox"/>	23	Motor axle	1
<input type="checkbox"/>	24	Wheel (44 mm)	4
<input type="checkbox"/>	25	1.0 Volt Solar Motor Unit	1
		Total	61

If you are missing any parts, please contact Thames & Kosmos customer service.

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

### Additional things you will need:

*sunlight, desk lamp with incandescent bulb, fluorescent lighting, index card, wooden blocks, tape measure or yard stick, chalk or tape, stopwatch or timer, plank of wood*

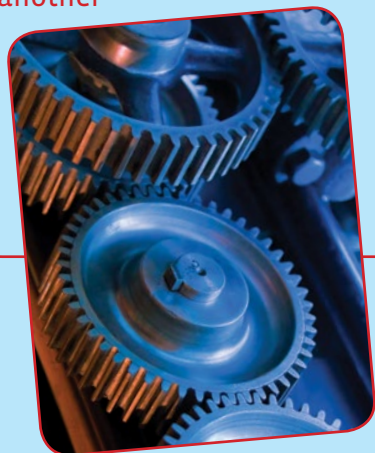


## Gearing Up: Transmissions

Pages 4 to 9



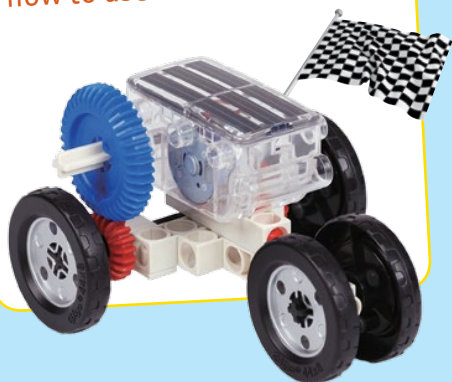
How to move mechanical energy from one place to another



## Powering Up: Solar Cells

Pages 9 to 24

Learn how solar cells convert sunlight into electricity, and how to use that electricity



## The Models: Part 1

Pages 25 to 38

Assemble solar powered vehicles



## The Models: Part 2

Pages 39 to 56

Assemble other solar powered devices and machines



## CHECK IT OUT

You will find supplemental information on pages 9, 16 to 17, 21 to 24, and 38.

# Gearing Up: TRANSMISSIONS

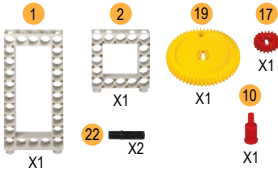
Transmissions allow you to move mechanical energy from one place to another. Your solar-powered models will depend heavily on transmissions to make their wheels and other components work. In this section, you will learn how the gears are used to make transmissions that either increase the speed of a wheel or increase the turning force of a wheel.

## EXPERIMENT 1

## Gear test 1

## YOU WILL NEED

→ 7 parts from the kit:



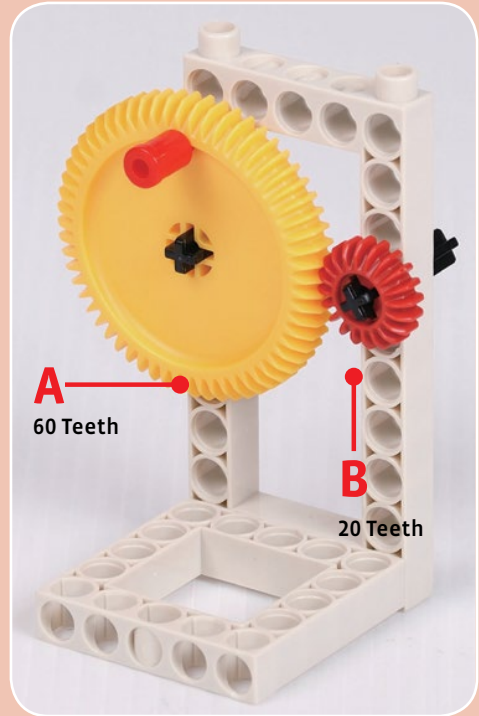
## HERE'S HOW

1. Assemble the parts as shown.
2. Slowly turn gear A one time around exactly, which is called one rotation. Carefully observe gear B as you do this.  
How many times does gear B turn for each full rotation of gear A?
3. Now slowly rotate gear B around once. Observe gear A as you do this.  
How many times does gear A turn for each full rotation of gear B?

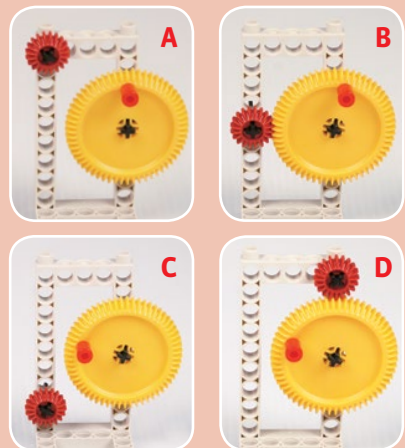
## → WHAT'S HAPPENING?

For each rotation of gear A, gear B rotates three times. Gear A has 60 teeth and gear B has 20 teeth. Thus, after the gears have meshed 20 teeth together, the small gear has already spun around once, while the large gear has only made it a third of the way around. For each rotation of gear B, gear A turns a third of a rotation.

Gear B spins faster at its center than gear A. So you see, gears can be used to change rotational speeds.



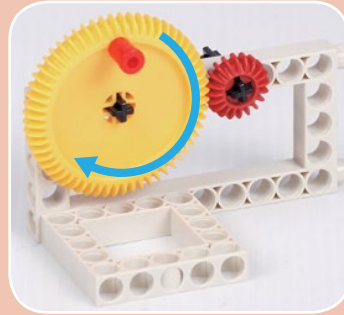
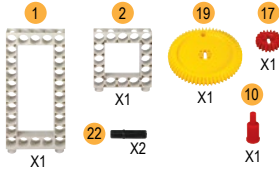
Which of these four locations for the red gear will allow it to turn when the yellow gear turns?



## Gear test 2

### YOU WILL NEED

→ 7 parts from the kit:



### HERE'S HOW

1. Assemble the parts as shown to the right.
2. Before you do anything else, make a prediction:  
When you turn the big yellow gear clockwise (as indicated by the blue arrow above), in which direction will the small red gear turn?
3. Now turn the gear and test your hypothesis.

**Answer A:** The red gear turns **counterclockwise**.



**Answer B:** The red gear turns **clockwise**.



### → WHAT'S HAPPENING?

The red gear turns counterclockwise when the yellow gear is turned clockwise. Gears that mesh with each other change the direction of rotation. So, not only can gear trains — series of interlocking gears — be used to change the speed of a gear, they can also be used to change the direction a gear is spinning.

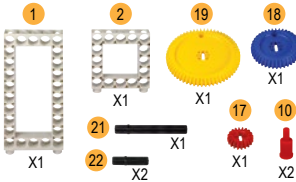


## EXPERIMENT 3

## Gear test 3

## YOU WILL NEED

→ 10 parts from the kit:



## HERE'S HOW

1. Assemble the parts as shown on the right.

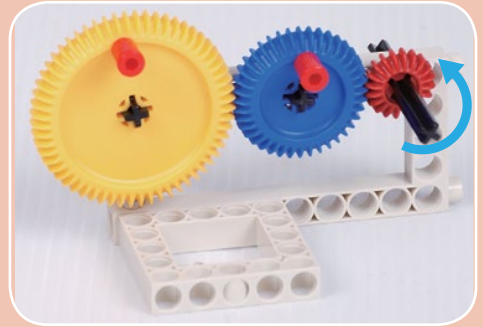
2. Now make a prediction.

When you turn the small red gear to the left, in which directions will the medium blue gear and large yellow gear turn?

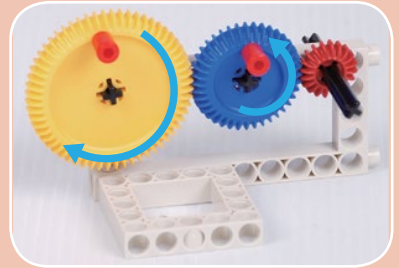
3. Now turn the gear and test your hypothesis.

## → WHAT'S HAPPENING?

The blue gear turns clockwise and the yellow gear turns counterclockwise. So, the yellow gear is actually spinning in the same direction as the starting red gear, because the direction has been changed twice. Has the gear train accomplished any change then? To answer that, observe the speed of the yellow gear in relation to the red gear.



Answer A: The blue gear turns **counterclockwise** and the yellow gear turns **clockwise**.



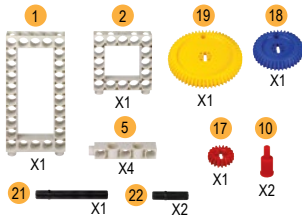
Answer B: The blue gear turns **clockwise** and the yellow gear turns **counterclockwise**.



## Gear test 4

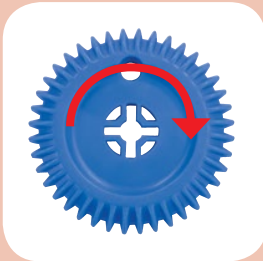
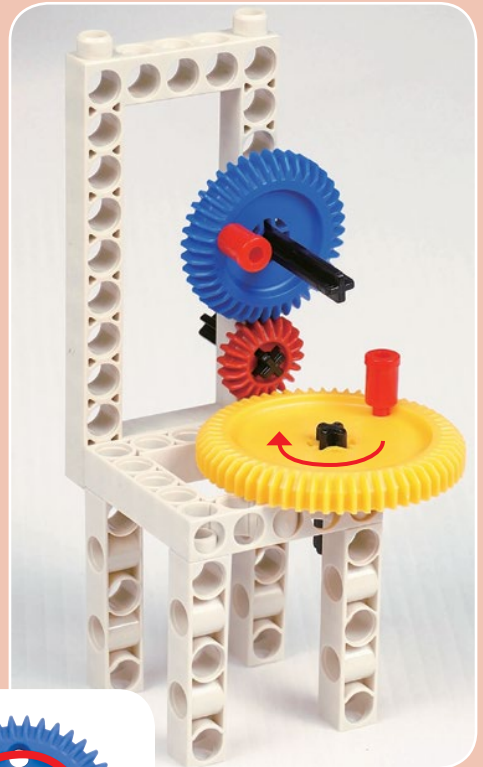
### YOU WILL NEED

→ 14 parts from the kit:

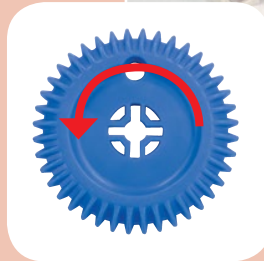


### HERE'S HOW

1. Assemble the parts as shown.
2. Now make your prediction:  
When you turn the yellow gear clockwise, in which direction will the blue gear turn?



Answer A: **clockwise**



Answer B: **counterclockwise**

### → WHAT'S HAPPENING?

The blue gear will turn clockwise. The gear train turned a corner! Here you see that these gears can be positioned at right angles from one another, changing the plane of motion.

$$\text{Gear Ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}}$$

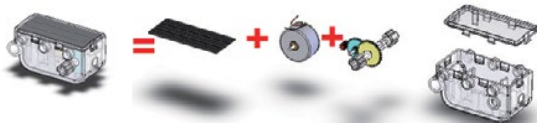
# MACHINES

For something to be called a **machine**, it has to have a source of power and a way to transmit power from one place to another — a **transmission**. Power can come from many sources, like heat or electricity. Power can be transmitted in many ways. Gear trains like the ones you have just experimented with in Experiments 1–4 are good examples.

This kit contains a special machine called the **solar motor unit**. It is a single-piece device that takes light and converts it into motion. The light source can be sunlight or even light from a powerful lamp. The motion is the spinning of an axle that sticks out from either side of the unit.

But how exactly does the solar motor unit convert light into motion? The **solar panel** on the top — a series of photovoltaic panels — generates electric current when exposed to enough light. That electric current in turn goes to powering an **electric motor**, which results in the spinning of the motor's shaft. From there, a **transmission** consisting of four gears carries the motion all the way to the **axles** on the sides of the unit, which can be used to activate your models!

The solar panel and the electric motor will be explained in the next section. First, let's look at how the transmission in the solar motor unit works.



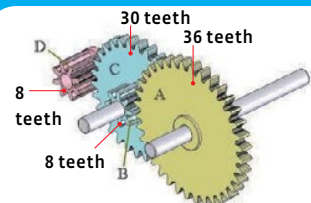
## INCREASING TORQUE

In Experiment 1, your gear train had a **gear ratio** of 1:3. For every one rotation of the large yellow driver gear, the small red driven gear rotated three times.

Inside the solar motor unit, the opposite happens. A series of four gears takes a fast-spinning motor shaft and reduces the speed.

But why would you want to slow it down? The answer is simple: when you reduce the speed of an output gear in a gear train, you increase the torque of the output gear. Torque is a measure of the turning force of a rotating object. In this case, you can think of it as the strength of a gear to turn another gear.

So, by decreasing the speed, the solar motor unit has increased the strength of the motor to turn gears and axles and power your vehicles and devices!

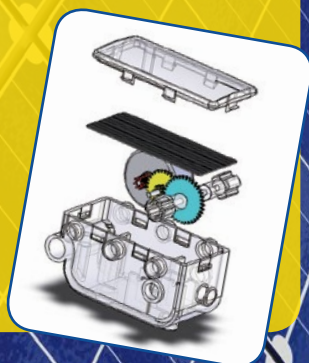


CHECK IT OUT

i

# Powering Up: SOLAR CELLS













To make the motor run, you need electricity supplied by the solar panel. In this chapter, you will conduct a series of experiments with a test car that will teach you how the solar panel works and under what conditions it works best.



# Build your test car

## YOU WILL NEED

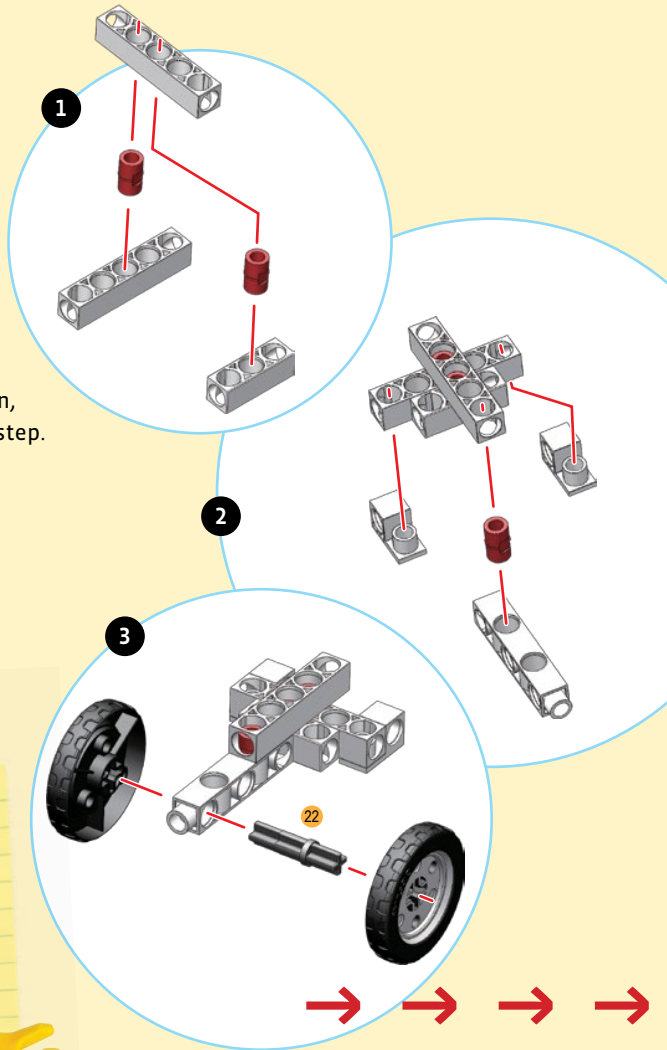
→ 20 parts from the kit:

- 4  
  
 X2
- 5  
  
 X1
- 7  
  
 X1
- 8  
  
 X2
- 12  
  
 X3
- 17  
  
 X2
- 18  
  
 X1
- 20  
  
 X1
- 22  
  
 X1
- 23  
  
 X1
- 24  
  
 X4
- 25  
  
 X1



## HERE'S HOW

1. Assemble all the parts as shown, following each picture step by step.



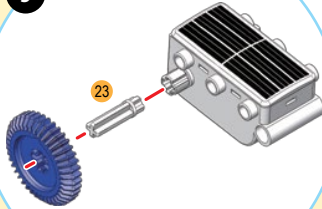
### TIP

To remove anchor pins, use the part separator tool as a lever!

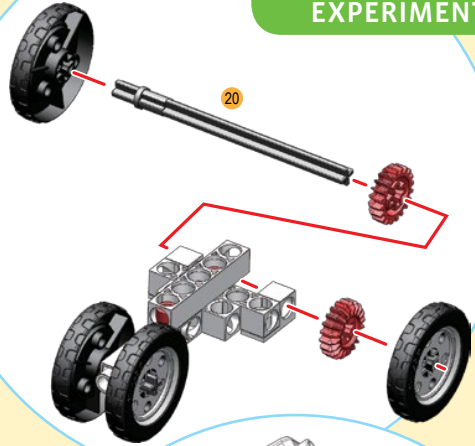


## Build your test car

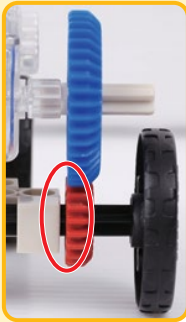
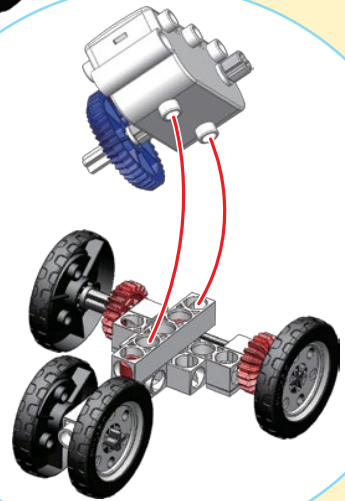
5



4



6



The model will run better with a 1 mm gap between the gear and frame.

