Build a Solar-Powered Bristlebot

Difficulty	
Time Required	Short (2-5 days)
Prerequisites	None
Material Availability	A kit containing all the electronics parts needed for this project can be found in the Science Buddies Store (https://store.sciencebuddies.org/JAM-6200-KIT/Advanced-Bristlebot-Kit.aspx).
Cost	Average ($40 - $80)
Safety	No issues

Abstract

You have probably heard about using *renewable* energy sources like wind and solar power to provide electricity to homes and buildings, as well as hybrid or fully electric cars that use less (or zero) gasoline. But what about solar-powered robots? As robots become more common, it is increasingly important to use "green" energy sources to power them. In this project, you will build and test a popular robot called a bristlebot — a tiny robot made using toothbrushes —that can operate on either battery or solar power, and investigate how well it performs in different weather conditions.

Objective

Compare the performance of solar and battery power for a bristlebot in different weather conditions.

Credits

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Cite This Page

MLA Style

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Introduction

Many of the devices you use every day require **electricity** to operate. Electricity can be supplied directly to devices that plug into wall outlets (like lamps and computers), and it can also be stored in **batteries** for cordless devices like television remote controls, cell phones, and even robots like the one you will build in this project! Modern life as you know it would not exist without electricity, but electricity comes at a cost. The electricity we use has to be created somehow, and creating electricity requires a source of **energy**.

One very common source of energy for creating electricity is burning **fossil fuels**, like oil and coal. Fossil fuels are being used up (mined or pumped out of the earth) faster than they are naturally replaced, so eventually we might run out of them. They also create *greenhouse gases* like carbon dioxide (CO_2), which contribute to *climate change*, and other pollutants that can harm the environment. **Renewable energy** sources are an alternative to fossil fuels. They get energy from sources that will not deplete, like the sun, the wind, or Earth's super-heated core. They also tend to be much cleaner and cause less pollution than fossil fuels.

Solar panels harness a big source of renewable energy: the Sun! They can create electricity from the Sun's rays, without creating any harmful emissions like fossil fuels do. You may have seen large solar panels on the roof of a house, but tiny solar panels are also used to power smaller devices like USB cell phone chargers or even miniature robots. In this project, you will build a miniature solar-powered robot, like the one shown in Figure 1. The robot is a type of **bristlebot**, a popular robot that gets its name from the fact that it uses toothbrushes as "feet."

