

EXPERIMENT MANUAL

SOLAR- Powered Rovers



THAMES & KOSMOS

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>>> IMPORTANT INFORMATION

SAFETY INFORMATION

>>> **Warning!** Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled.

>>> Keep the packaging and instructions as they contain important information.

>>> Store the experiment material and assembled models out of the reach of small children.

>>> A parent or other adult should supervise all outdoor experiments with the models. Outdoor experiments should not be conducted near streets.

>>> Be careful when inserting the wooden dowels into the plastic components. If you put too much force on them, they can warp, splinter, or break. Do not injure yourself!

Dear Parents,

Physics is an exciting and varied science that is not hard to understand, especially when you use fun models to demonstrate physics principles in action. It can be a lot of fun to figure out the astonishing physical phenomena that we encounter every day and to put this understanding to use.

This experiment kit and the working models you can build with it introduce your child to physical science topics including solar power and energy transformation.

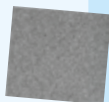
The individual experimental models are assembled step by step using an adjustable building system. It will require a little practice and patience at first. And your child will be particularly happy to have your help with the models that he or she finds more difficult. Please help your child each step of the way.

We wish you and your child lots of fun experimenting, discovering, and learning!

TIPS

WORKING WITH BAMBOO

Bamboo is a super strong natural material. The thickness of the bamboo dowels can vary, as the material can be affected by humidity and other factors. When working with the bamboo dowels, you may find that some of them do not slide easily into the plastic connectors. If a bamboo dowel does not slide smoothly into a connector, try the other end of the dowel or a different bamboo dowel. We have included a piece of sandpaper. With the sandpaper, you can sand down the bamboo dowel to reduce its thickness.



PART SEPARATOR TOOL

When you want to take one model apart to build another one, you will need the part separator tool. Use the narrow end of the lever to remove anchor pins. Use the wide end to pry up bushings and gears.



USING THE SOLAR PANEL

The solar panel will generate enough power to drive the models in this kit when the irradiance on the solar panel is greater than 650 W/m^2 (watts per square meter). Sunlight outside on a sunny day is certainly powerful enough, and even some indoor light sources are sufficient. Experiment with different light sources!

Follow these tips for the best driving performance:

- Make sure the axles spin freely.
- Find and remove any obstacles.
- Use the models on flat, smooth surfaces.
- Use a powerful enough light source.
- Change the gear train to give the driven axle more power.

>>> KIT CONTENTS

GOOD TO KNOW! If you are missing any parts, please contact Thames & Kosmos customer service.

US: techsupport@thamesandkosmos.com
UK: techsupport@thamesandkosmos.co.uk

What's inside your experiment kit:

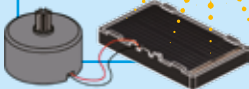


Checklist: Find – Inspect – Check off

✓ No.	Description	Qty.	Item No.
<input type="radio"/> 1	Short anchor pin	1	7344-W10-C2D
<input type="radio"/> 2	Two-to-one converter	2	7061-W10-G1S2
<input type="radio"/> 3	90-degree converter X	2	7061-W10-X1D
<input type="radio"/> 4	1-hole connector	1	7430-W10-B1S
<input type="radio"/> 5	String connector, black	1	7410-W10-B1D
<input type="radio"/> 6	String connector, gray	2	7410-W10-B1S
<input type="radio"/> 7	3-hole dual rod	4	7413-W10-Y1S2
<input type="radio"/> 8	5-hole rod	1	7413-W10-K2D
<input type="radio"/> 9	Bamboo dowel, 90 mm	6	R36#7402-1
<input type="radio"/> 10	Bamboo dowel, 150 mm	1	R36#7402-2
<input type="radio"/> 11	Retaining ring	9	7388-W10-H2D
<input type="radio"/> 12	Bushing	4	7388-W10-H1D
<input type="radio"/> 13	Hook connector (U-shape)	2	7403-W10-B1D

✓ No.	Description	Qty.	Item No.
<input type="radio"/> 14	Bridge connector (H-shape)	2	7403-W10-B2D
<input type="radio"/> 15	150-degree connector	2	7403-W10-A2D
<input type="radio"/> 16	Wheel	4	7388-W10-L1D
<input type="radio"/> 17	Mini gear, 10-teeth	1	7388-W10-D1S
<input type="radio"/> 18	Mini gear, 20-teeth	2	7422-W10-D1S
<input type="radio"/> 19	Mini gear, 30-teeth	1	7388-W10-E1S
<input type="radio"/> 20	Solar cell (1V) and motor set	1	7422-W85-A
<input type="radio"/> 21	Tripod connector	1	7422-W10-B1D
<input type="radio"/> 22	Motor housing	1	7422-W10-C2D
<input type="radio"/> 23	Die-cut plastic sheet of panels	1	K41#7422-1
<input type="radio"/> 24	Sand paper	1	E41-18
<input type="radio"/> 25	Part separator tool	1	7061-W10-B1Y

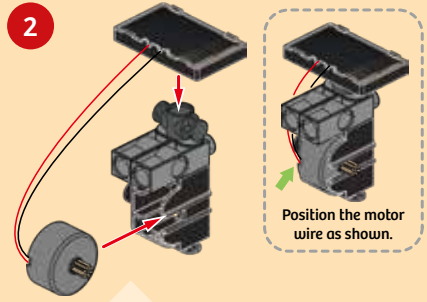
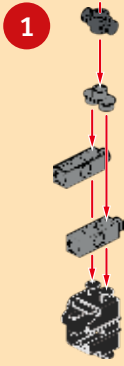
SOLAR PANEL TEST



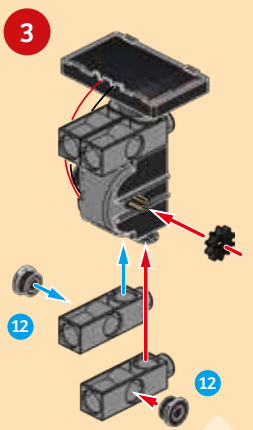
Place part 20, the solar cell and motor assembly, in direct sunlight. As soon as enough light energy strikes the solar panel, the motor shaft starts spinning. The solar shaft (the solar cell together with its frame) is a little photovoltaic system. These systems convert light energy — whether from

the sun or from a powerful artificial light source — into electric current. Electric current is nothing more than electrons flowing in a conductive material. Electrons are the tiny negatively charged particles that circle around the positively charged nucleus of an atom.