7



### → WHAT'S HAPPENING?

You assembled a simple test vehicle with which you can now conduct a number of experiments to learn about putting solar power to work!

## EXPERIMENT 6

## Light sources

### YOU WILL NEED

- test car model
- a sunny day
- an overcast day
- desk lamp with incandescent bulb
- fluorescent lighting

### HERE'S HOW

Test how well your solar motor unit powers your model car in the following light conditions.

1. Outside on a sunny day, with the sun high in the sky.
2. Outside on a cloudy or overcast day
3. Inside under a desk lamp with an incandescent bulb (75 watts or greater recommended).
4. Inside under fluorescent lighting, such as long fluorescent tubes or compact fluorescent bulbs.

Under which light source does the model run the fastest along the ground? Which light sources do not provide enough energy to run the motor at all? What do you notice about the relationship between the intensity of the light and the speed of the motor?

### → WHAT'S HAPPENING?

Sunlight on a sunny day should power the motor to run the fastest. An incandescent bulb will also run the motor, if the lamp is close enough to the solar panel. Even though a fluorescent bulb appears very bright to us, it does not emit the amount of light energy needed to run the motor. A cloudy day however may actually provide enough sunlight to power the motor — the sun is that powerful!



# Testing different light levels

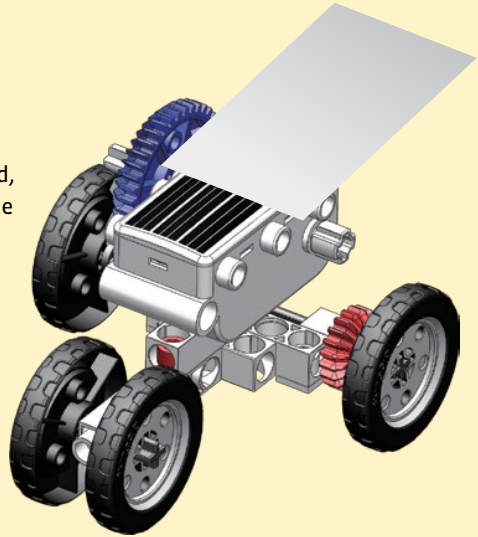
## YOU WILL NEED

- test car model
- a sunny day or a desk lamp with incandescent bulb
- small card (e.g. index card)



## HERE'S HOW

1. Put the test car outside in the sunlight or under a desk lamp so that the motor is running.
2. With a small card, such as an index card, cover a third of the solar panel's surface area and note the speed of the motor.
3. Cover half of the solar panel's surface area and again note the speed.
4. Cover two-thirds of the solar panel.  
**Does the motor still run?**



### → WHAT'S HAPPENING?

The surface area of a solar panel is directly proportional to the electrical power output. Assuming the same light conditions, the larger your solar panel, the more electricity it will generate.



## Optimum tilt of the solar panel

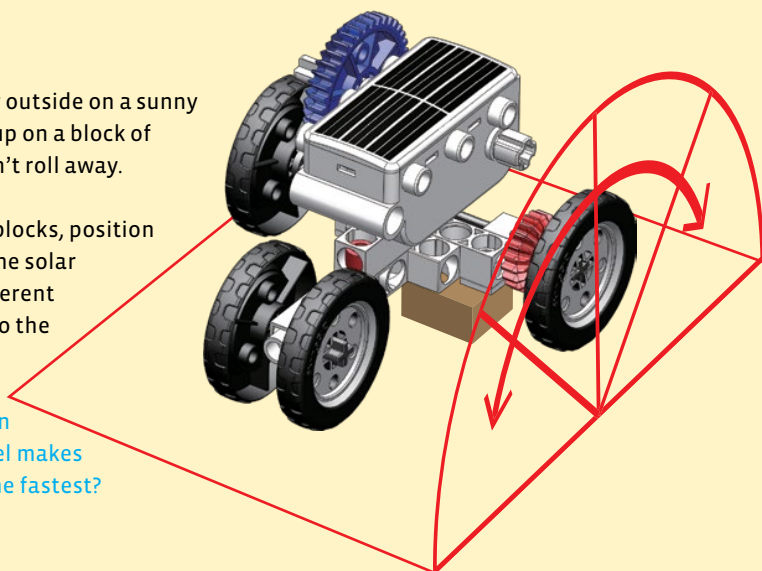
### YOU WILL NEED

- test car model
- a sunny day, when the sun is high in the sky
- small blocks of wood

### HERE'S HOW

1. Take the test car outside on a sunny day and prop it up on a block of wood so it doesn't roll away.
2. Using different blocks, position the car so that the solar panel sits at different angles relative to the sun.

What orientation of the solar panel makes the motor run the fastest?



### → WHAT'S HAPPENING?

The motor runs the fastest when the solar panel is most directly facing the sun. Because the sun is so far away, its rays hit Earth virtually parallel to one another. When the solar panel's surface is directly facing the sun, the light rays hit it perpendicularly. When the solar panel's surface is tilted at an angle to the sun, the light rays hit it at an angle. The more perpendicular the angle is, the more energy per surface area there is. See page 23 to learn more about this.

# How Does a Solar Cell Work?

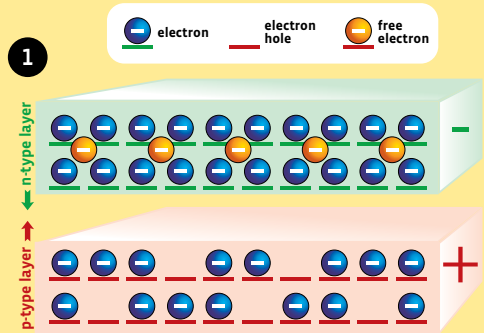
A solar cell is a flat device that uses an electronic material called a **semiconductor** to convert **photons**, or particles of light energy, into electrical energy. The semiconductor creates a **voltage**, or difference in electrical potential energy, between two surfaces when it is exposed to light. You can think of it like a battery, which also has a voltage between to points. This technology is called **photovoltaics**.

The phenomenon of electricity is nothing more than the movement of negatively charged particles, called **electrons**, through a material, called a **conductor**. Electricity flows easily through some materials, like metal, and poorly or not at all through other materials, like plastic. We have discovered materials, like **silicon**, which are naturally poor conductors in pure form, but can be treated to become better conductors under special conditions. These are called **semiconductors**.

In a solar cell, electrons are excited into motion by exposure to energy from light. The solar cell is designed to make the electrons flow in a specific direction, creating a negative pole on the side where there are more electrons and a positive pole on the side where there are fewer electrons, or more “empty holes” for electrons. To achieve this electron flow, pure silicon must be treated to become a better conductor. This is done by adding impurities, or other elements, to the silicon, in a process called doping.

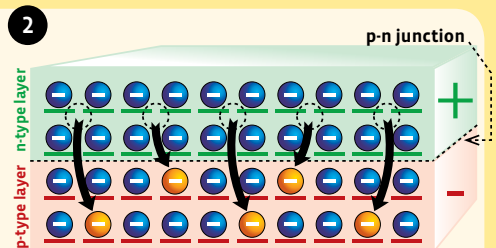
## 1. Two layers of silicon

There are two layers of treated silicon in the solar cell. Phosphorus is added to the first layer, resulting in an abundance of free electrons. Because electrons have a negative charge, this layer has a negative charge, and is thus called **n-type doped silicon**. The other layer is doped with Boron, resulting in an absence of electrons, or more holes for electrons. This gives the layer an overall positive charge, and is thus called **p-type doped silicon**.



## 2. The layers come together

The n-type silicon layer is positioned right next to the p-type layer. All of the free extra electrons in the n-type layer flow to fill up the holes in the p-type layer, creating an electric field. Right along the line where the two layers meet, something → →



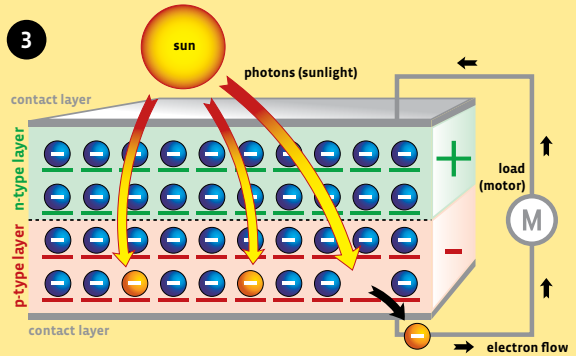
## CHECK IT OUT



interesting happens: electrons are able to move from the n-type layer into the p-type layer, but not from the p-type layer into the n-type layer. This area where the two layers meet is called the **p-n junction**. You can think of it like a hill, where electrons can easily roll down the hill (to the p-type layer) but it is very hard for them to go back up the hill (to the n-type layer).

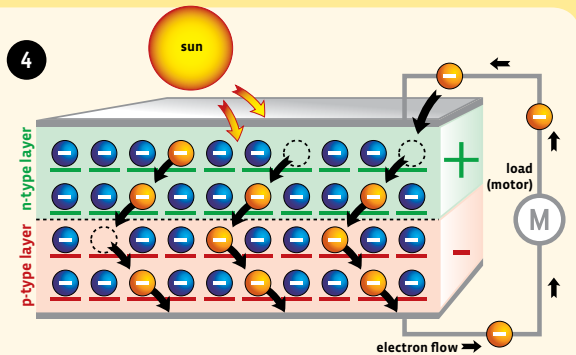
### 3. Let there be light

When the cell is exposed to light, the energy from the light excites the electrons in the p-type layer, and they break free from their holes. With **contacts and wires** attached to conduct electrons out of the p-type layer, through a **load** (such as a light bulb or motor), and back to the n-type layer, we now have a complete solar cell circuit.



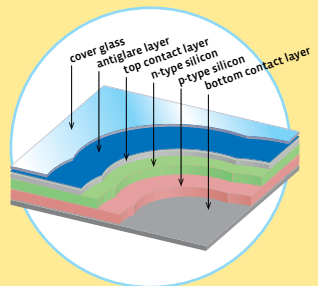
### 4. The electrons flow

When an electron moves, the hole it was previously sitting in becomes empty, and another electron can easily move into its position. And because electrons can only travel in one direction through the p-n junction, they must pass through the wire and load to get back to the n-type layer. This creates the electric current.



This basic solar cell with one p-type layer, one n-type layer, and one p-n junction is called a first generation photovoltaic. A second generation photovoltaic has many layers and multiple p-n junctions, to absorb more light. There is also a

third generation photovoltaic, which does not use the traditional p-n junction at all. This is a simplified description and we encourage you to find out more about how solar cells work from books, the internet, and your science teacher.



## Time trials

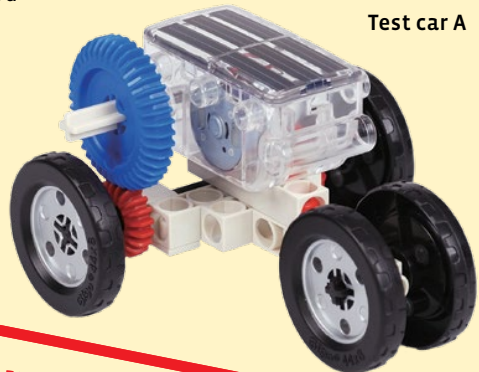
### YOU WILL NEED

- test car model
- *tape measure or yard stick*
- *chalk or tape*
- *stopwatch or timer*
- *area of smooth, flat ground outside on a sunny day*

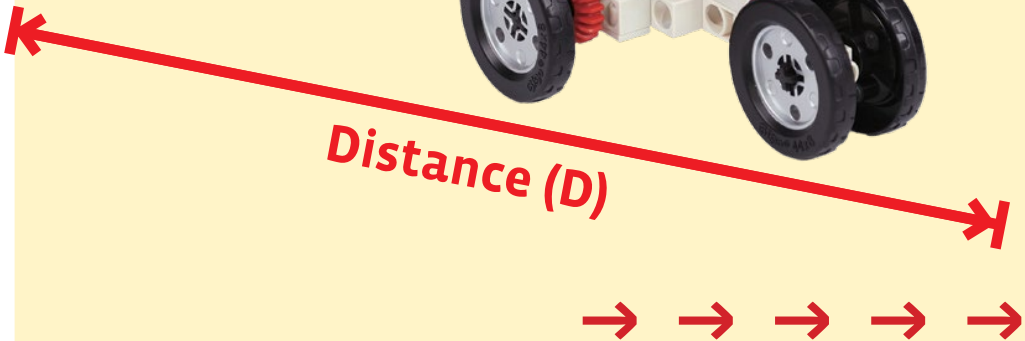


### HERE'S HOW

1. With your tape measure or yard stick, measure a distance along the smooth, flat ground and mark the start and end points with chalk or a piece of tape. For our example, we will choose three feet. But you can experiment with different distances.
2. Using the stopwatch or timer, time how long it takes the test car to travel between the start and end points. Record the time.



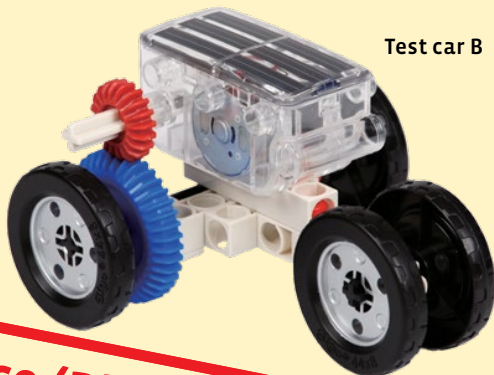
Test car A



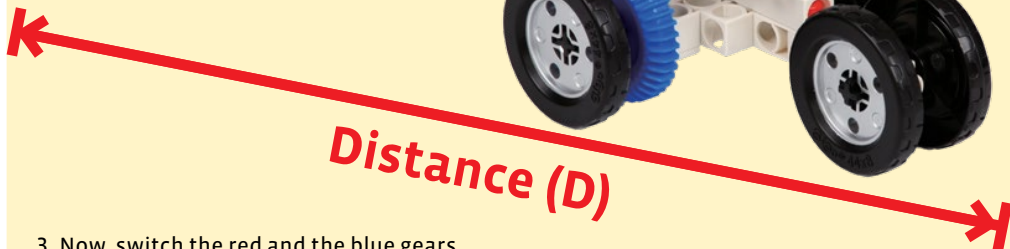
EXPERIMENT 9

# Time trials

Test car B



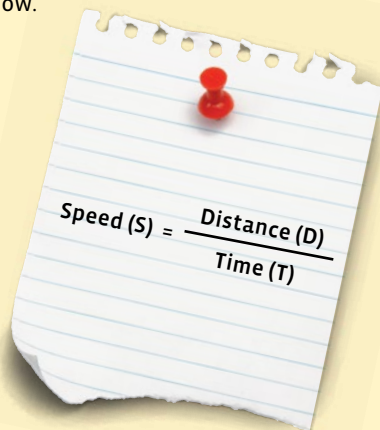
## HERE'S HOW IT CONTINUES



- Now, switch the red and the blue gears on your test car to make a different version of the car. We will call this new version “test car B,” and the original version “test car A.” You will have to remove the motor and rear axle in order to switch the gears, and then replace them again.
- Like you did before with test car A, use the stopwatch or timer to time how long it takes for test car B to travel between the start and end points. Record the time below.

### → WHAT'S HAPPENING?

Test car A clearly moves faster than test car B. Using the speed calculation here, you will see that car A moves about twice as fast as car B. Changing the gears about changed the speed of the car. It also changed the torque. Move on to the next experiment to learn more.



#### Examples

$$\text{Speed of Car A} = \frac{D}{T} = \frac{3 \text{ ft}}{4 \text{ sec}} = 0.75 \text{ ft/sec}$$

$$\text{Speed of Car B} = \frac{D}{T} = \frac{3 \text{ ft}}{8 \text{ sec}} = 0.375 \text{ ft/sec}$$

#### Your Test Cars

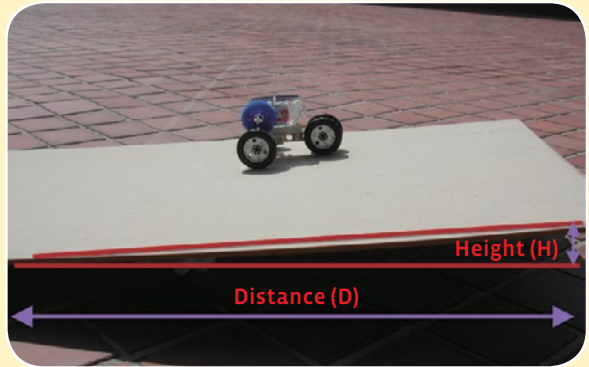
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<input type="text"/>	seconds	_____			

<input type="text"/>	feet	_____	=	<input type="text"/>	ft/sec
<input type="text"/>	seconds	_____			

# Torque over speed

## YOU WILL NEED

- test car models A and B from Experiment 9
- *tape measure or yard stick*
- *large plank of wood, or sturdy piece of cardboard, or other flat panel*
- *wooden blocks or books*
- *stopwatch or timer*
- *sunny day*



## HERE'S HOW

1. Find a large plank of wood, or a sturdy piece of cardboard, or some other flat panel that is at least three feet by two feet and that you can use as a ramp.
2. Set up the ramp with one end on a short block of wood or a thin book so that the ramp is at a low-grade slope (a slight upward slant).
3. Now time how long it takes both test cars (A and B) to climb from one end of the ramp to the other.  
*Do both cars make it up the ramp?*
4. Add another block of wood or book to increase the slope (or steepness) of the ramp.
5. Again, test both cars on the ramp. Continue to increase the slope of the ramp and test the model cars until one of them can no longer climb the ramp.
6. Now, continue to test the remaining car on increasingly steep ramps until the car can no longer climb as well.