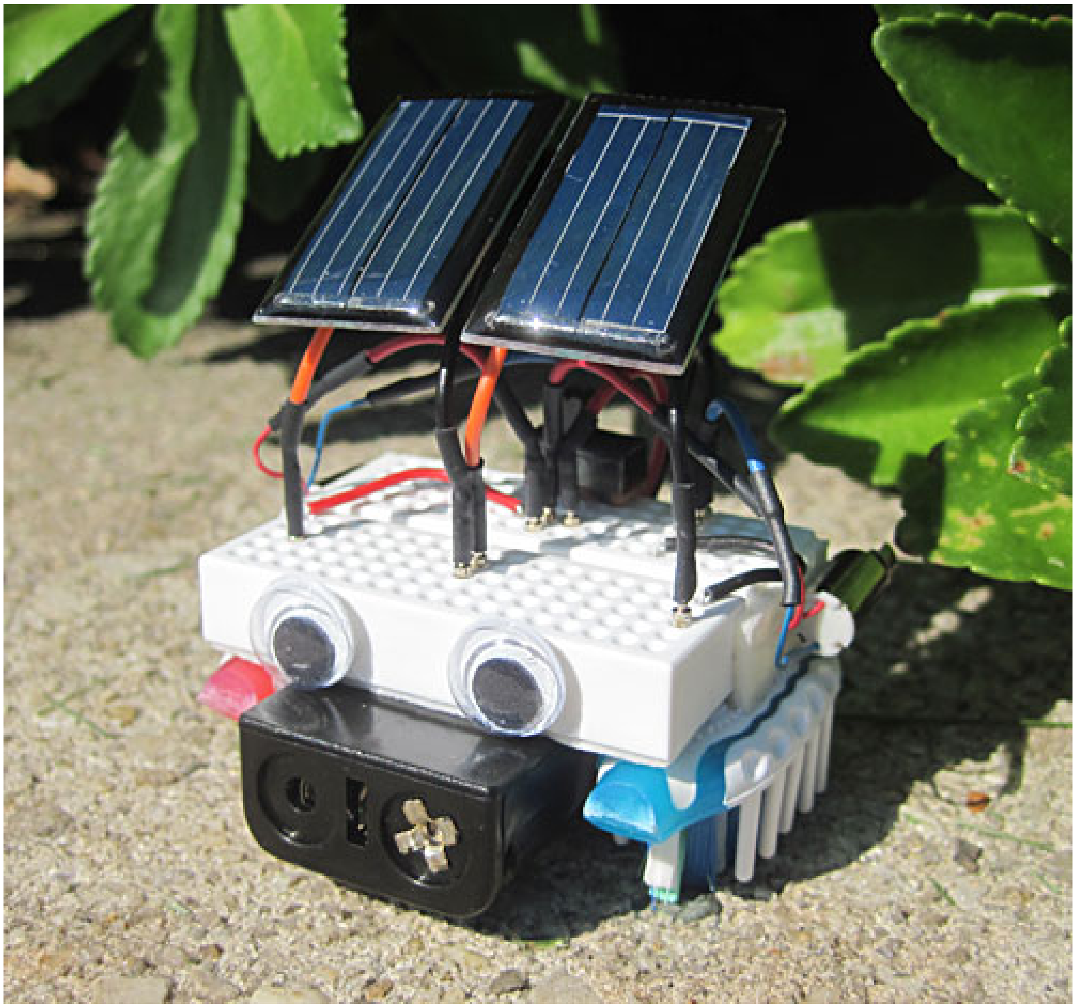


Figure 1. A mini solar-powered robot.

Despite the clean, renewable nature of solar power, it does have some drawbacks. The power output of solar panels can drop dramatically when it is cloudy, and they do not work at night when it is dark out. One of the biggest challenges to wide-scale use of solar power is figuring out how to effectively *store* energy gathered during the day for use at night, or during bad weather when the solar panels cannot create electricity.

With that in mind, the robot you build in this project will have two different sources of power: solar panels and stored energy in the form of batteries. You will build an electrical **circuit**—or a loop through which electricity can flow—that lets you toggle between powering the robot from its batteries or its solar panels (the solar panels do not recharge the batteries; you can just pick between the two). The circuit will provide power to two **motors** that make the robot move. You will investigate how the two different power supplies affect the robot's speed in different weather conditions. As you test your robot and analyze the results, consider some of the challenges that need to be overcome as fossil fuels are replaced with renewable energy.

Terms and Concepts

- Electricity
- Battery
- Energy
- Fossil fuels
- Renewable energy
- Solar panel

- Bristlebot
- Circuit
- Motor
- Breadboard

Questions

- Why is renewable energy important?
- What are some sources of renewable energy?
- What are some of the limitations of solar power?
- Do you think your robot will be faster using battery power or solar power?
- Do you think the weather will have any effects on the robot when it is running on battery power? What about the solar panels?

Bibliography

- Woodford, C. (2014, May 14). *Electricity*. Retrieved August 22, 2014, from http://www.explainthatstuff.com/electricity.html (http://www.explainthatstuff.com/electricity.html)
- Grusin, M. (n.d.). *What is a Circuit?* SparkFun Electronics. Retrieved July 31, 2014, from https://learn.sparkfun.com/tutorials/what-is-a-circuit (https://learn.sparkfun.com/tutorials/what-is-a-circuit)
- Shorter, M. and Bartlett, J. (n.d.). *How to Use a Breadboard*. SparkFun Electronics. Retrieved June 3, 2014, from https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard/introduction (https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard/introduction)
- U.S. Energy Information Administration. (n.d.). *EIA Energy Kids — Solar*. Retrieved August 25, 2014, from http://www.eia.gov/kids/energy.cfm?page=solar_home-basics (http://www.eia.gov/kids/energy.cfm?page=solar_home-basics)