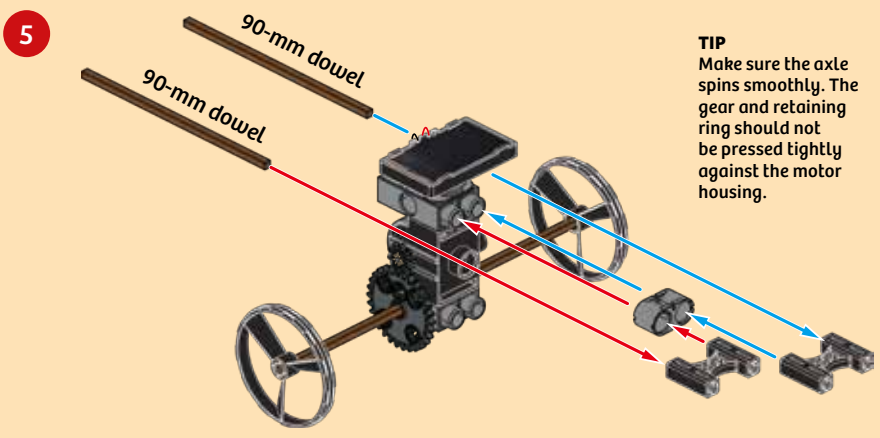
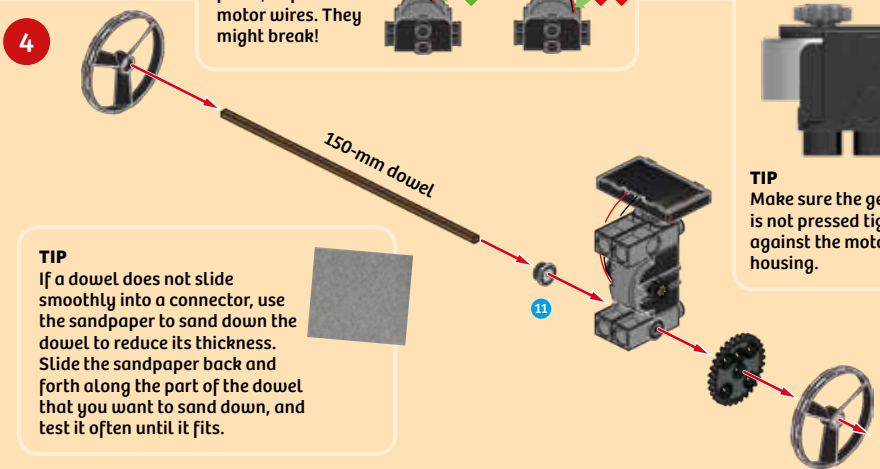
SOLAR ROVER



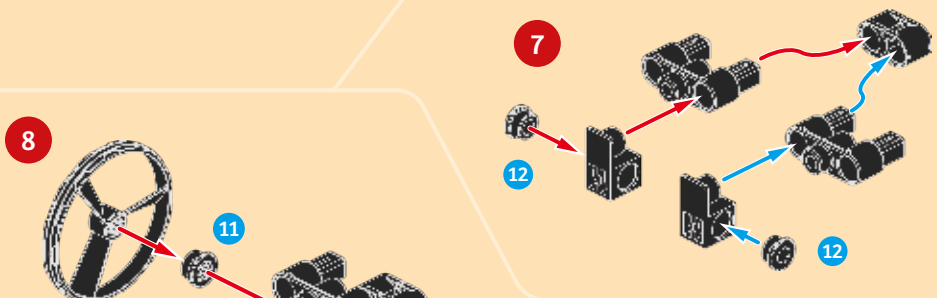
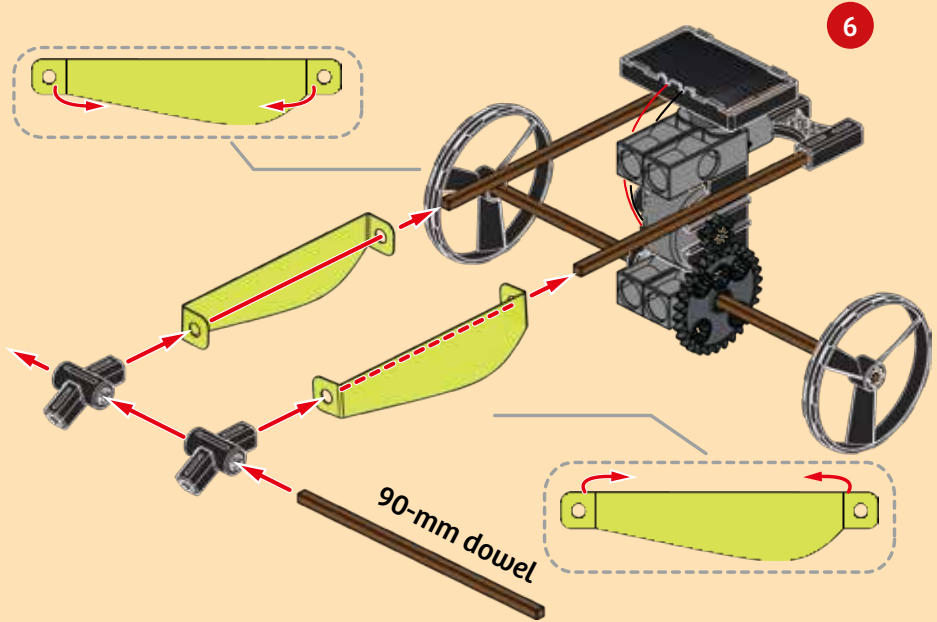
IMPORTANT!
Do not twist, pinch, or pull the motor wires. They might break!



TIP
Make sure the gear is not pressed tightly against the motor housing.