### → WHAT'S HAPPENING?

Test car B, which was the slower car from Experiment 9, should have been more capable of climbing the steeper ramp than test car A. From the results of these last two experiments, you can see how gears can be used to either increase speed or increase torque depending on what is needed. The solar panel can provide only a limited amount of energy, so we have to use gears to either use that energy towards achieving more speed or more power.

CHECK IT OUT



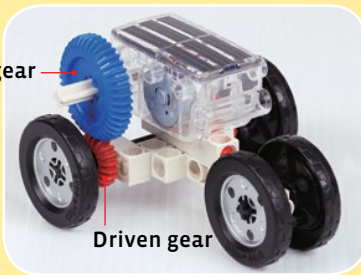
## SPEED, TORQUE, AND NUMBER OF TEETH

From the experiments so far, we have learned that torque and turning speed have an inverse relationship in a gear train. When you increase one, the other decreases. Gear turning speed and the number of teeth also have an inverse rela-

tionship. So, this means that torque and the number of gear teeth are directly proportional.

Here we will calculate how much the torque and speed differ between test car models A and B.

### Model A : 40-tooth gear driving a 20-tooth gear



Gear ratio =

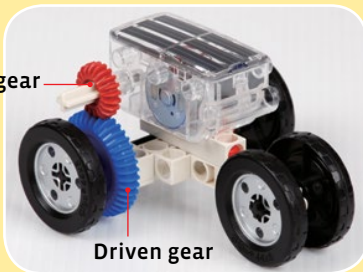
$$\frac{\text{Teeth on driven gear}}{\text{Teeth on driver gear}} = \frac{20}{40} = \frac{1}{2}$$

➔ Torque decreases by 2 times  
Speed increases by 2 times



-----  
Good for speed on flat surfaces

### Model B : 20-tooth gear driving a 40-tooth gear



Gear ratio =

$$\frac{\text{Teeth on driven gear}}{\text{Teeth on driver gear}} = \frac{40}{20} = 2$$

➔ Torque increases by 2 times  
Speed decreases by 2 times



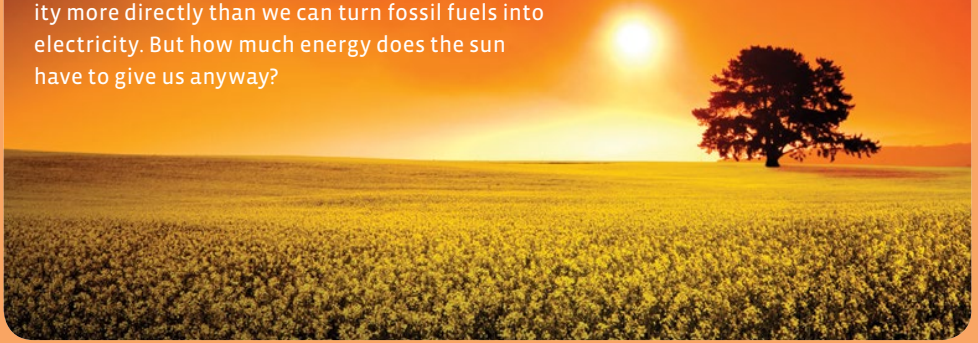
-----  
Good for power going up hills

The relationship between number of teeth, speed, and torque in a gear train:

$$\text{Gear Ratio} = \frac{\text{Teeth count driven gear}}{\text{Teeth count driver gear}} = \frac{\text{Speed of driver gear}}{\text{Speed of driven gear}} = \frac{\text{Torque of driven gear}}{\text{Torque of driver gear}}$$

## Solar Energy

Most of the energy we use comes from the sun, in one way or another. Even fossil fuels are just the remains of prehistoric plants and animals, which lived on and stored energy from the sun. With solar cells, we can turn the sun's energy into electricity more directly than we can turn fossil fuels into electricity. But how much energy does the sun have to give us anyway?



# THE SUN

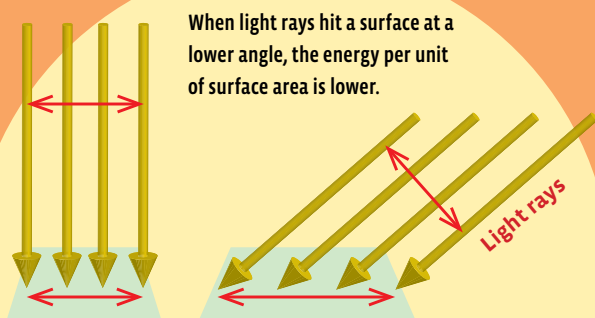
The sun gives off light — just like a lamp, but much, much brighter. While a lamp needs electricity to light up, the sun has its own source of fuel inside it. The sun is so powerful that not even all the lamps in the world could produce as much light as the sun.

The energy from the sun is called radiant energy. About 600 million tons of hydrogen are fused into helium in the sun's interior every second. When this happens, huge amounts of energy are released in the form of light and heat. Each second, the sun produces a radiant energy of 63,000 kilowatt-hours per square meter (kWh/m<sup>2</sup>).



## THE ANGLE OF SOLAR RADIATION

The sun is so far away from Earth, that the sun's rays hit Earth in virtually parallel lines. So when the sun is directly overhead, its rays hit Earth perpendicular to the ground (at a 90° angle). When the sun is low in the sky relative to your position on Earth, the sun's rays hit the ground at an angle. They also pass through more layers of atmosphere coming in at an angle.



The greater the slant at which the sun's light hits the ground, the larger the area that the same amount of light, or photons, are distributed across. Because the same amount of energy is spread over a larger surface area, the energy per unit of area is lower. This is why the sun feels hotter when it is high in the sky in summer than when it is low in the sky in winter.

Even at a distance of 150 million kilometers, where Earth orbits the sun, the power of this radiation still amounts to 1.4 kWh/m<sup>2</sup>. Only a portion of that energy is absorbed by Earth, while the other half is reflected back into space.

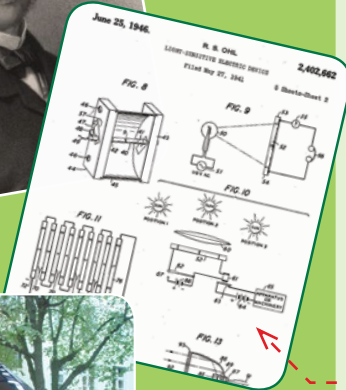
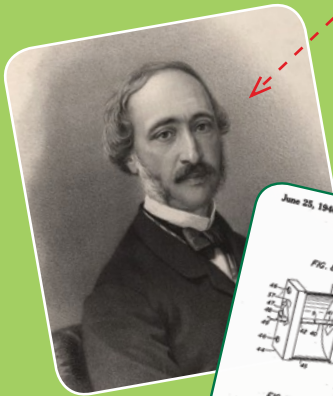
The sun's radiation is highly variable in different regions of the world. That has to do with cloud cover and Earth's tilt. In New York, about 1,000 kWh/m<sup>2</sup> of solar energy are available per year, while the figure is about 1,700 in Los Angeles, 2,000 kWh/m<sup>2</sup> in the Caribbean, and 2,200 kWh/m<sup>2</sup> in the Sahara desert. Compare these numbers to the fact that the average American uses only about 13,500 kWh in a whole year.

In total, Earth gets about  $1.1 \times 10^{18}$  kWh of energy from the sun every year. To put this

in perspective, the amount of energy produced and consumed in one year by everyone on Earth is only about  $1.3 \times 10^{14}$  kWh. Thus, the sun gives us 8,000 times more energy than we consume in a year! This means that in about an hour, the sun delivers as much free energy as all of Earth's inhabitants combined use in an entire year.



# History of Solar Cell Technology



A single silicon crystal

Vanguard I (NASA)



A French physicist named **Alexandre-Edmond Becquerel** discovered the photovoltaic effect in 1839. He showed that light can affect electrical current in materials. His experiment proved that metal electrodes immersed in acid produce more electricity when they are placed in the sunlight. Later on, scientists named this the **photoelectric effect**, or **photovoltaic effect**. This important discovery clearly showed that under certain circumstances, light can be converted into electrical energy.

In 1883, an American inventor named **Charles Fritts** built the first solar cell using plates made of an element called selenium. It was very inefficient by today's standards.

Over the years, many scientists did a lot of research on the photoelectric effect. In 1939, an American engineer named **Russell Ohl** discovered the p-n junction in **silicon**, and by 1946, he had **patented** the first modern solar cell.

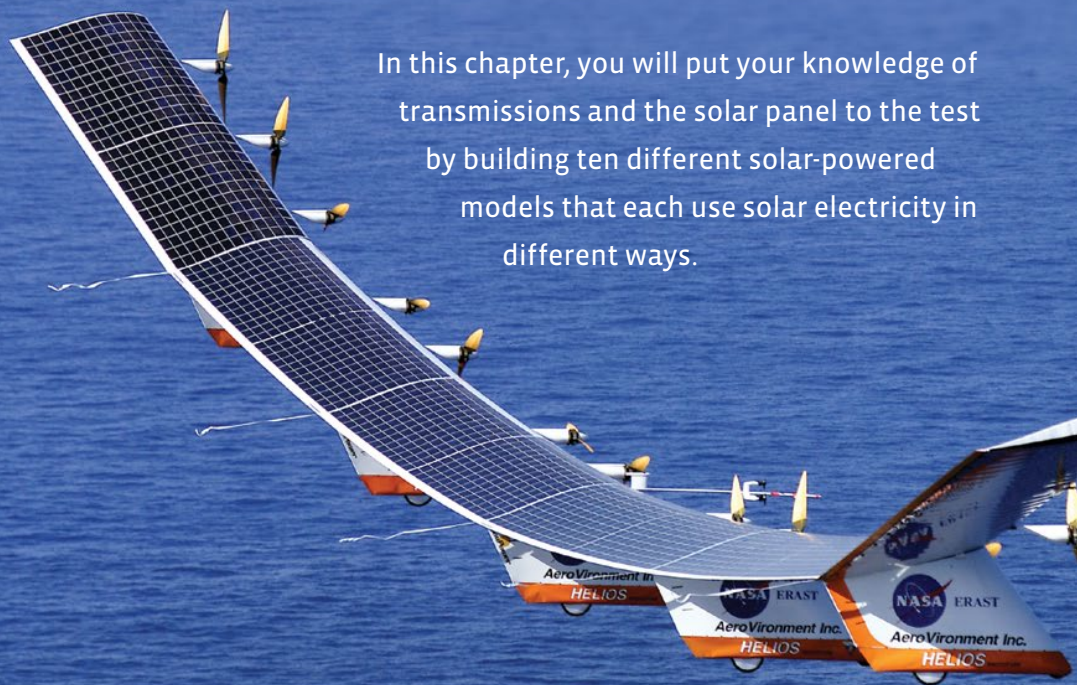
In 1958, the U.S. sent **Vanguard I**, the first solar-powered satellite, into space, showing how much photovoltaic technology had progressed in just over 100 years.

Since the 1980s, photovoltaic systems have been increasingly installed around the world to generate electricity for commercial, residential, and industrial applications.

# The Models:

## Putting Your Solar Panel to Work

In this chapter, you will put your knowledge of transmissions and the solar panel to the test by building ten different solar-powered models that each use solar electricity in different ways.

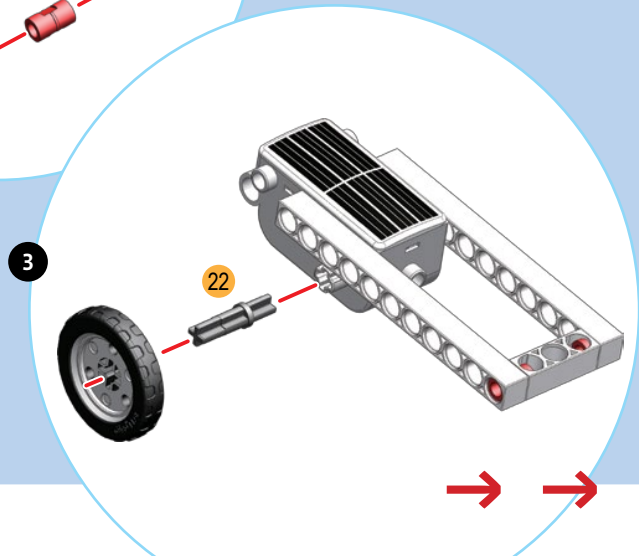
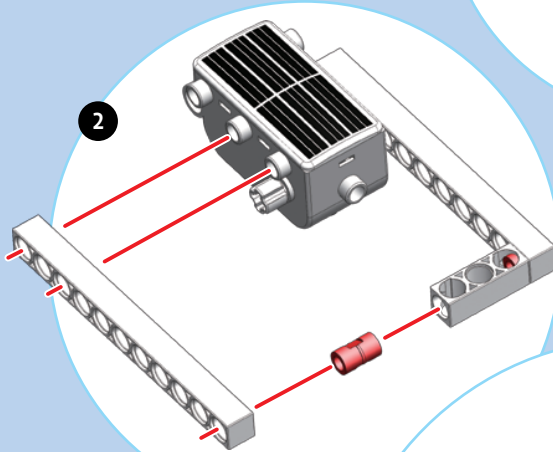
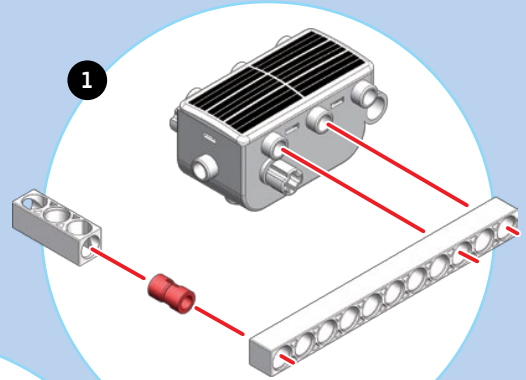
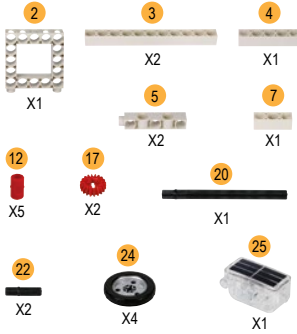


The NASA Helios Prototype was a solar- and fuel-cell-powered, remote-controlled, flying vehicle (NASA).

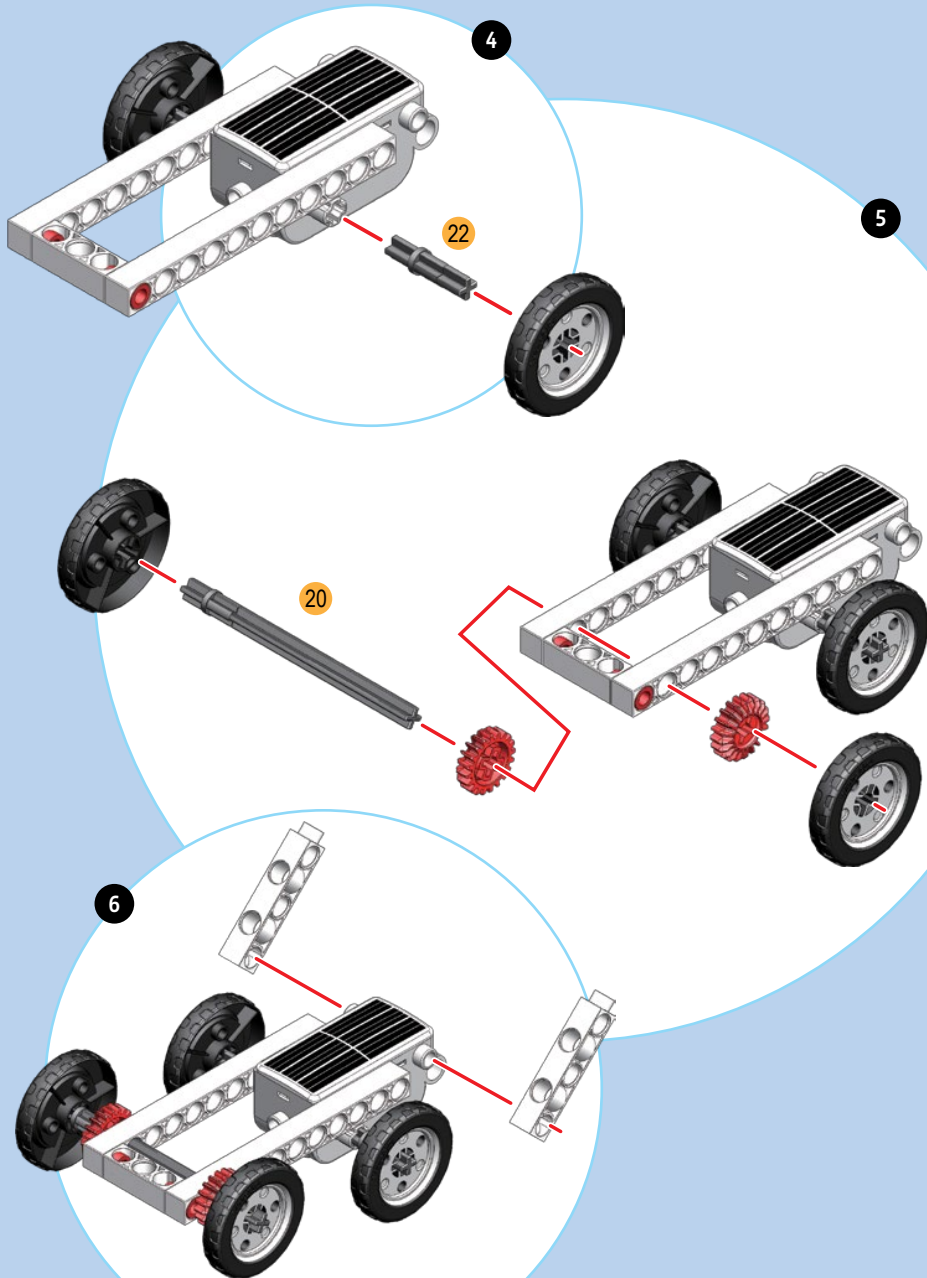
# Race car

## YOU WILL NEED

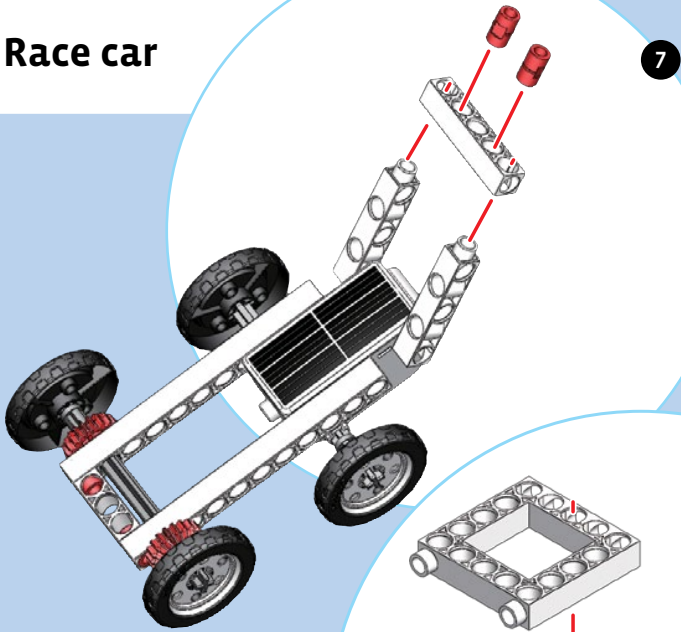
→ 22 parts from the kit:



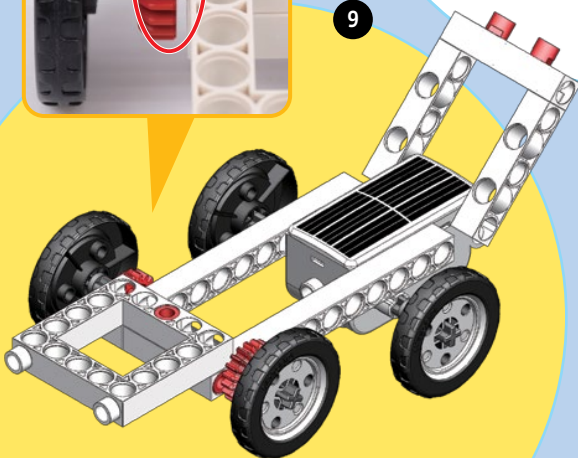
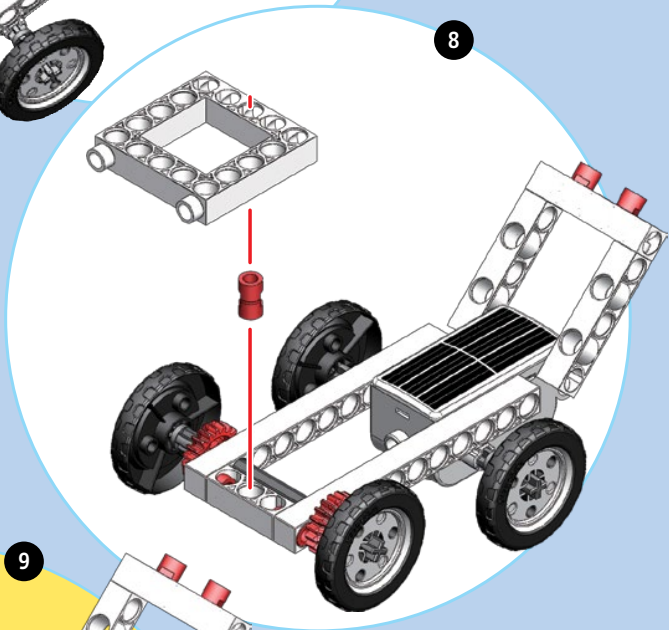
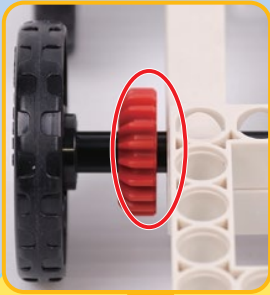
# Race car



# Race car



The model will run better with a 1 mm gap between the gear and frame.



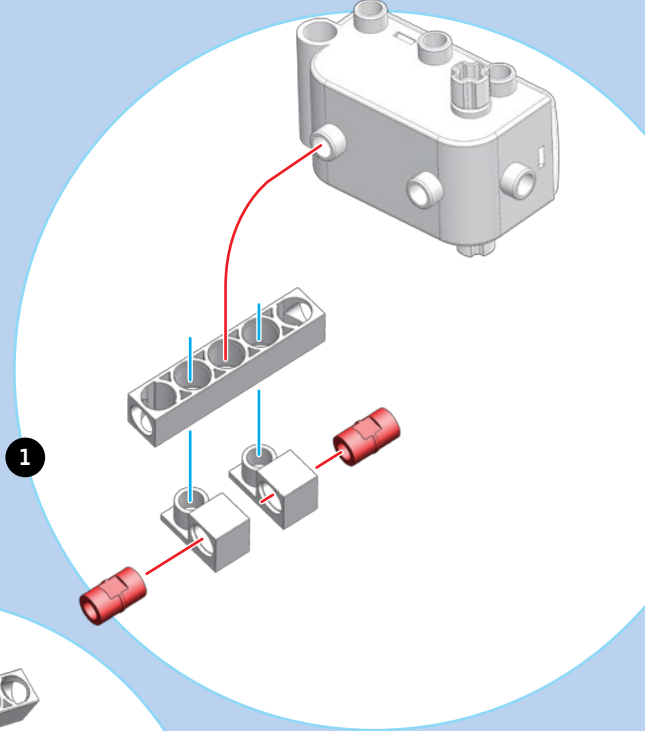
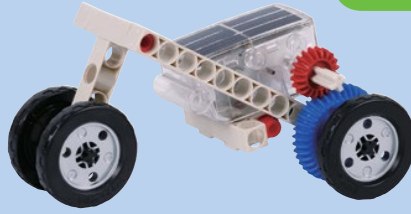
EXPERIMENT 12

# Motorcycle

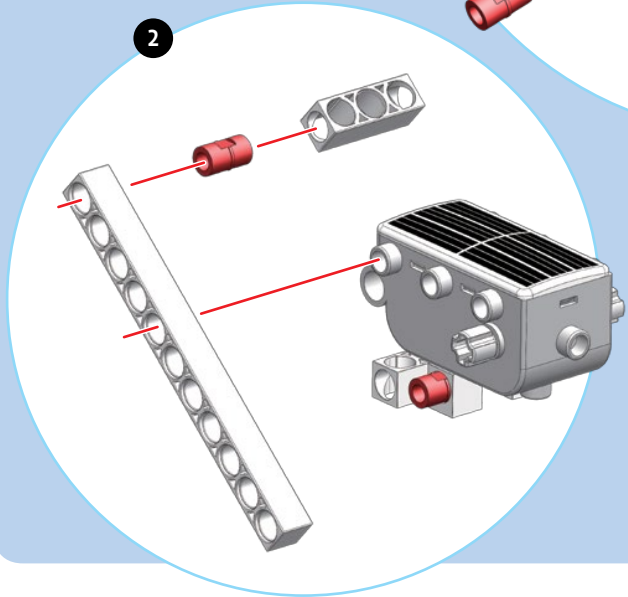
## YOU WILL NEED

→ 22 parts from the kit:

- |   |   |   |   |
|---|---|---|---|
|  |  |  |   |
| X2  | X1  | X1  |   |
|  |  |  |  |
| X1  | X2  | X4  | X1  |
|  |  |  |   |
| X1  | X1  | X1  |   |
|  |  |  |  |
| X1  | X1  | X4  | X1  |



1



2



# Motorcycle

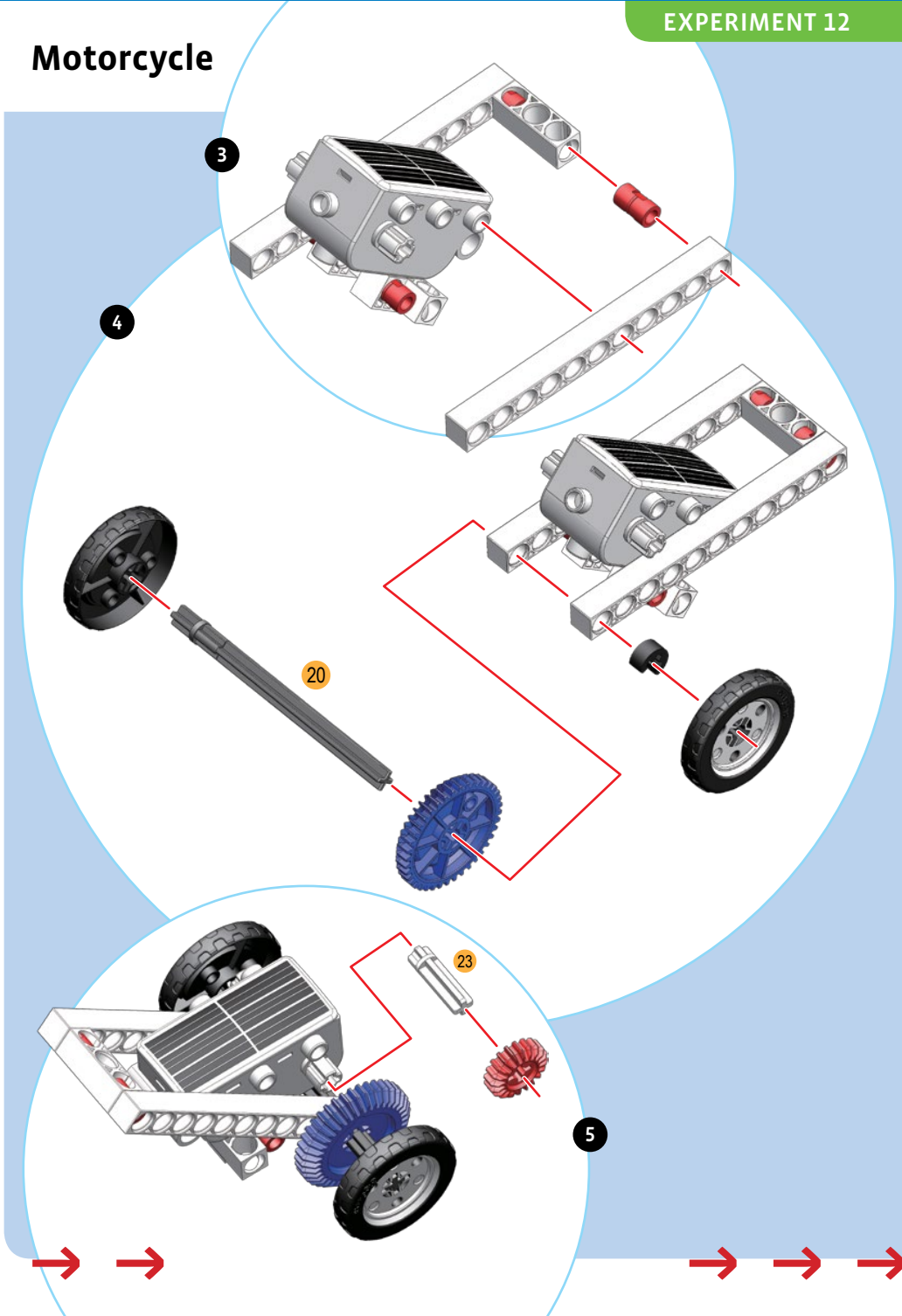
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4

20

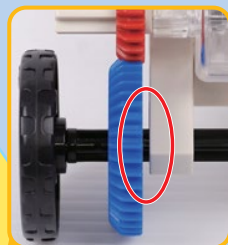
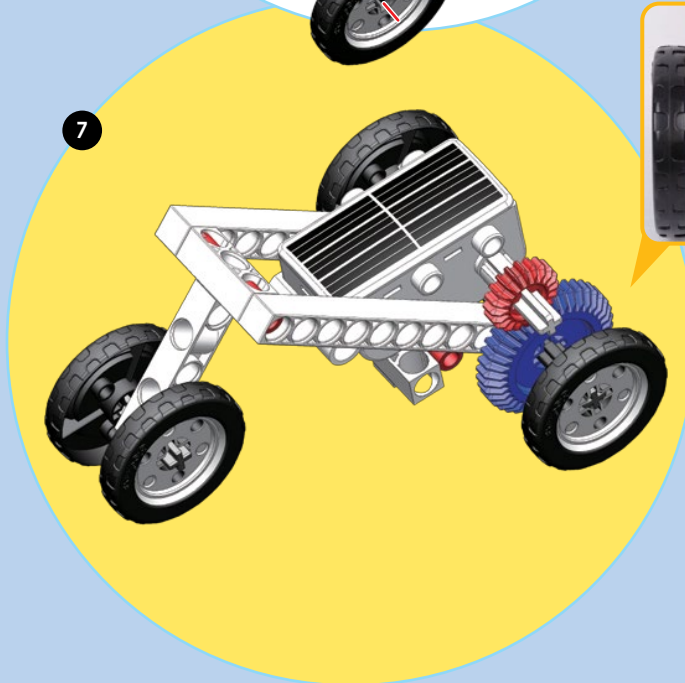
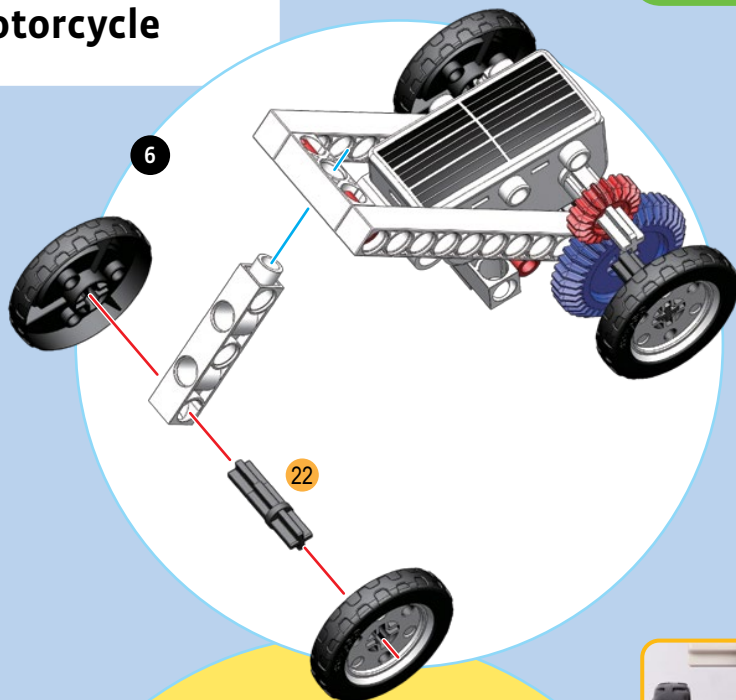
23

5





# Motorcycle



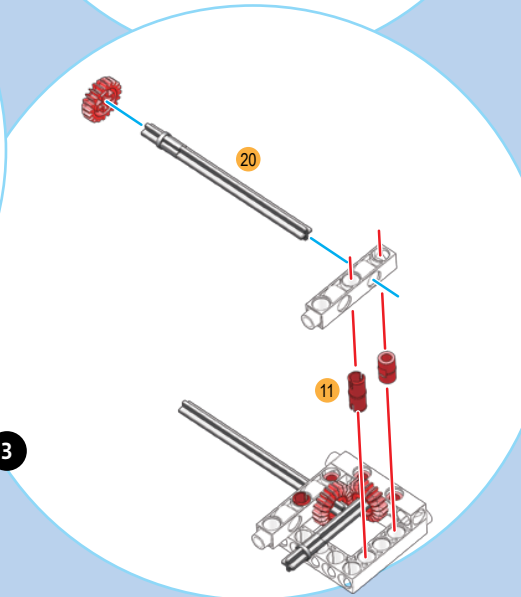
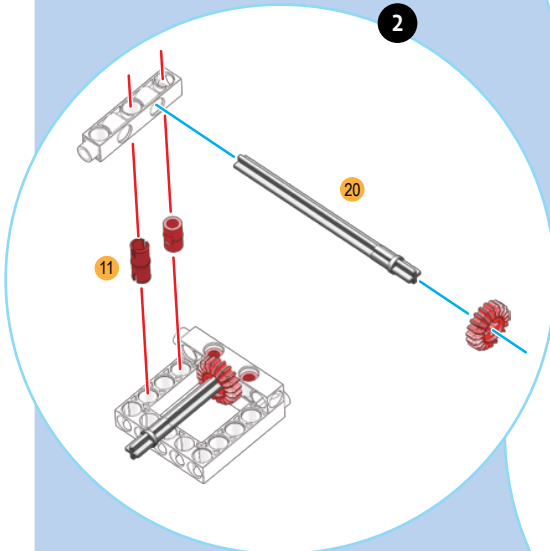
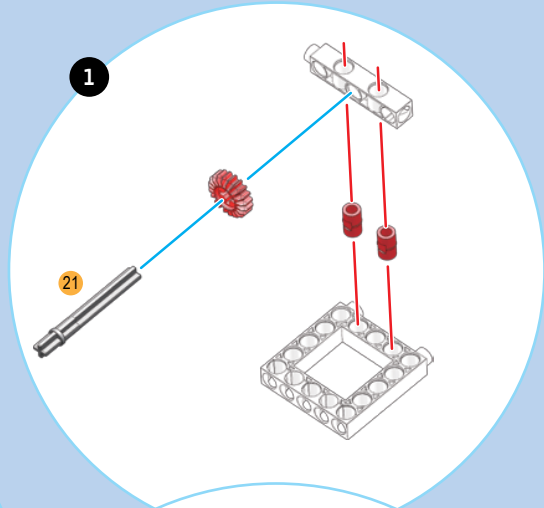
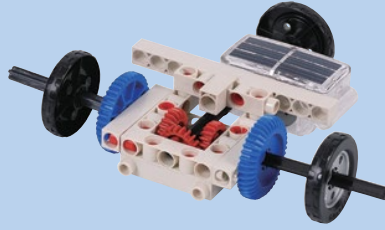
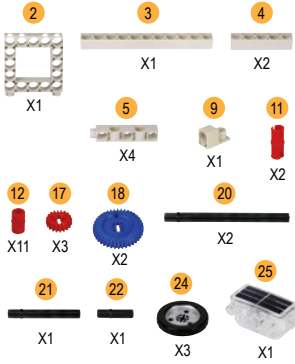
The model will run better with a 1 mm gap between the gear and frame.