Materials and Equipment Buy Kit (https://store.sciencebuddies.org/JAM-6200-KIT/Advanced-Bristlebot-Kit.aspx)

The following materials are available in the Science Buddies Store (https://store.sciencebuddies.org/JAM-6200-KIT/Advanced-Bristlebot-Kit.aspx):

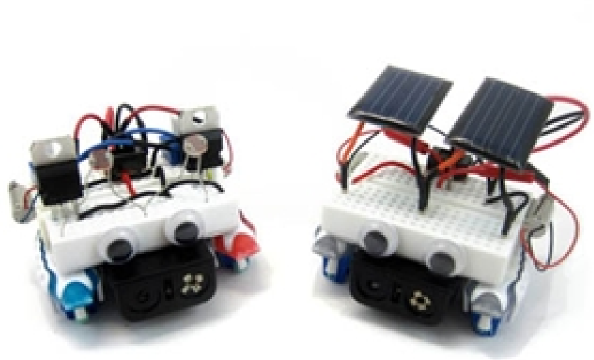
- Advanced Bristlebot Kit (1). You will need the following materials from the kit:
  - Mini breadboard
  - 2xAAA battery holder
  - AAA batteries (2)
  - Mini vibration motors (2)
  - Toggle switch
  - Mini solar cells (2)
  - 1 inch red jumper wire
  - 1 inch black jumper wire
  - *Note*: This kit also contains materials for the Build a Light-Tracking Bristlebot (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_p012.shtml) project, a robot which will automatically drive toward a light source.

You will also need the following materials, not included in the kit:

- Identical toothbrushes (2); be sure the longest bristles on the brush are all *slanted* in the same direction. See Figure 3 in the Procedure (#procedure) for details.

- Scissors or wire cutters
- Double-sided foam tape
- Optional: Craft materials to decorate your robot (such as googly eyes, colorful pipe cleaners, etc.)
- Outdoor area with direct sunlight
- A smooth surface you can take outdoors, or outdoor furniture, on which to test the robot; for example, a smooth piece of wood, plastic, or glass, or a large textbook. The robot will not travel very well on rough surfaces (like sidewalks or dirt) because the toothbrush bristles might get stuck.
- Objects to create walls to make the robot go straight; for example, two rulers or two textbooks you can place side by side.
- Stopwatch
- Lab notebook

Order Product Supplies



Project Kit: $59.95

Experimental Procedure

Gathering Your Materials

1. Gather all the materials you will need to build your robot. The parts you will need from your Advanced Bristlebot Kit are shown in Figure 2.