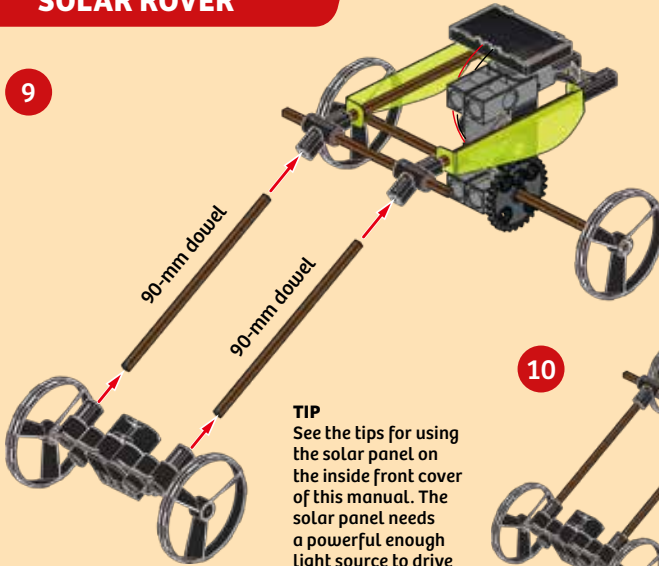
SOLAR ROVER



TIP
 Make sure the axle spins smoothly. The retaining rings on the axle should not be pressed tightly against the bushings that hold the axle.

SOLAR ROVER

9

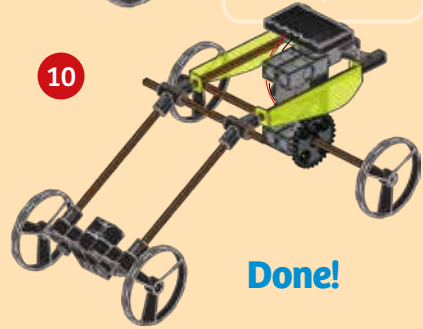


TIP
See the tips for using the solar panel on the inside front cover of this manual. The solar panel needs a powerful enough light source to drive the motor and move the car.

SOLAR PANEL AND ELECTRIC MOTOR

The solar panel has a solar cell in it that generates electricity when bright light shines directly on it. The electricity powers the electric motor.

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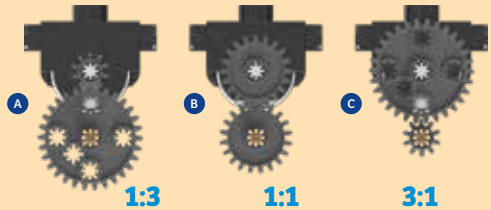


EXPERIMENT 1

HERE'S HOW

Follow steps 1 through 10 to build the solar rover model.

- 11 As assembled, the model starts out with its gears in setup A: The small gear is on the motor shaft and the large gear is on the axle. Test drive the model on a smooth, flat surface outside in bright sunlight. Observe.
- 12 Replace the small and large gears with medium gears (B). Retest the model under the same conditions as before. Observe.
- 13 Alter the model so the large gear is on the motor shaft and the small gear is on the axle (C). Retest the model as before. Observe.



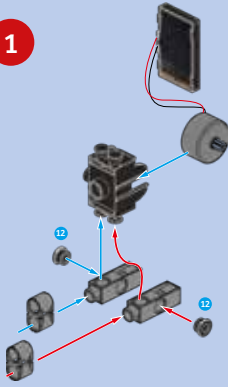
WHAT'S HAPPENING?

You tested the solar rover with three gear ratios. The model should have moved with gear ratio A, which is a 1:3 ratio. The model should have moved faster with gear ratio B, a 1:1 ratio. But the model most likely did not move at all with gear ratio C, a 3:1 ratio. Since the power input from the solar cell was the same each time, the difference in motion was caused by the gearing. Gear ratio A provides more torque (turning force) but at a lower speed, while gear ratio C provides the least torque — not enough to move the model.

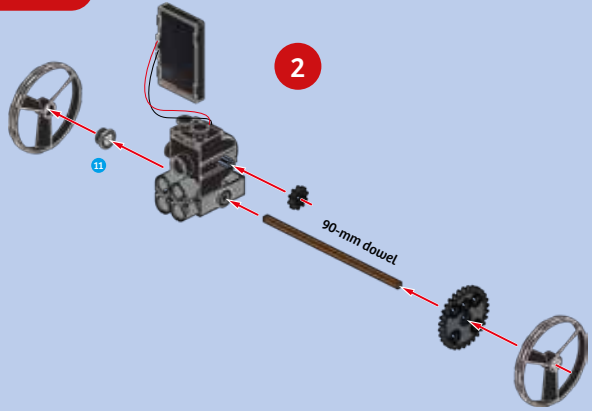
TIP: See the tips for using the part separator tool to disassemble models on the inside front cover of the manual.

COMPACT SOLAR CAR

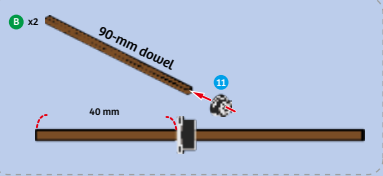
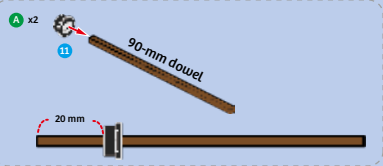
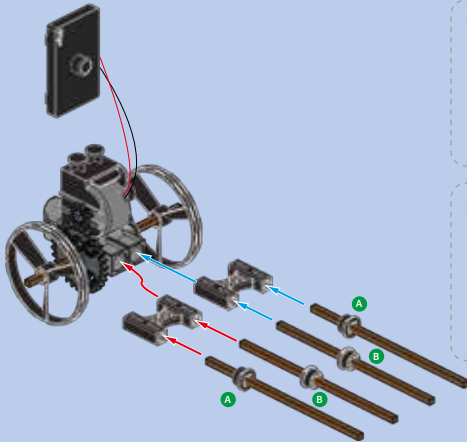
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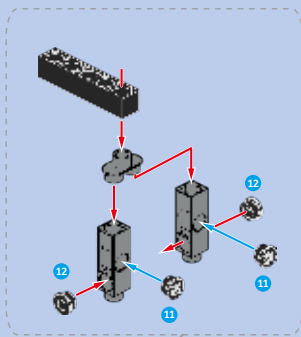
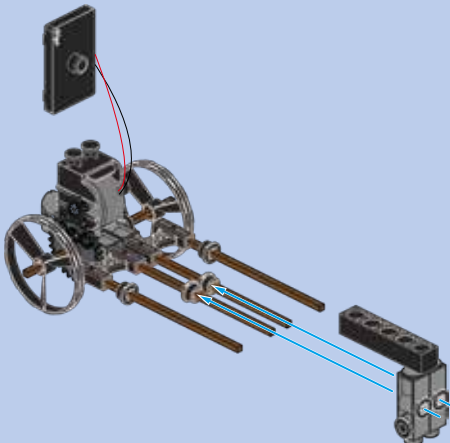
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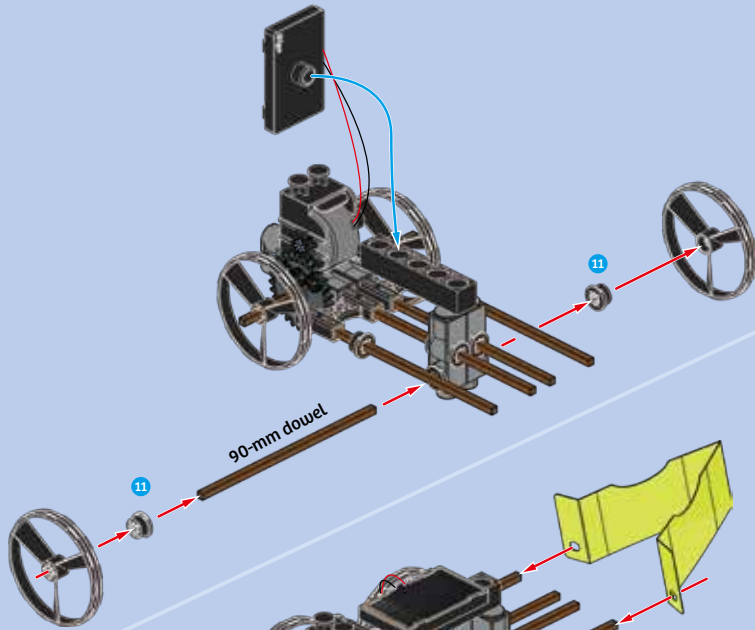