# Gyrocar

## YOU WILL NEED

→ 35 parts from the kit:

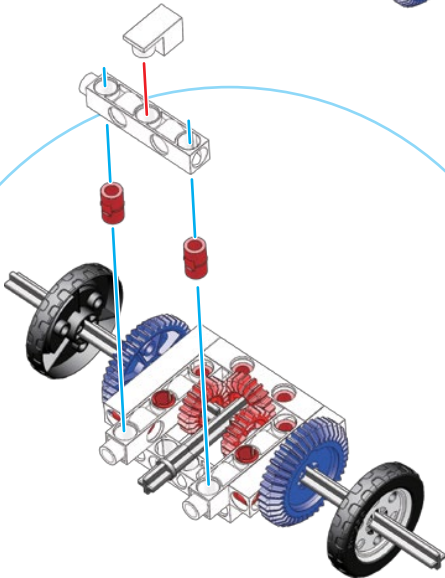
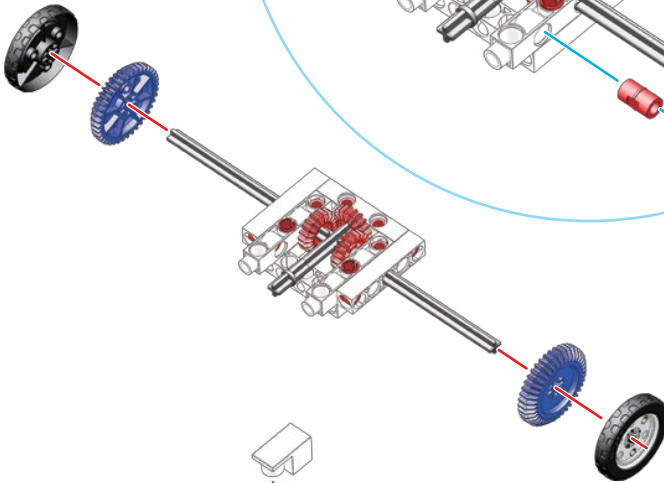
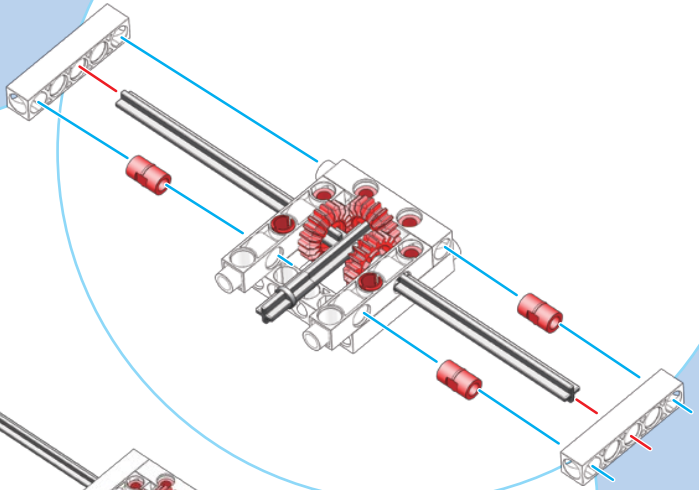


# Gyrocar

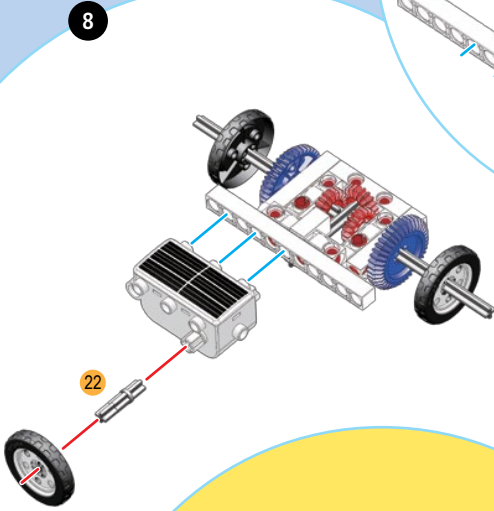
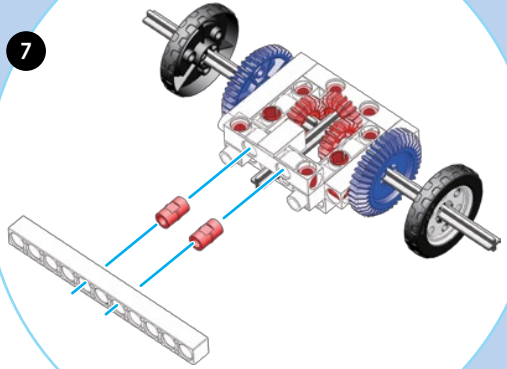
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5

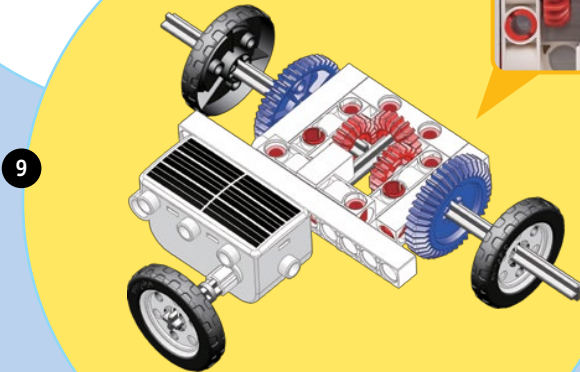
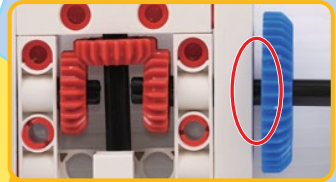
6



## Gyrocar





















The model will run better with 1 mm gaps between the gears and frames.

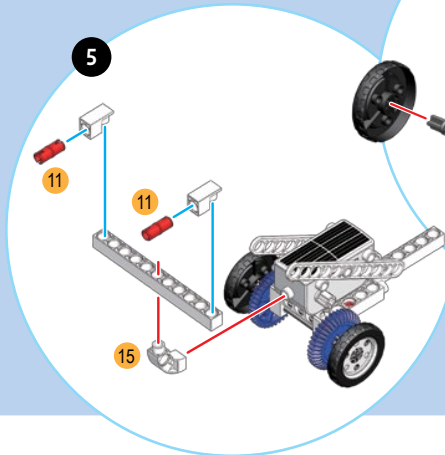
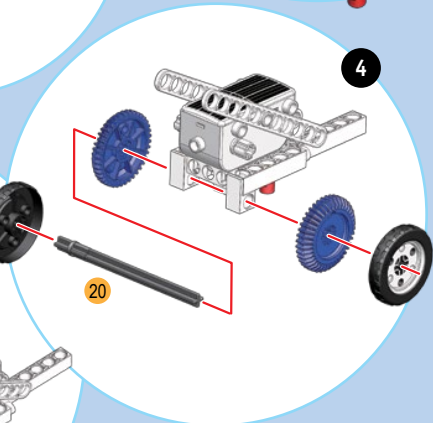
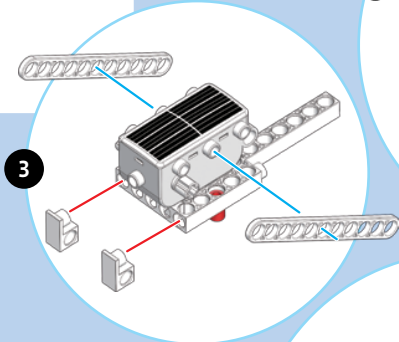
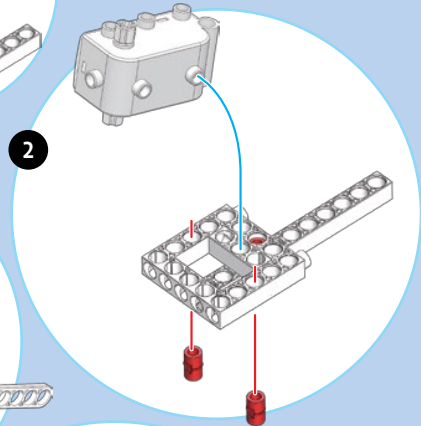
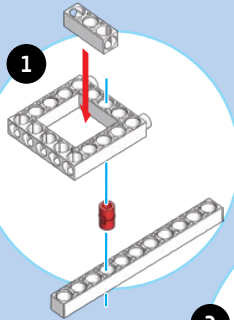


# Sports car

## YOU WILL NEED

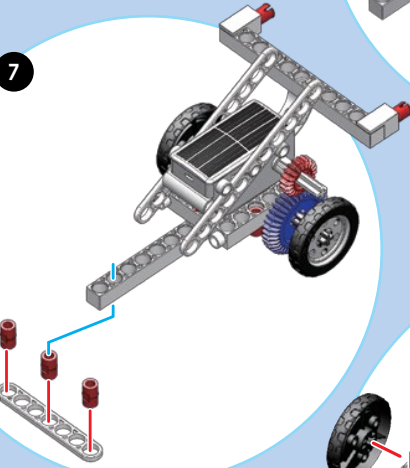
→ 44 parts from the kit:

- |  |   |   |
|--|---|---|
| <br>2<br>X1   | <br>3<br>X2  | <br>5<br>X4  |
| <br>8<br>X2   | <br>9<br>X2  | <br>11<br>X2 |
| <br>14<br>X2  | <br>15<br>X3 | <br>17<br>X1 |
| <br>20<br>X1  | <br>22<br>X2 | <br>23<br>X1 |
| <br>24<br>X4  | <br>25<br>X1 |   |
| <br>12<br>X11 | <br>7<br>X1  | <br>6<br>X2  |
| <br>18<br>X2  |   |   |

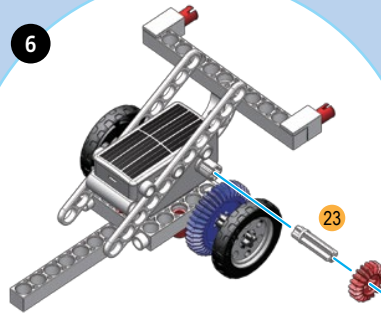


# Sports car

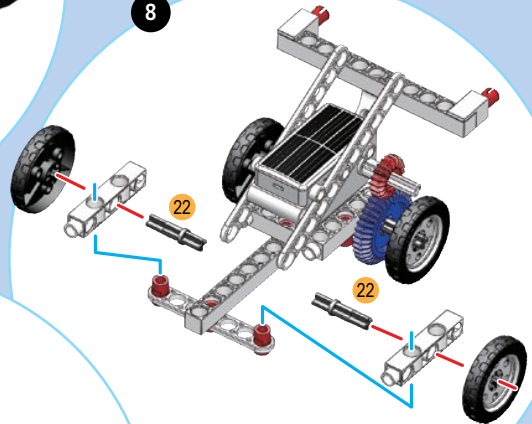
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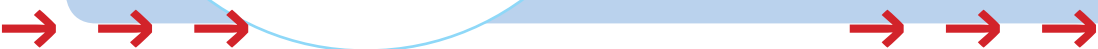
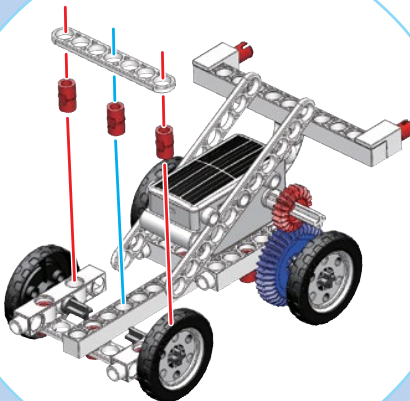
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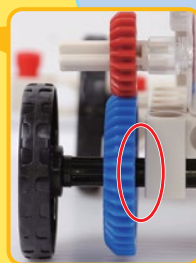
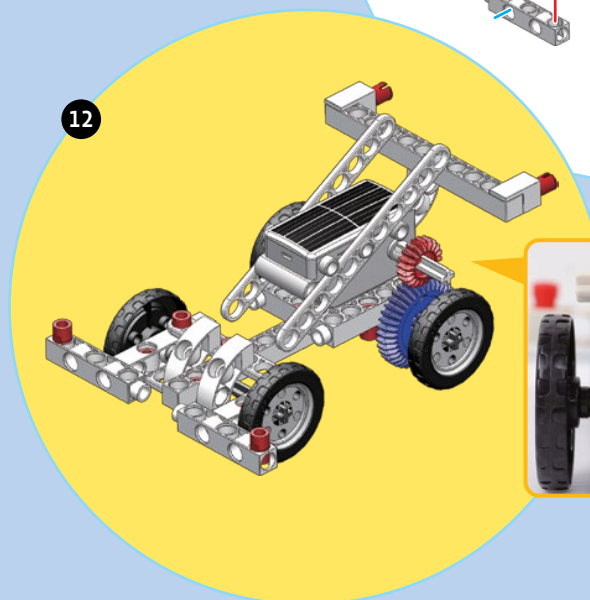
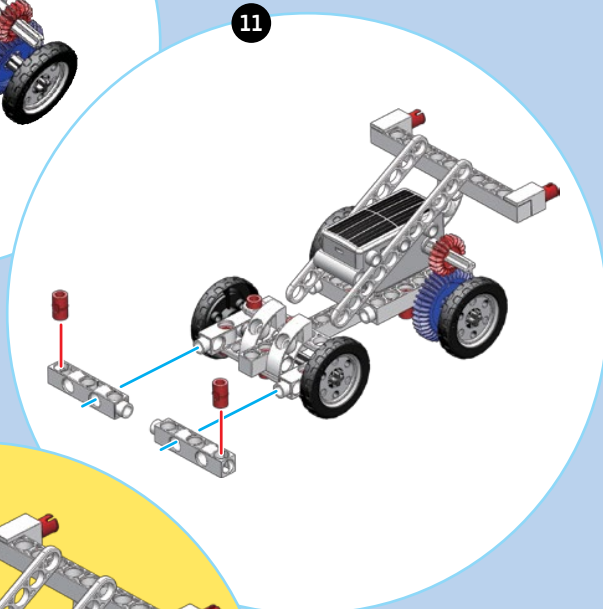
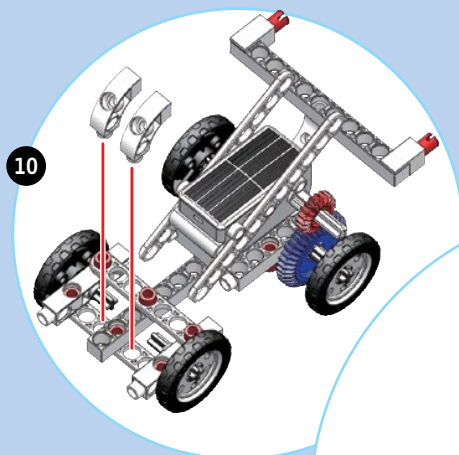
8



9



## Sports car



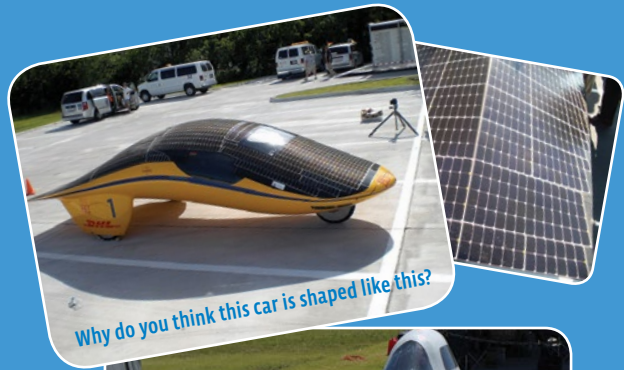
The model will run better with a 1 mm gap between the gear and frame.



# SOLAR VEHICLES IN THE REAL WORLD

In solar vehicle design, **weight** and **surface area** are two key factors: the lower the weight, the less power you need to move a vehicle — the greater the surface area, the more solar electricity you can produce. The challenge is that when you add surface area, you usually add weight.

Each year, engineers from around the world compete in the **World Solar Challenge**, a solar-powered car race that covers 1,877 miles from north to south across Australia.