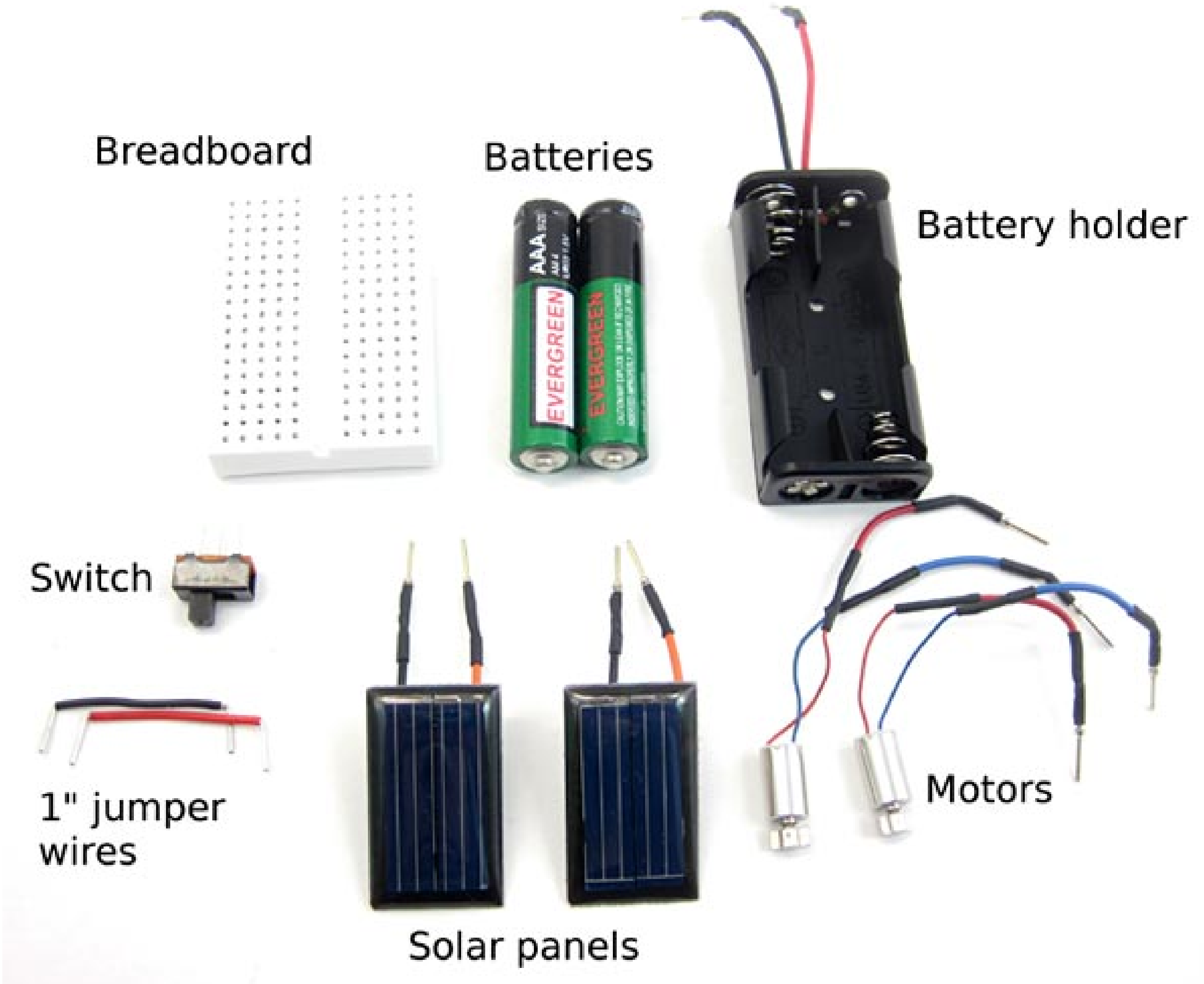


Figure 2. The parts you will need from your Advanced Bristlebot Kit.

2. In addition to the parts from the kit, you will also need two identical toothbrushes with *slanted* bristles. It is very important that the longest bristles are *all slanted in the same direction*. The longest bristles will reach down and touch the ground, acting as the robot's "feet." If the bristles are all slanted in one direction, when the motors vibrate, they will help push the robot forward. However, if the bristles point straight down, or are slanted in multiple directions, the robot might just spin in circles or go sideways instead of straight. Figure 3 shows an example of the type of toothbrush you can use.

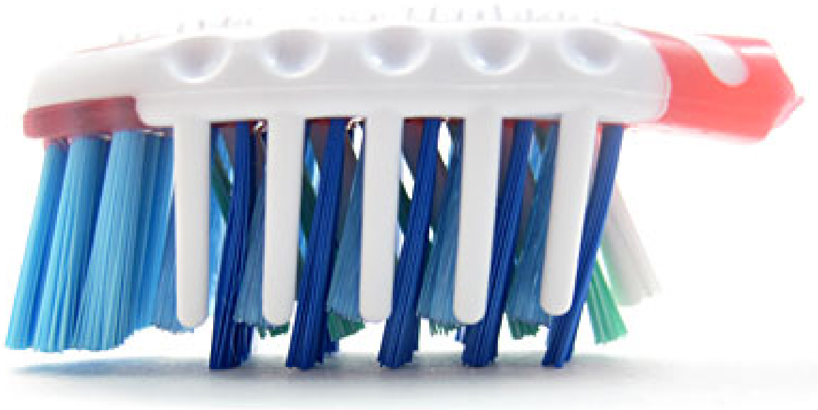


Figure 3. An example of the type of toothbrush head that will work well for making your robot. Notice how the *longest* blue bristles are the only ones that touch the ground when the toothbrush head is standing up, and they are all slanted in the same direction. Even though some green and white bristles are slanted in the opposite direction, this is okay because they do not actually touch the ground. Remember that you need two of the exact same type of toothbrush.