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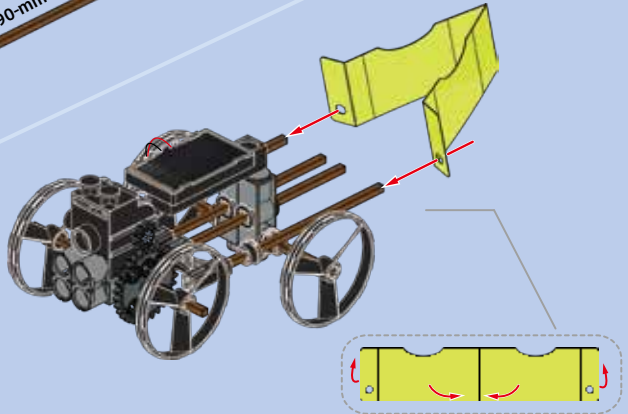


COMPACT SOLAR CAR

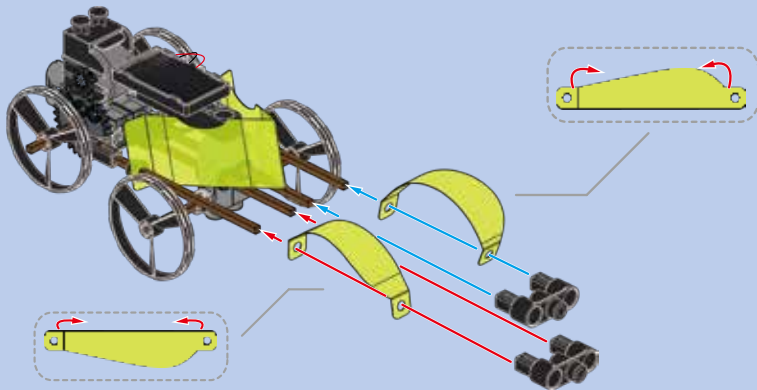
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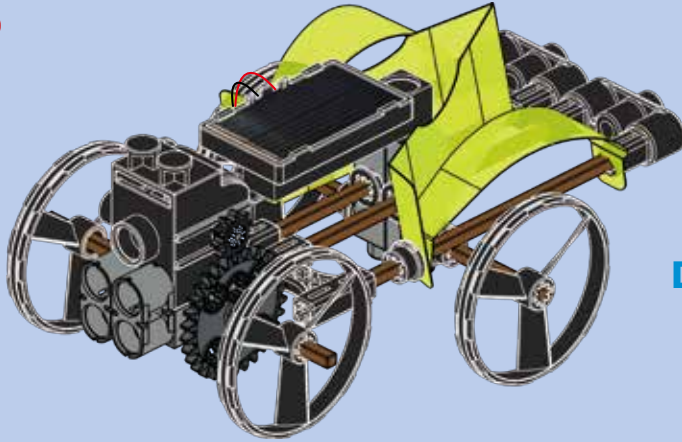


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COMPACT SOLAR CAR

8



Done!

EXPERIMENT 2

HERE'S HOW

Follow steps 1 through 8 to build the compact solar car model.