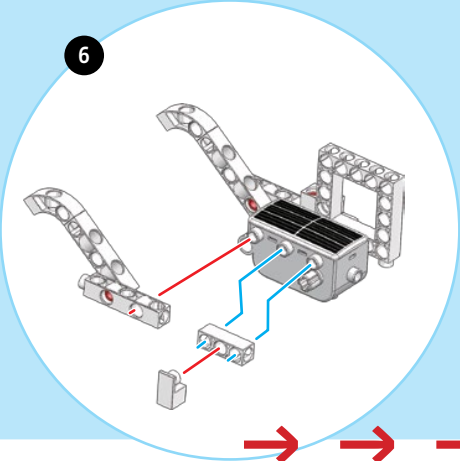
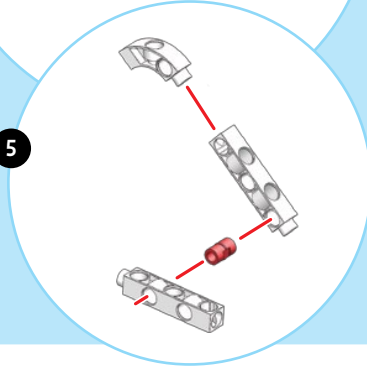
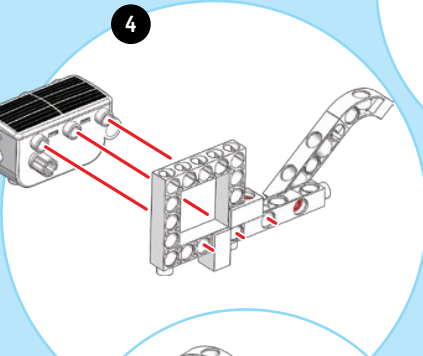
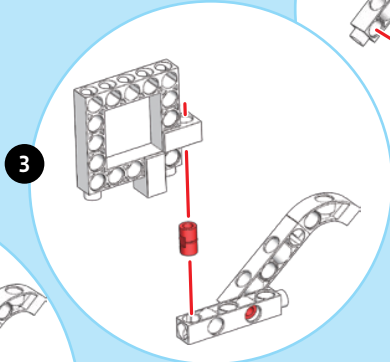
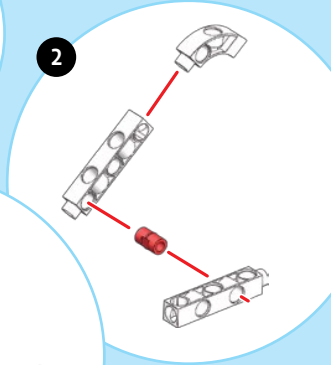
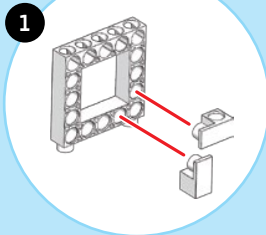
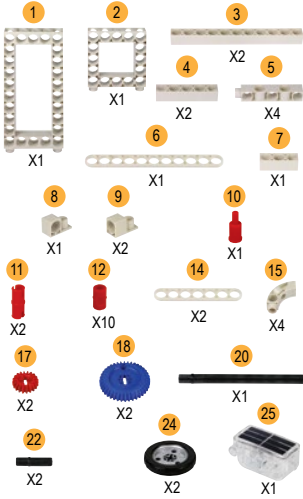
Solar-powered airplanes need huge wings to provide enough surface area to generate electricity sufficient to get the plane off the ground (NASA).



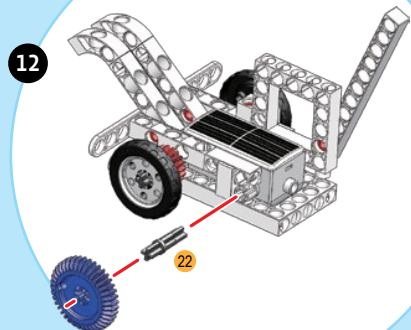
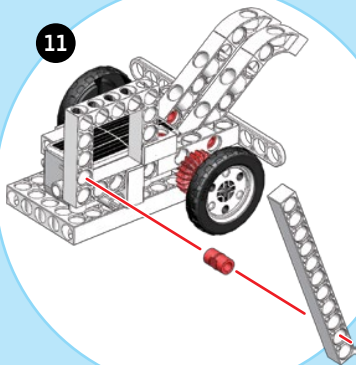
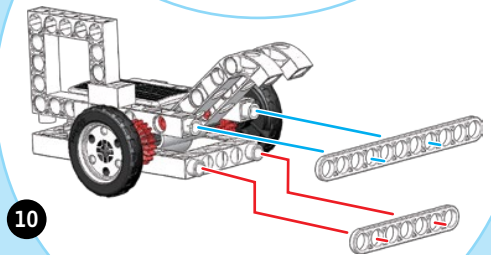
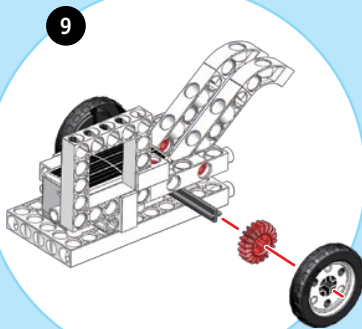
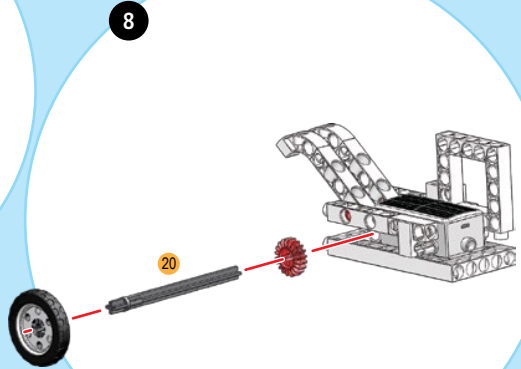
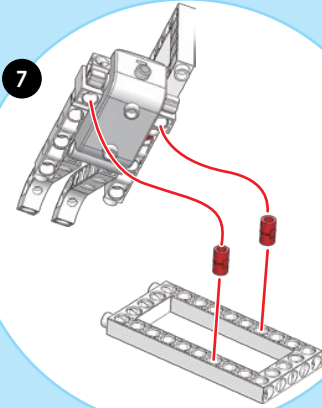
# Excavator

## YOU WILL NEED

→ 44 parts from the kit:

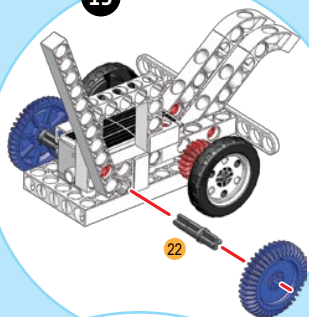


## Excavator

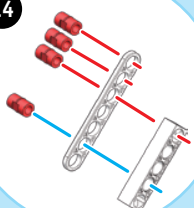


# Excavator

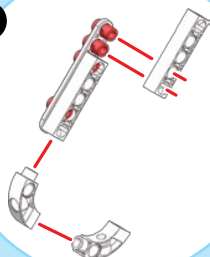
13



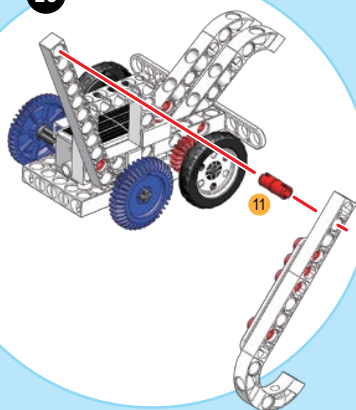
14



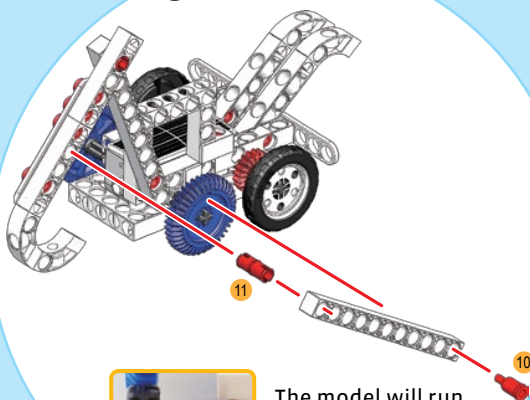
15



16



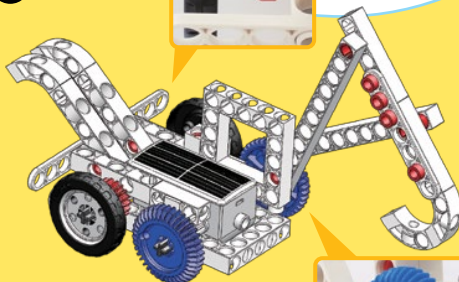
17



18



The model will run better with a 1 mm gap between the gear and frame.



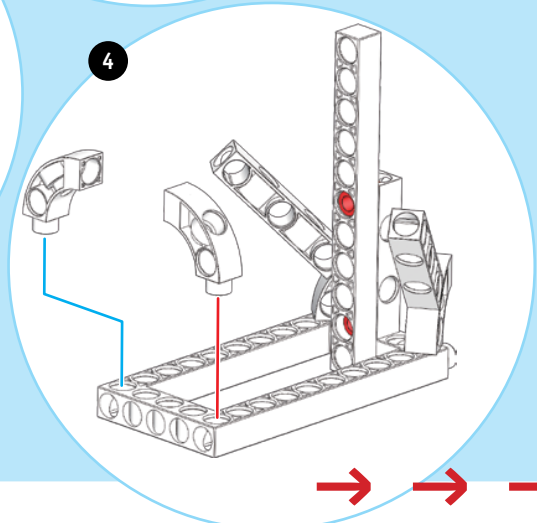
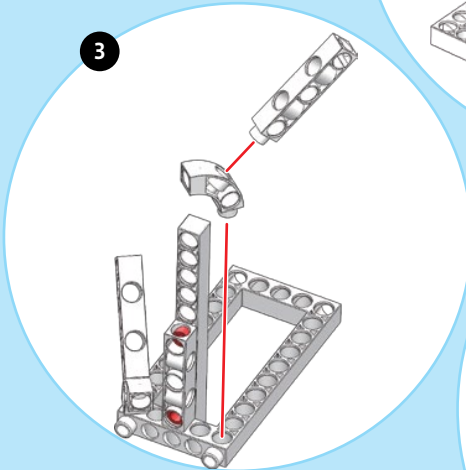
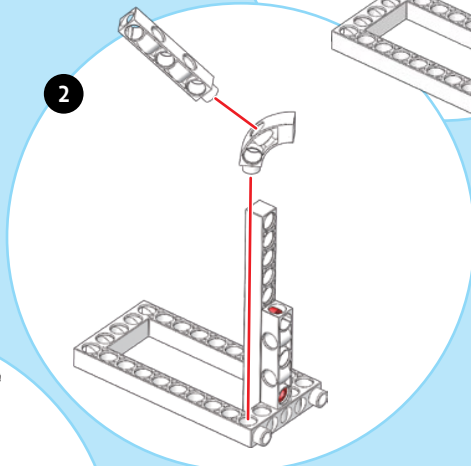
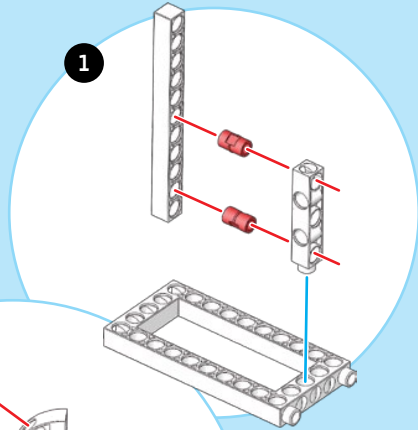
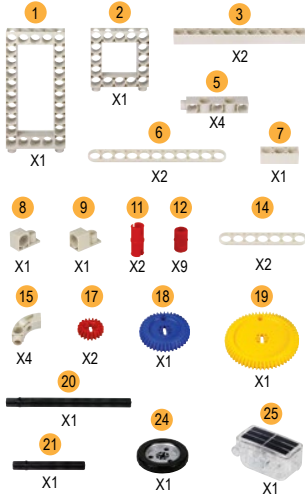
Make sure this axle does not stick out through the gear.



# Solar fan

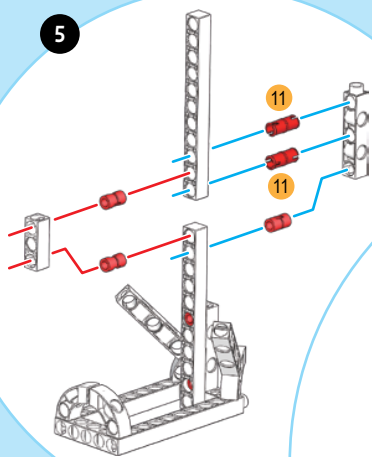
## YOU WILL NEED

→ 38 parts from the kit:

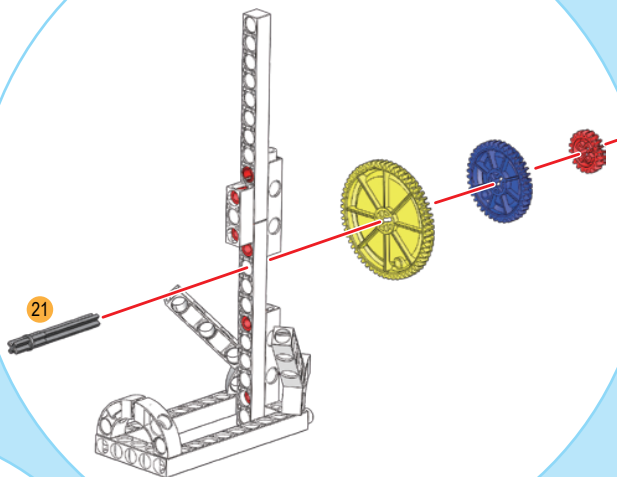


# Solar fan

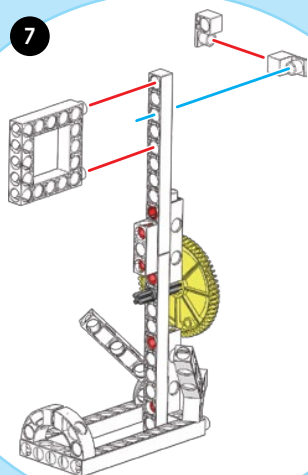
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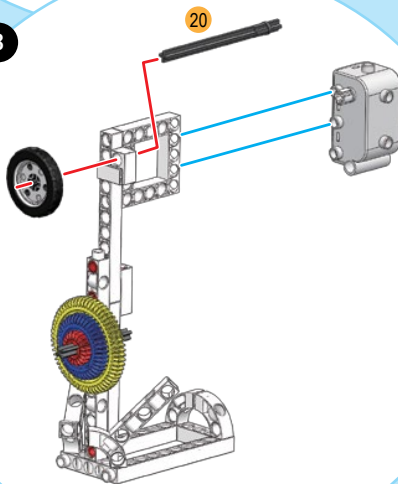
6



7

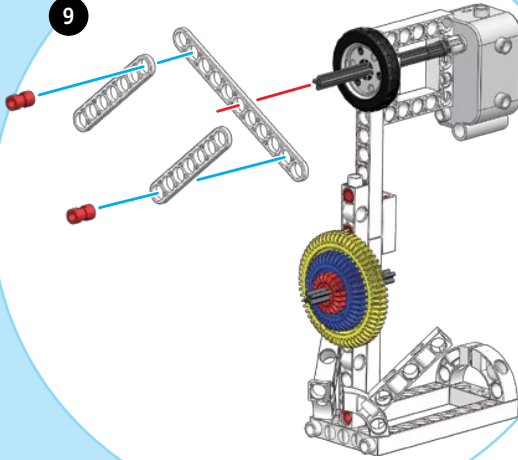


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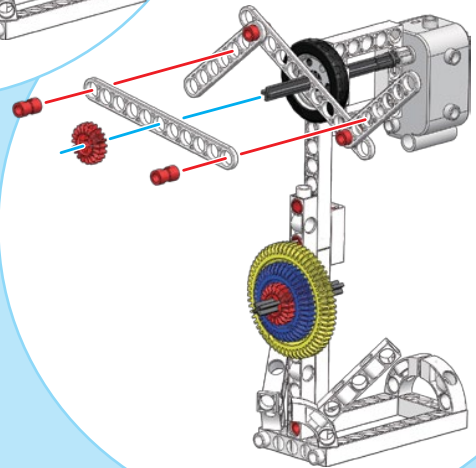


# Solar fan

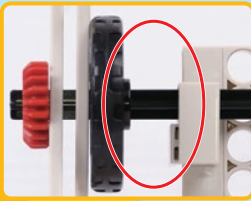
9



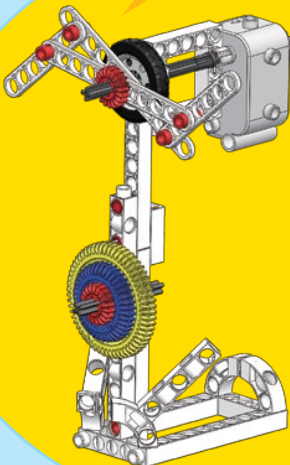
10



Leave a good distance between the wheel and frame.