3. Have an adult help you carefully use scissors or wire cutters to cut the heads off both toothbrushes, as shown in Figure 3. If you cannot cut all the way through the neck of the toothbrush, you can cut it as deeply as possible, then bend the head back and forth several times to snap it off.

Assembling Your Robot's Body

1. Insert the two AAA batteries into the battery holder, as shown in Figure 4. Make sure the "+" symbols on the batteries line up with the "+" symbols inside the battery holder, just like you would when putting batteries into any other device.

Figure 4. Put the batteries in the battery holder.

2. Peel the paper backing off the bottom of the *breadboard* (the white rectangular piece of plastic with holes in it), as shown in Figure 5. This exposes a sticky layer on the bottom of the breadboard.

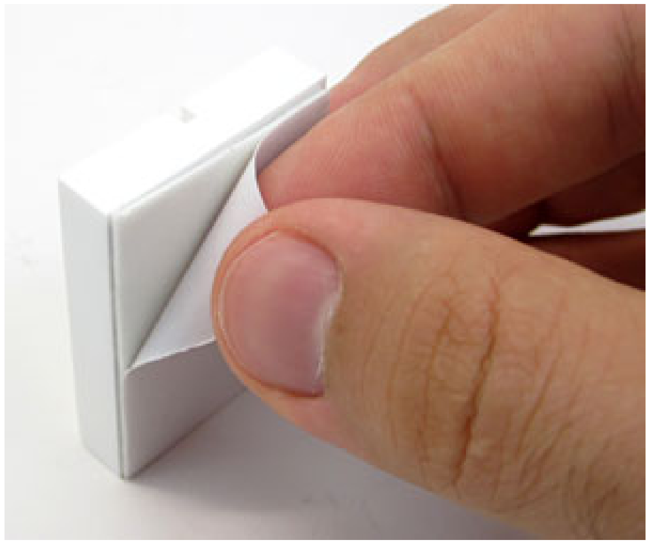


Figure 5. Peel the backing off the bottom of the breadboard.

3. Firmly press the battery holder onto the double-sided tape so it is *centered* under the breadboard, as shown in Figure 6.
    a. The battery holder's long side should be lined up with the breadboard's short side, so the battery holder will stick out a little bit on either end of the breadboard.
    b. It is important to make sure the battery holder is perfectly centered so that there is room for you to attach a toothbrush head on either side of the battery holder.

Figure 6. Mount the battery holder to the bottom of the breadboard.

4. Firmly press the smooth part of both toothbrush heads onto the sticky part of the breadboard, one on either side of the battery holder, as shown in Figure 7. The longest bristles should slant toward the battery holder's wires, which will be the back end of the robot.

Figure 7. Mount the toothbrushes, brush-side up, next to the battery holder.

5. Flip the robot body over so that the holes of the breadboard are on the top. Attach one motor to the side of the breadboard, as follows (and as shown in Figure 8).
    a. Cut a small piece of double-sided tape.
    b. Firmly press the sticky part of the tape onto the side of the breadboard, above the side of one of the toothbrush heads.
    c. Peel the paper backing off the tape.
    d. Firmly press the motor onto the sticky tape, as shown in Figure 8.
        i. The motor's wires should be pointing forward (the opposite direction of the battery holder's wires).
        ii. The motor has a small semi-circular weight sticking out of the end opposite its wires. This weight will spin when the motor is turned on. Make sure this weight sticks out *past* the edge of the tape and the breadboard; this will ensure it does not hit them when it spins.