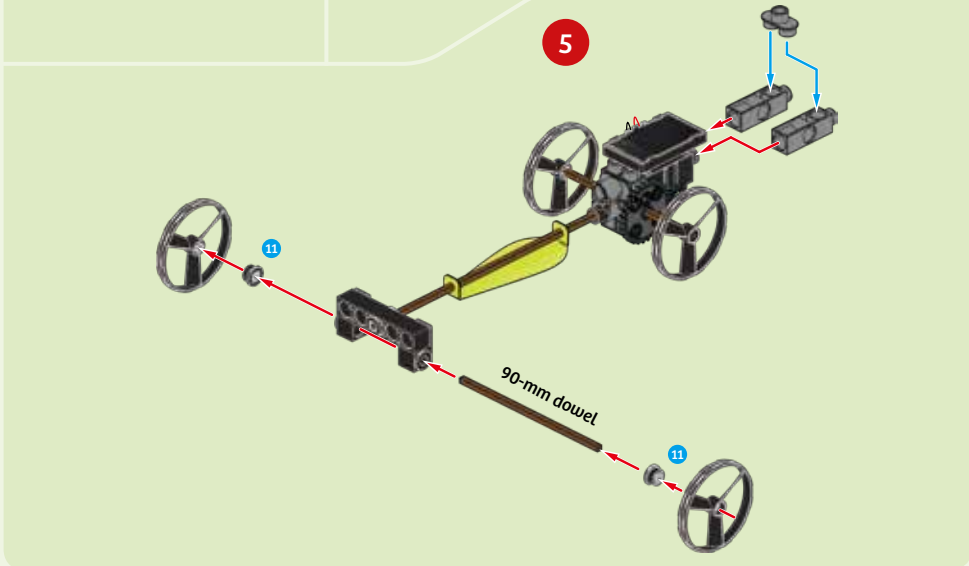
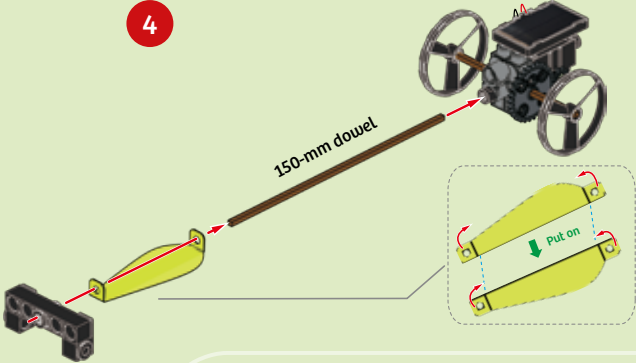
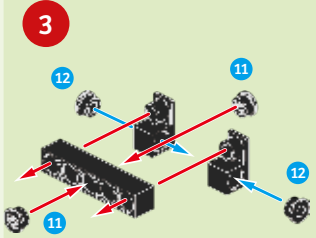
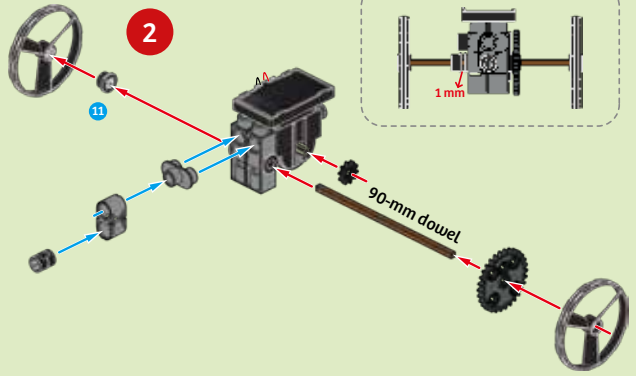
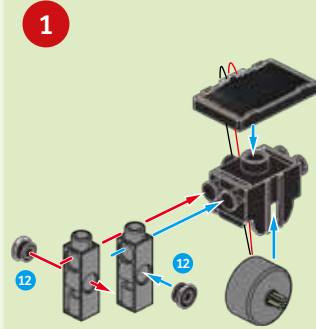
- 9 Test drive the model on a smooth, flat surface outside in bright sunlight. Observe.
- 10 Cover half of the solar panel with a small piece of cardboard, carefully taping it on with adhesive tape. Retest the model under the same conditions as before. Observe.
- 11 Cover the entire solar panel with a small piece of cardboard, taping it on as before. Retest the model under the same conditions as before. Observe.

WHAT'S HAPPENING?

Depending on the strength of the sunlight, your model may have stopped working with just half of its solar panel covered. Or, it may have moved very sluggishly with half of the panel covered and then not at all with the entire panel covered.

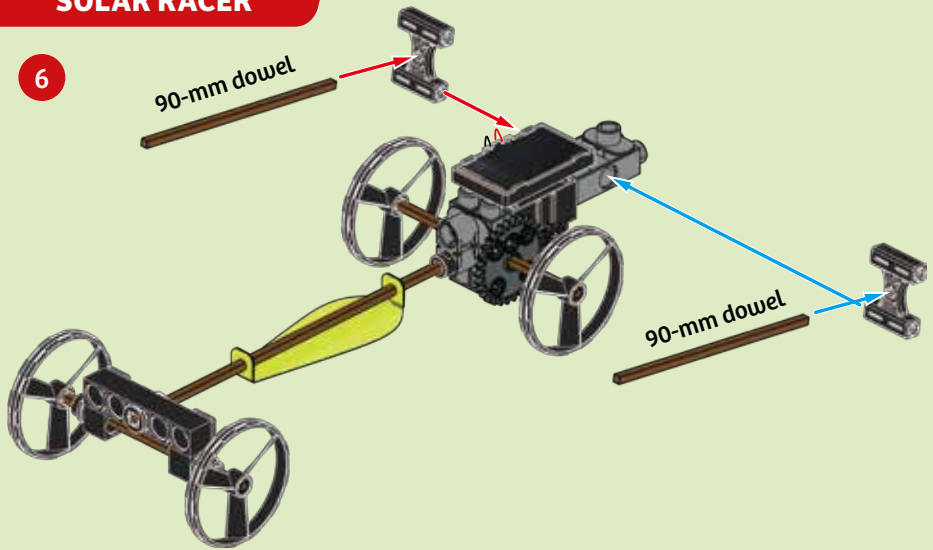
There is a relationship between the surface area of the solar panel and its generated output, or performance. The smaller the surface area, the lower the power output of the solar panel. This relationship is not uniform, though; that is, the performance isn't reduced by half if you cover half of the panel. This is due to the fact that the system also has a motor connected which, in turn, drives several gears. If you were to measure only the current from the solar panel, you would see a direct relationship between the incoming energy and the current produced.