11



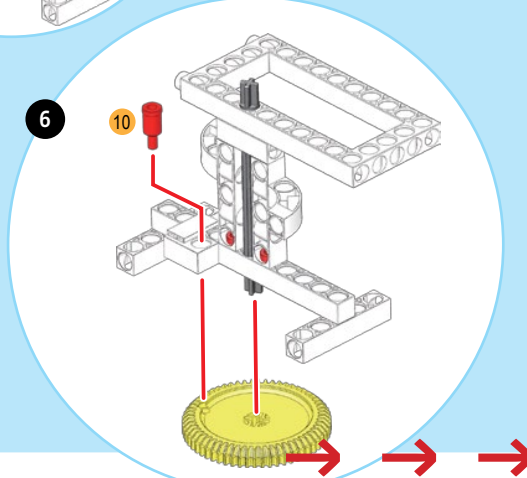
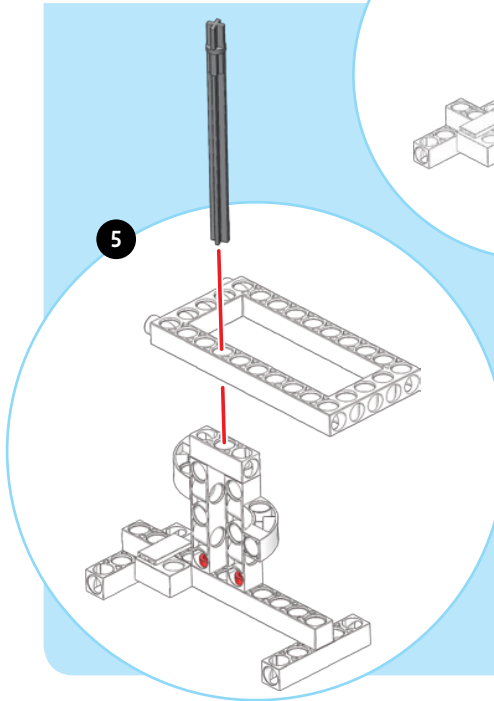
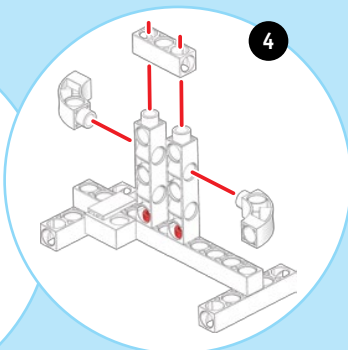
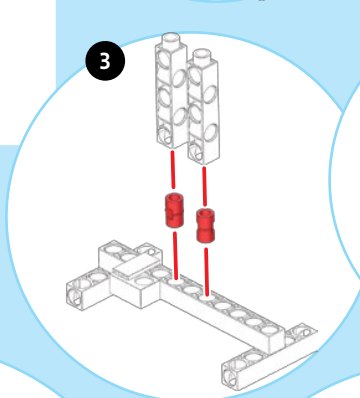
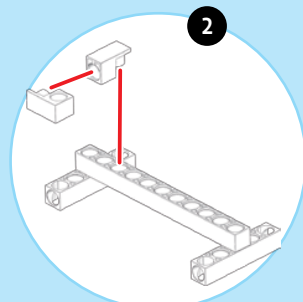
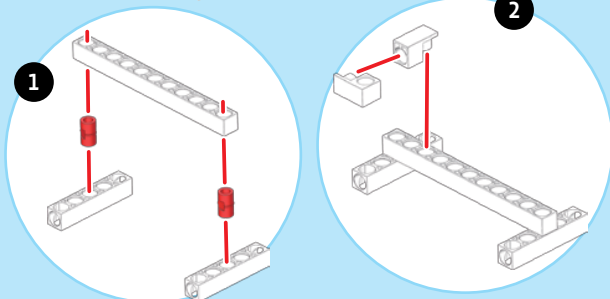
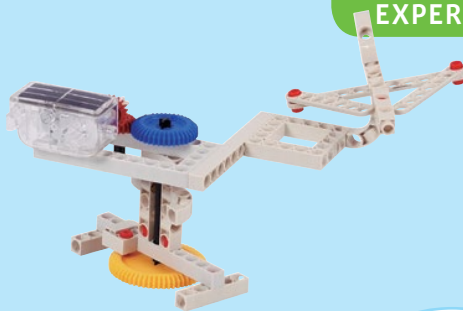
EXPERIMENT 17

# Rotating plane

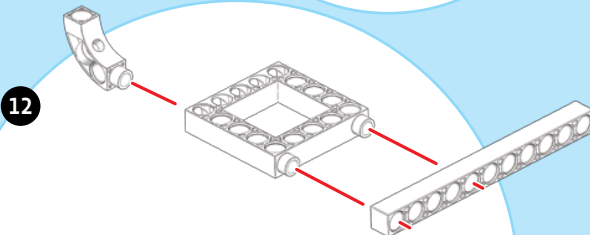
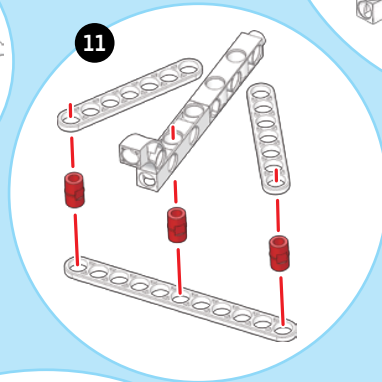
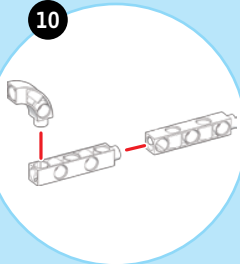
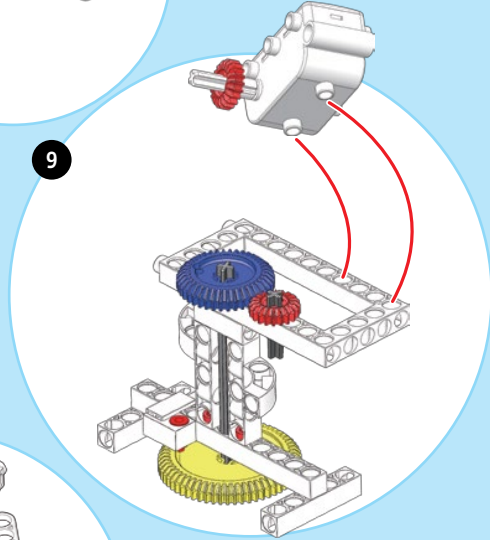
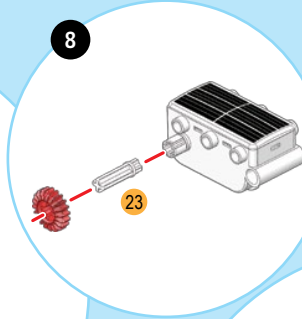
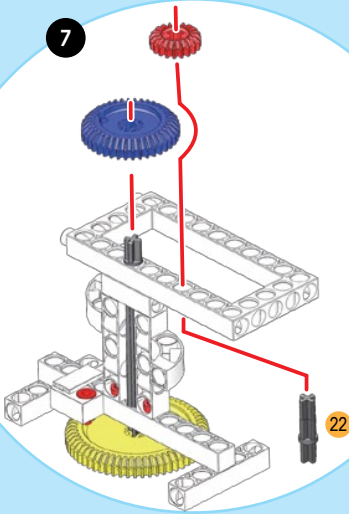
## YOU WILL NEED

→ 37 parts from the kit:

- 1 X1
- 2 X1
- 3 X2
- 4 X2
- 5 X4
- 6 X1
- 7 X1
- 8 X1
- 9 X1
- 10 X1
- 12 X8
- 14 X2
- 15 X4
- 17 X2
- 18 X1
- 19 X1
- 20 X1
- 22 X1
- 23 X1
- 25 X1



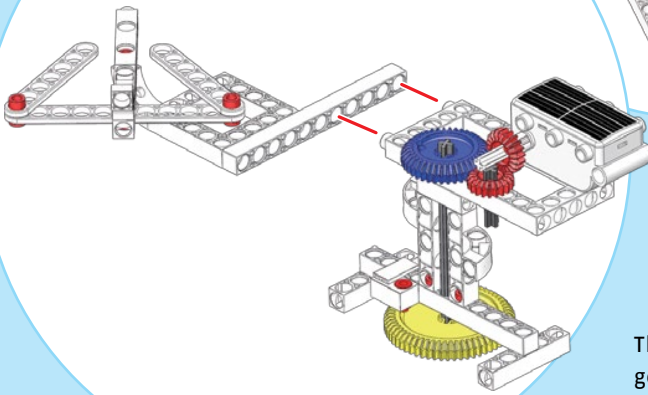
# Rotating plane



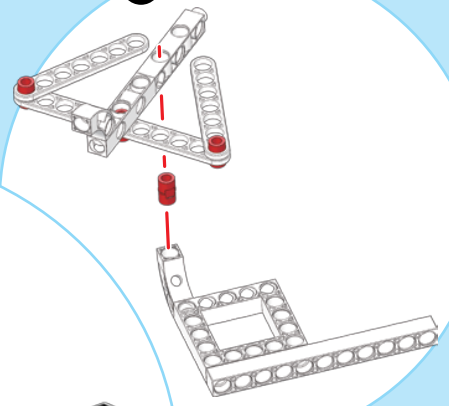


# Rotating plane

14

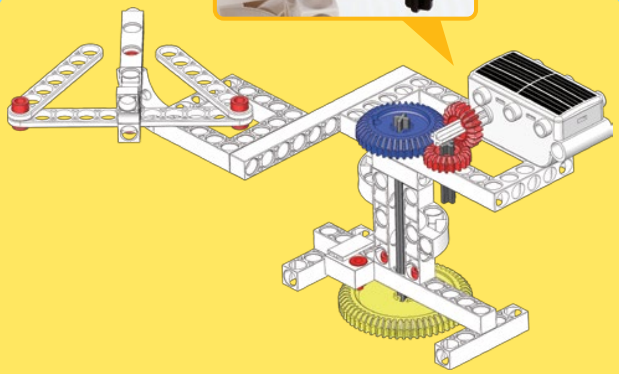


13



The small and medium gears must be meshing.

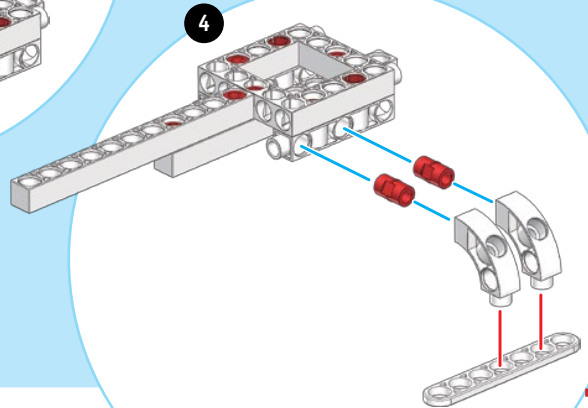
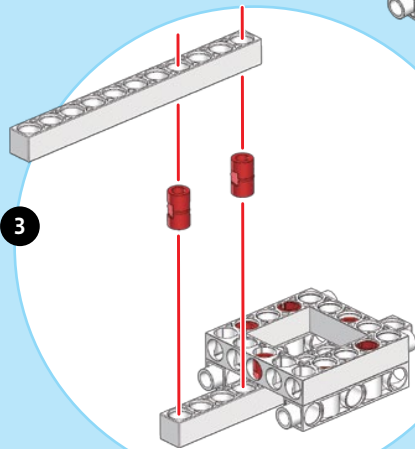
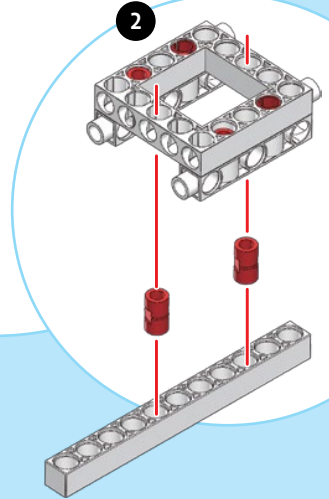
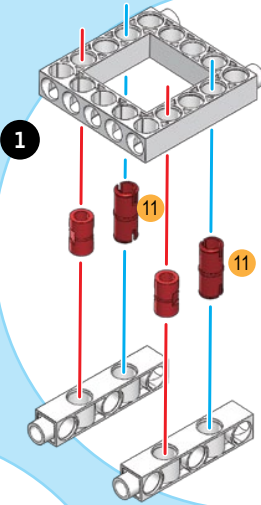
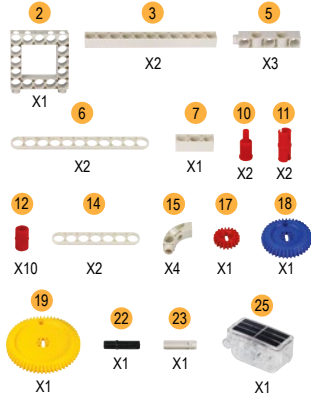
15



# Helicopter

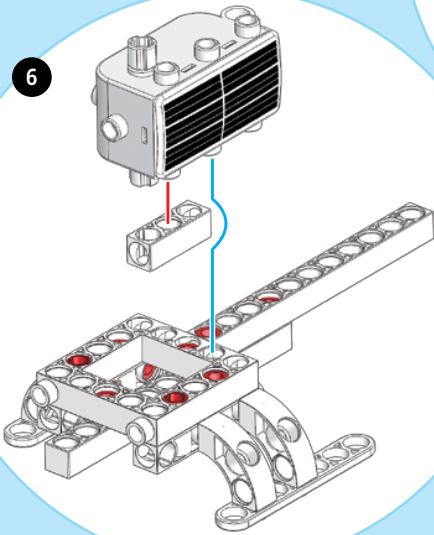
## YOU WILL NEED

→ 35 parts from the kit:

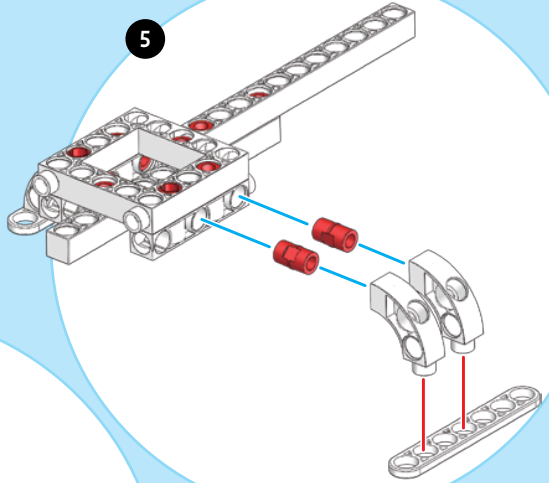


# Helicopter

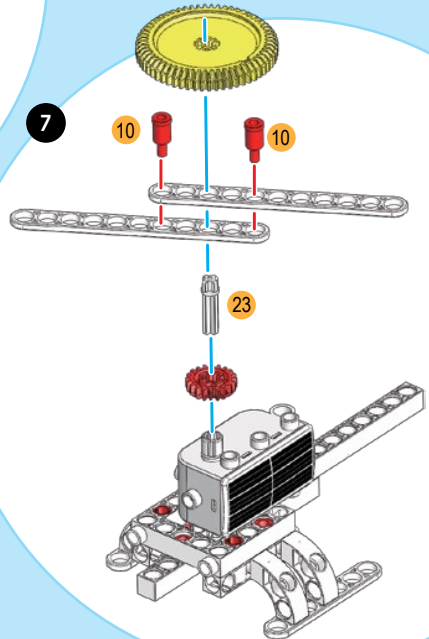
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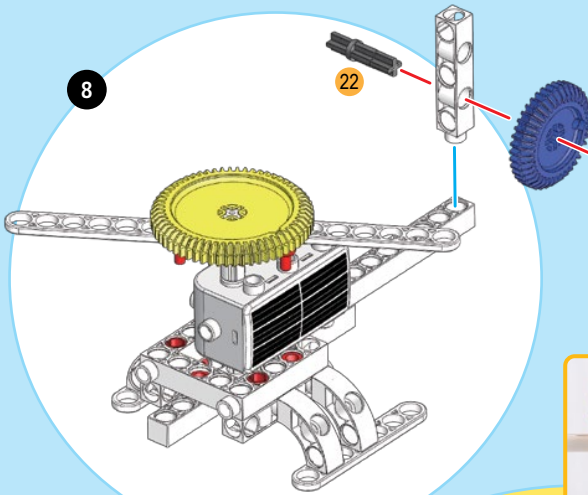
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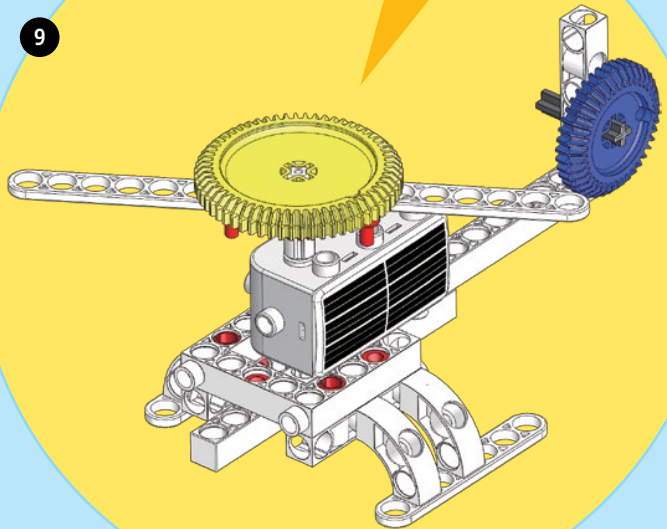
7



# Helicopter



Make sure there is a good distance between the small gear and the solar motor unit.