SOLAR RACER

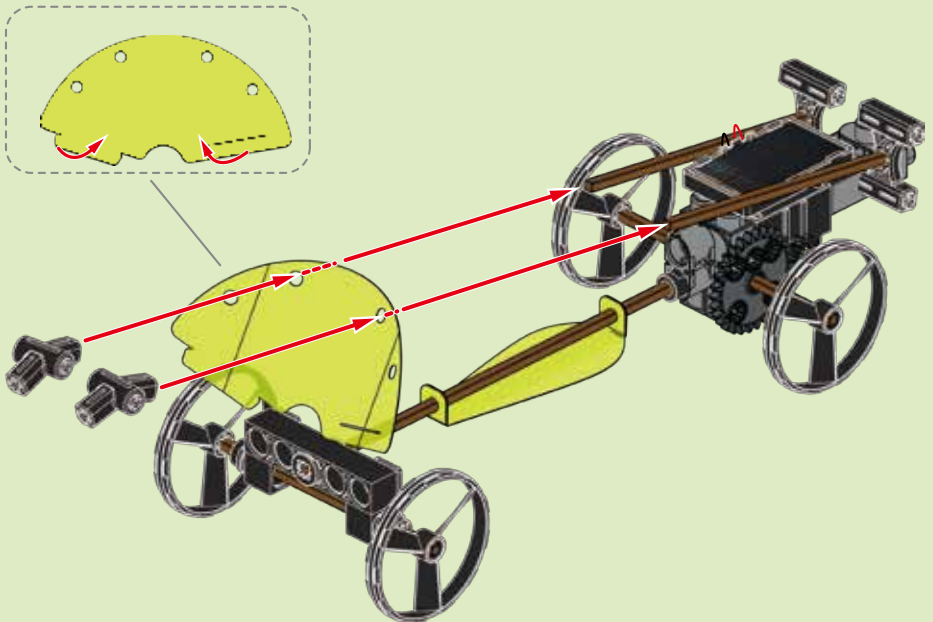


SOLAR RACER

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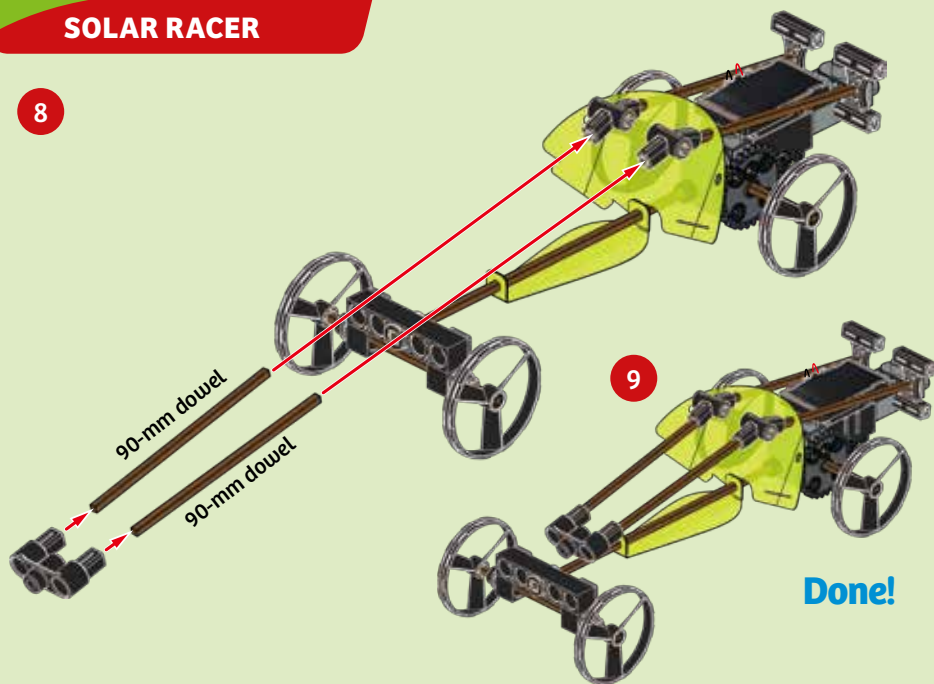


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SOLAR RACER

8



EXPERIMENT 3

HERE'S HOW

Follow steps 1 through 9 to build the solar racer model.

- Find different light sources from the list below and test out how well the racer moves with each light source.

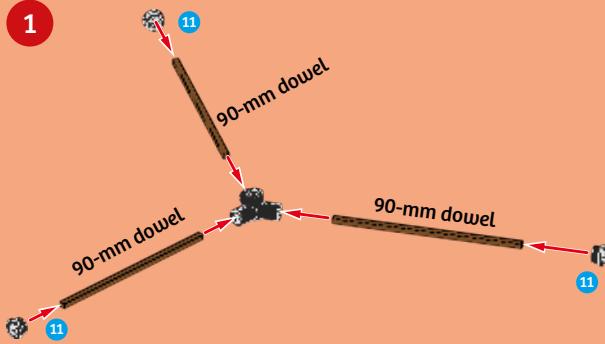
Light source	Does the car move?
Sunlight on sunny day	
Sunlight on cloudy day	
Sunlight through a glass window	
Light from smartphone flashlight	
Light from LED light bulb	
Light from incandescent light bulb	
Light from TV screen	

WHAT'S HAPPENING ?

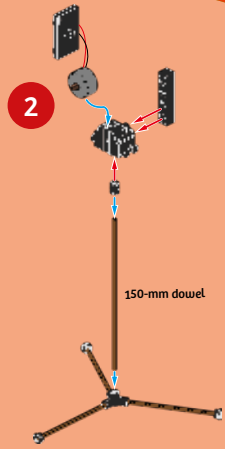
You tested the solar racer under a number of different light conditions. Perhaps you even thought of some other light sources to try. You probably observed that sunlight, even on a cloudy day, is much more powerful than any of the artificial light sources. The type of glass in your window will affect the power output of the solar cell. A double-pane or coated window will reduce the amount of sunlight coming through the window. You probably got the racer model to move with some, but not all, of the light bulbs you tested. And the light from a TV screen is definitely not powerful enough to drive the motor.

SOLAR FAN

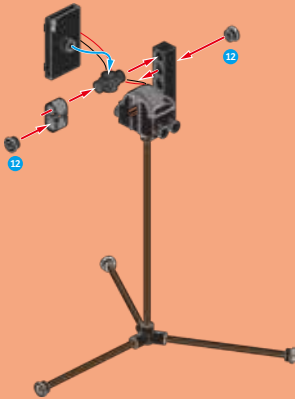
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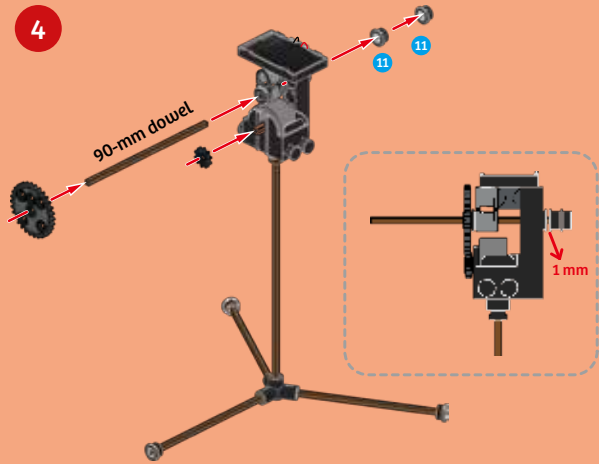
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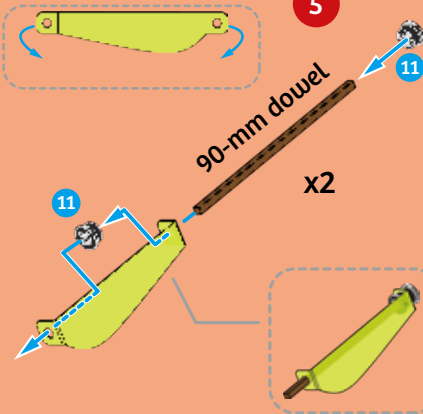
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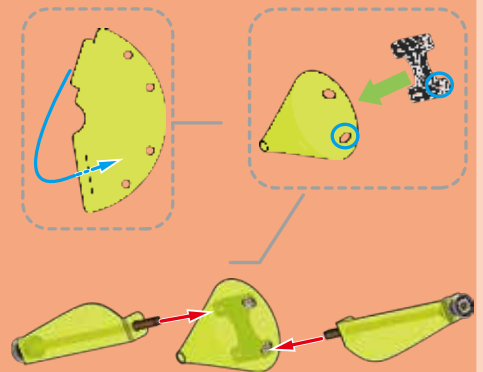
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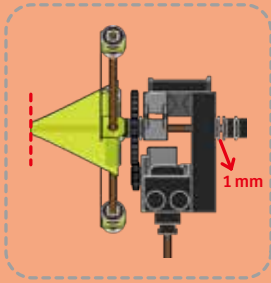
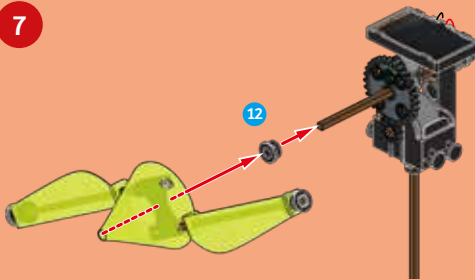


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SOLAR FAN

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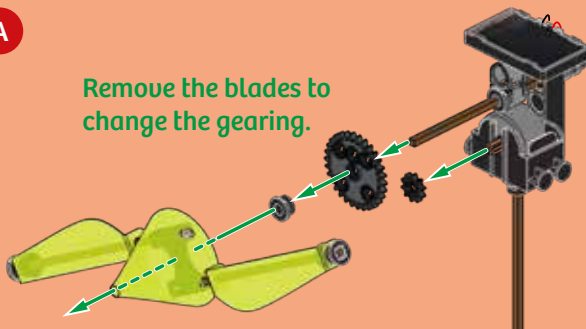
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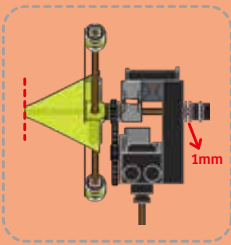
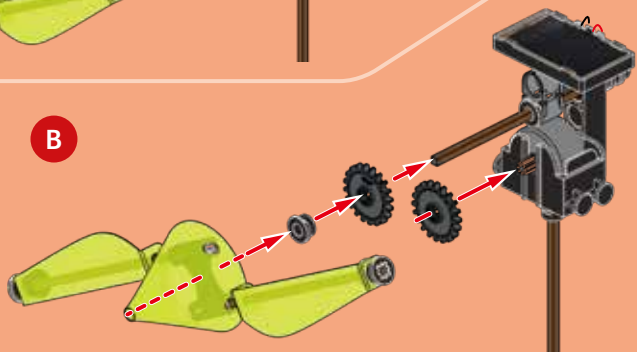
Jump to the next page to start the experiment. Follow the steps below to change the gearing on the fan model when the experiment instructions tell you to do so.

A

Remove the blades to change the gearing.



B



SOLAR FAN

C



EXPERIMENT 4

HERE'S HOW

Follow steps 1 through 8 to build the solar fan model.

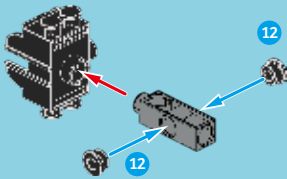
- 9 Test the solar fan model as built (1:3 gear ratio) outside in bright sunlight. Observe.
- 10 Follow steps A through C to change the gearing to a 1:1 gear ratio. Retest the model under the same conditions as before. Observe.
- 11 Alter the model again so the large gear is on the motor shaft and the small gear is on the axle (3:1 gear ratio). Retest the model under the same conditions as before. Observe.

WHAT'S HAPPENING ?

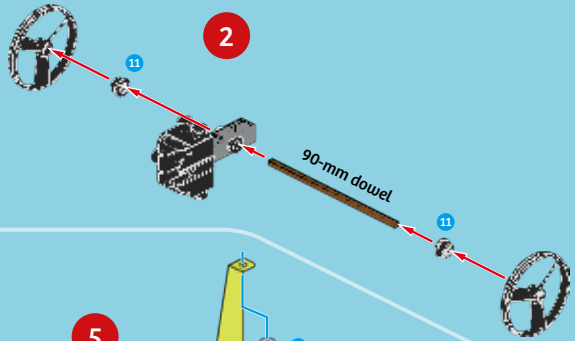
The 1:1 gear ratio should have caused the fan blades to spin faster than the 1:3 gear ratio. And the 3:1 gear ratio should have caused the fan blades to spin faster than the 1:1 gear ratio. As you recall, the 3:1 gear ratio did not provide enough torque to drive the car in Experiment 1. However, because the fan blades are so light, the 3:1 gear ratio does provide enough torque to turn them. It takes more power to move the whole car across a floor than to turn just the fan blades in the air with no resistance (except the air itself).