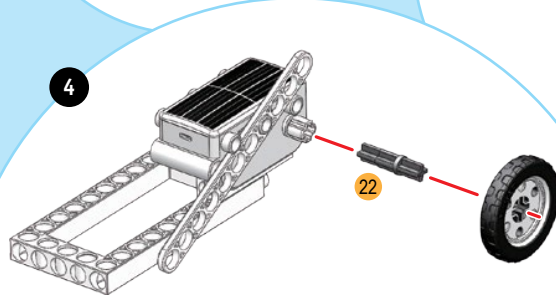
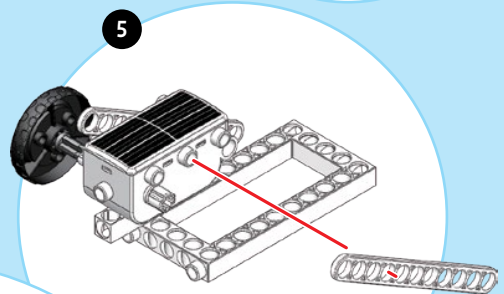
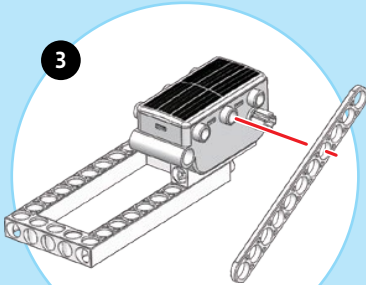
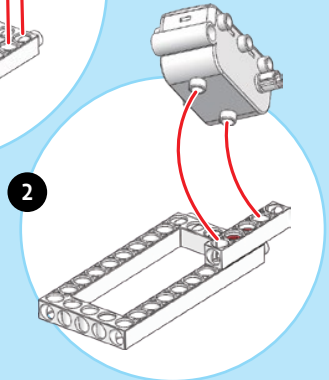
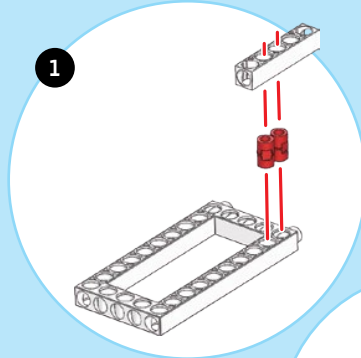


# Hammer machine

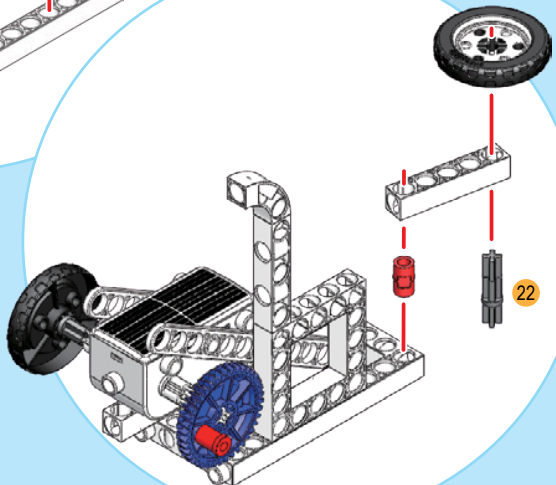
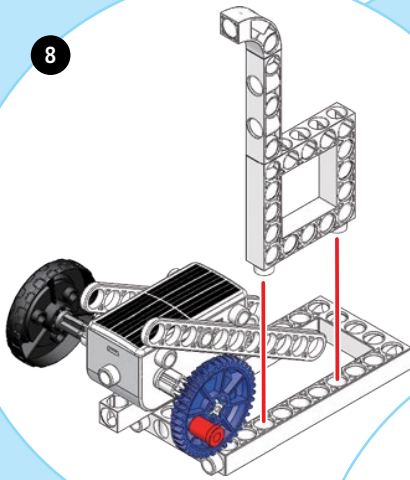
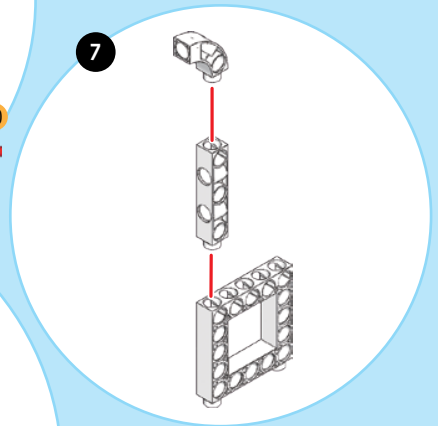
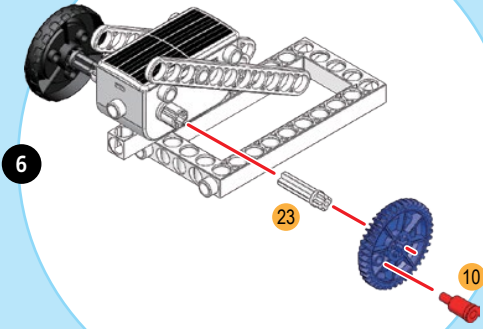
## YOU WILL NEED

→ 29 parts from the kit:

- 1 X1
- 2 X1
- 3 X1
- 4 X2
- 5 X2
- 6 X2
- 7 X1
- 8 X1
- 9 X1
- 10 X1
- 11 X1
- 12 X6
- 14 X1
- 15 X1
- 18 X1
- 22 X2
- 23 X1
- 24 X2
- 25 X1



# Hammer machine

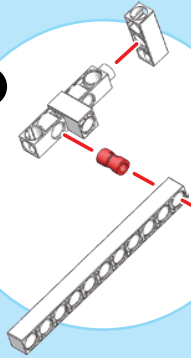


# Hammer machine

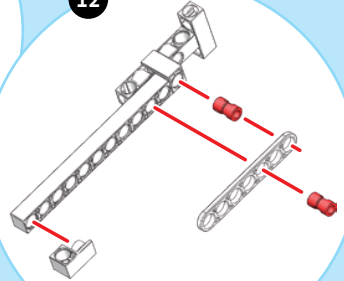
10



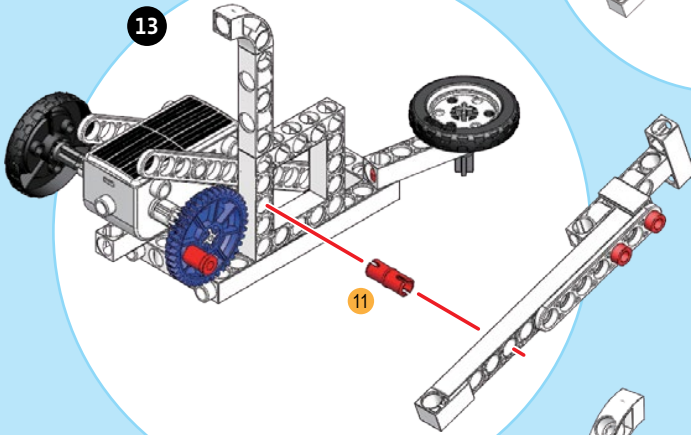
11



12

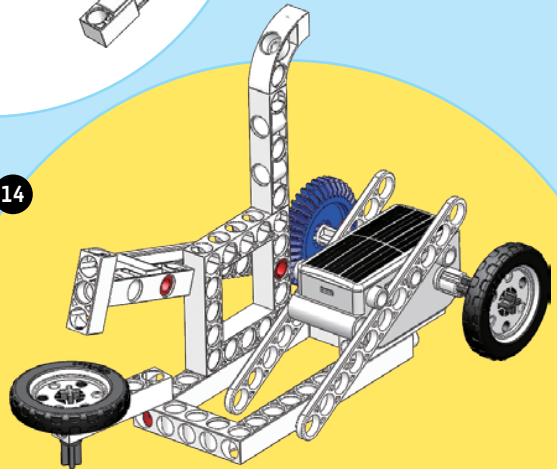


13



11

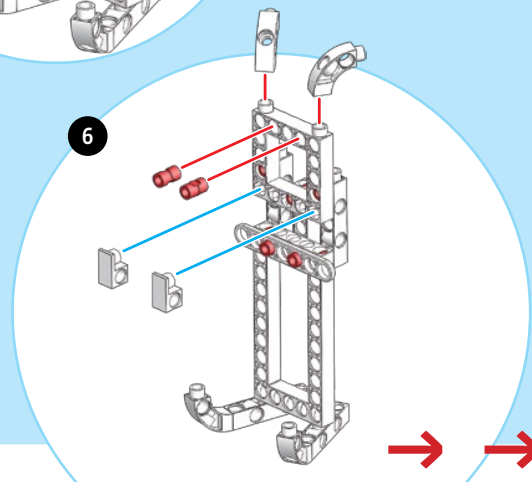
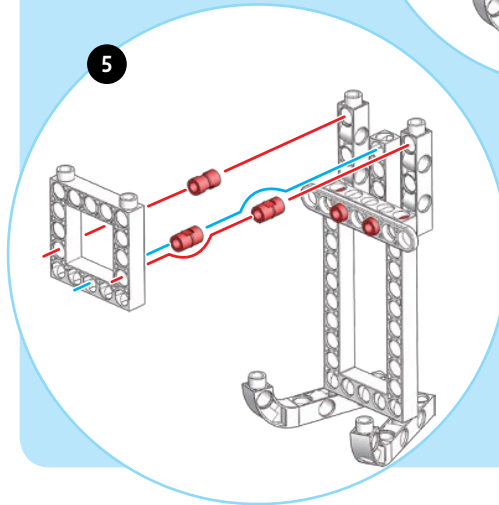
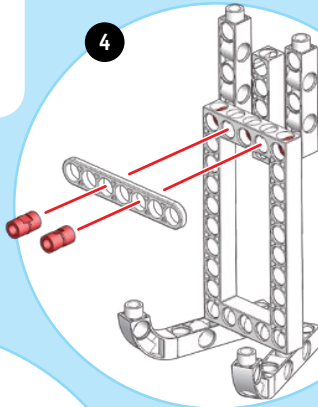
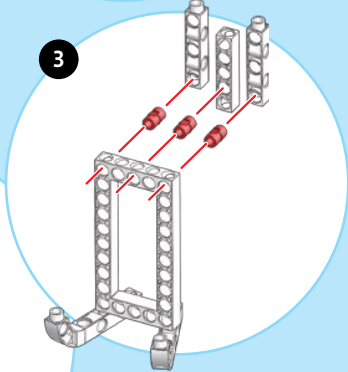
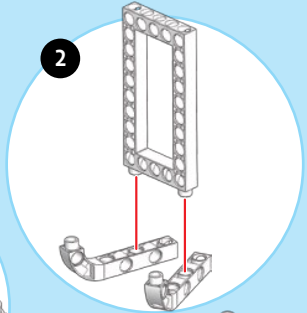
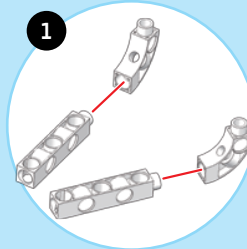
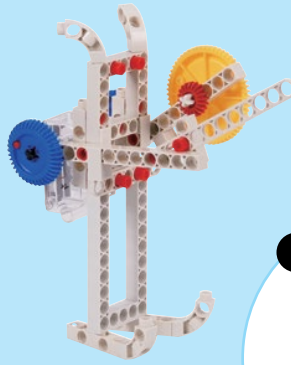
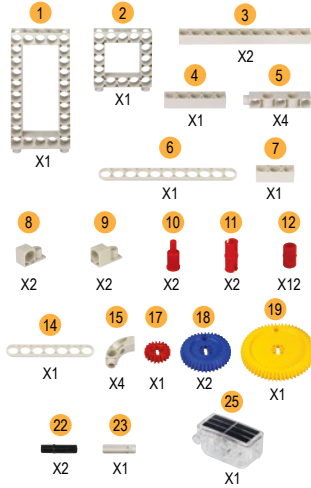
14



# Robot knight

## YOU WILL NEED

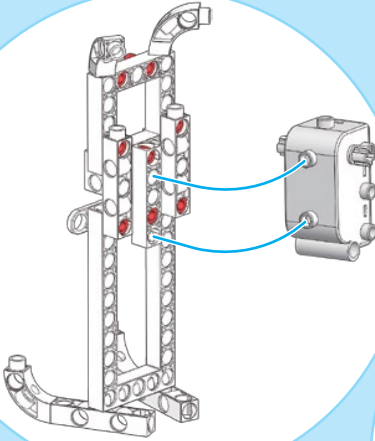
→ 44 parts from the kit:



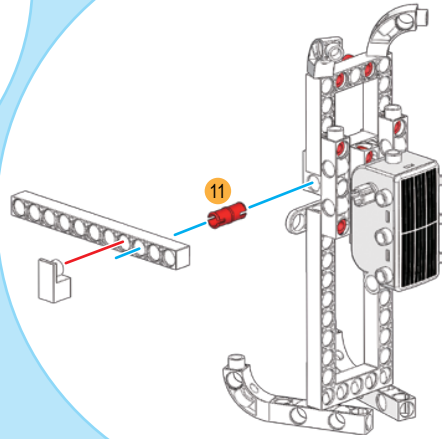


# Robot knight

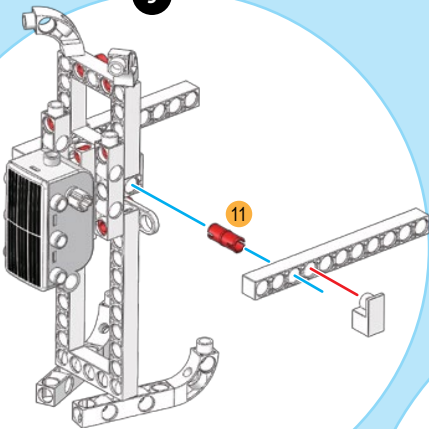
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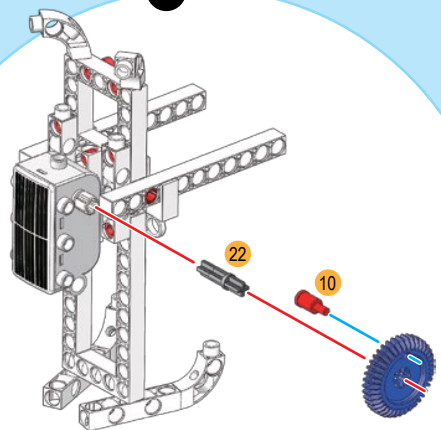
8



9

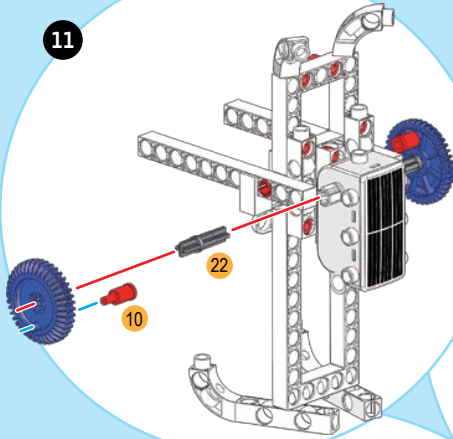


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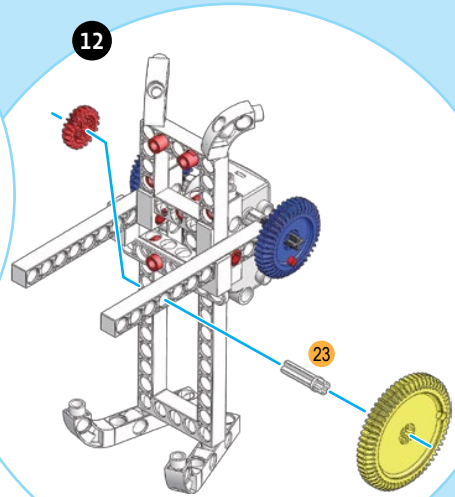


# Robot knight

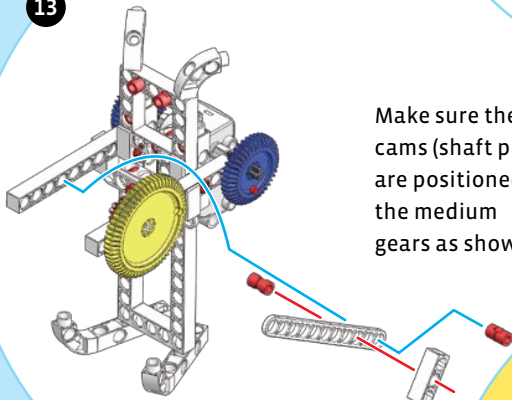
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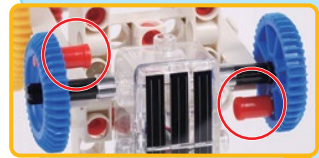
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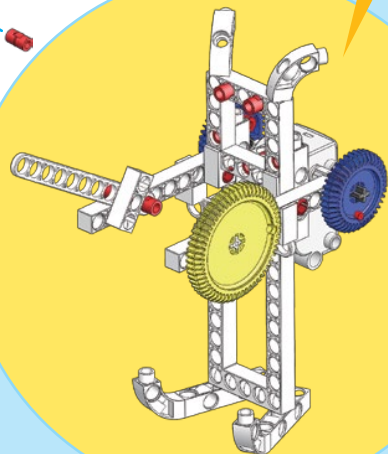
13



Make sure the cams (shaft pins) are positioned in the medium gears as shown.



14



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Distributed in North America by Thames & Kosmos, LLC. Providence, RI 02903  
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# The most important units of measure in physical science:

The unit of length is the meter (1 m).

→ 1 m = 100 centimeters (cm) = 1,000 millimeters (mm)

→ 1,000 m = 1 kilometer (km)

The unit of volume is the cubic meter (1 m<sup>3</sup>).

→ 1 m<sup>3</sup> corresponds to a cube with sides 1 m in length.

→ 1 m<sup>3</sup> = 1,000 liters (L)

→ 1 L = 1 cubic decimeter (dm<sup>3</sup>) = 1,000 cubic centimeters (cm<sup>3</sup>) = 1,000 milliliters (ml)

The unit of angle is the degree (°).

→ A complete circle is divided into 360°;

→ A right angle has 90°, a semicircle has 180°.

The unit of time is the second (s).

→ 3,600 s = 60 minutes (min) = 1 hour (h)

The unit of mass is the kilogram (kg).

→ 1 kg = 1,000 grams (g) = 1,000,000 milligrams (mg)

The unit of speed is meters per second (m/s).

→ This unit indicates the distance covered in a certain amount of time, which is also measured in kilometers per hour (km/h).

→ 1 m/s = 3.6 km/h

The unit of force is the newton (N).

→ 1 N is the force needed to accelerate (to make go faster) a mass of 1 kg by 1 m/s in 1 second. The unit of weight (force of gravity) is likewise the newton (N).

→ In everyday life we normally use mass, indicated in kilograms (kg). The force of gravity acting on the mass of 1 kg at Earth's surface equals 9.81 N.