SUN BOT

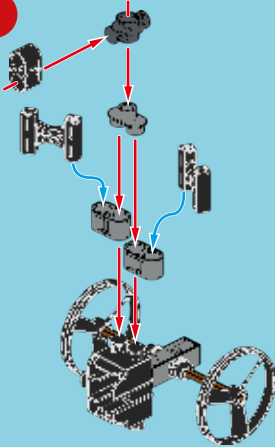
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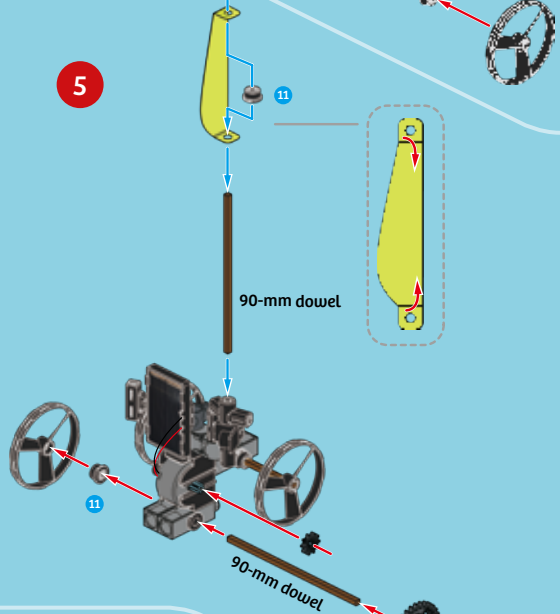
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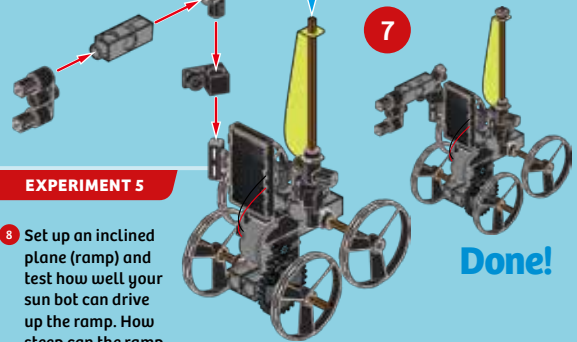
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EXPERIMENT 5

- 8 Set up an inclined plane (ramp) and test how well your sun bot can drive up the ramp. How steep can the ramp be before the sun bot can't climb it?

Done!

CHECK IT OUT!

ENERGY FROM THE SUN

The terms “solar energy” and “solar power” refer to the energy of the solar radiation that we are able to harness and use. The sun is a star that is 150 million kilometers from Earth. Despite this immense distance, solar energy has an enormous impact on our lives: Life is not possible without the sun!

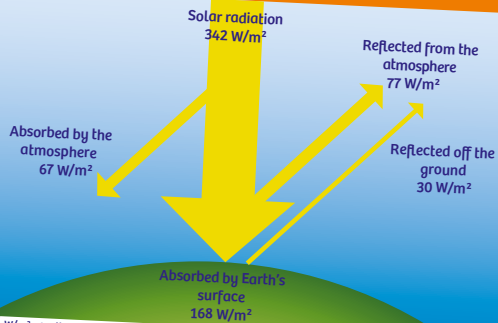
You can feel how strong solar energy is on any sunny day. Just lay out for a bit in the sun in the middle of summer. But be careful — you need to protect yourself adequately against sunburn. The sun emits so much energy because it is a gigantic nuclear reactor. It is so hot on the inside that the atoms, the building blocks of all matter, fuse together. Even on the sun’s surface, it is still around 5,500 degrees Celsius. The nuclear fusion produces nearly inexhaustible amounts of energy. This is radiated out into space. And some of it strikes Earth’s surface as electromagnetic radiation, as light.



AMAZING ENERGY RESERVES

The solar energy striking Earth’s atmosphere each year is an unimaginable 1,500,000,000,000,000 kilowatt hours. This corresponds to about 10,000 times the energy consumption of all of humanity (as of 2010). By comparison: A three-person household in a single-family home consumes 4,000 kilowatt hours of power each year on average, which is but a tiny fraction of the incident solar energy.

However, a large portion of the solar energy is lost in the atmosphere, since it is “swallowed up” there or reflected back. The rest of it is enough, though, to give us sunlight that we can use to generate electricity.



CHECK IT OUT!

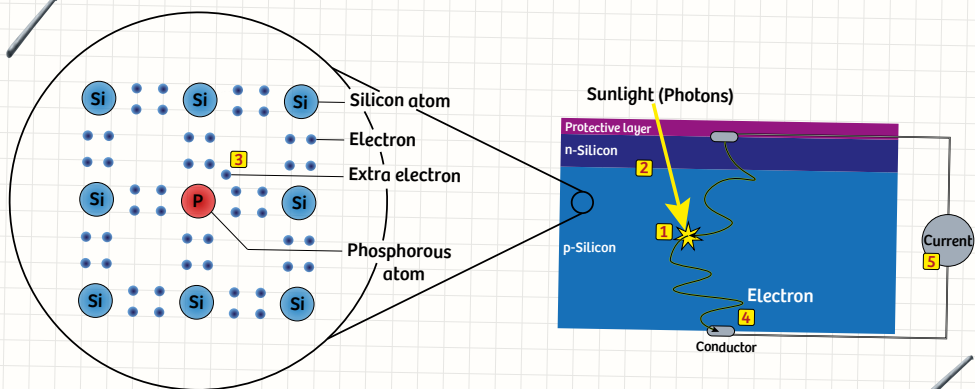
HOW DOES A SOLAR CELL WORK?

The solar cell in this experiment kit consists mostly of a material called silicon, which is a special semi-metal. Nine out of ten solar cells made worldwide are made of silicon, which is also the primary material in computer chips.

Electrons — those tiny, negatively charged particles flying around atoms — give rise to electric current. They are located directly on silicon atoms. Movement of electrons leads to a change in electrical charge and is known as electric current. To generate electricity, you need to make the electrons move. That actually happens automatically when light strikes the silicon. Light particles, called photons, are able to displace electrons from their spots on the silicon atom (1). But how does the electron know that it's supposed to move in a certain direction, such as through the wire into your motor? This is where the structure of silicon and the design of the solar cell come into play.

Since current is to be generated in a solar cell, the electrical properties of silicon are important. Silicon is a semiconductor. During manufacture, its electrical properties can be precisely specified by introducing other elements (such as phosphorous) into the semi-metal. In a solar cell, two silicon layers that have been altered in different ways are sandwiched together (2). This results in additional electrons being present (3) and electrons only being able to move in a certain direction. All of the electrons that are set in motion under the light end up flowing through on a conductive material (4).

However, since the material is not lacking electrons, it has to be “emptied” from the other side. A circuit (circular flow) is formed, and current flows through it (5).





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