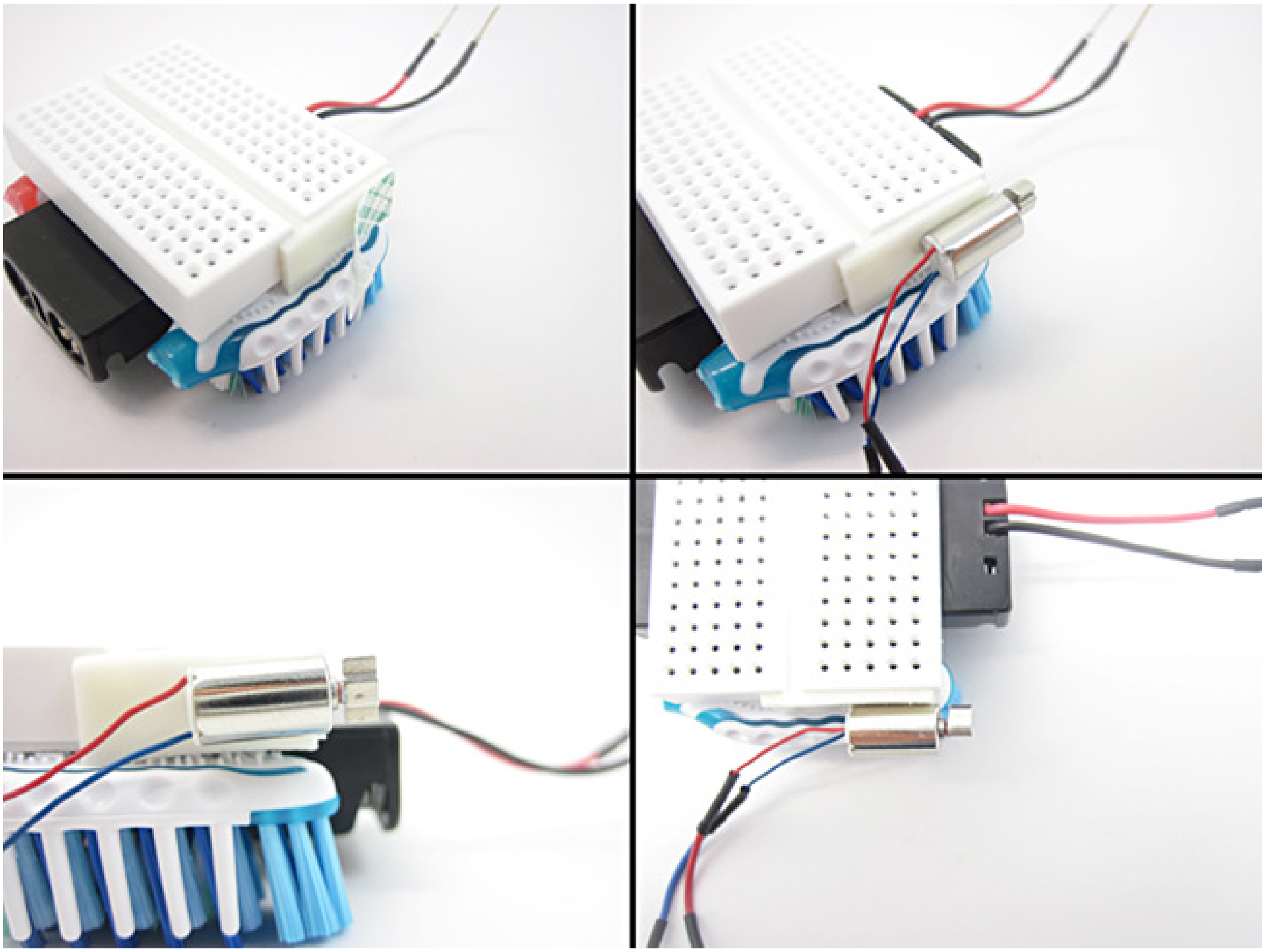


Figure 8. Attach a motor to one side of the breadboard using double-sided tape, as shown here.

6. Repeat step 5 for the other motor and the other side of the breadboard. Your robot body should now look like Figure 9.

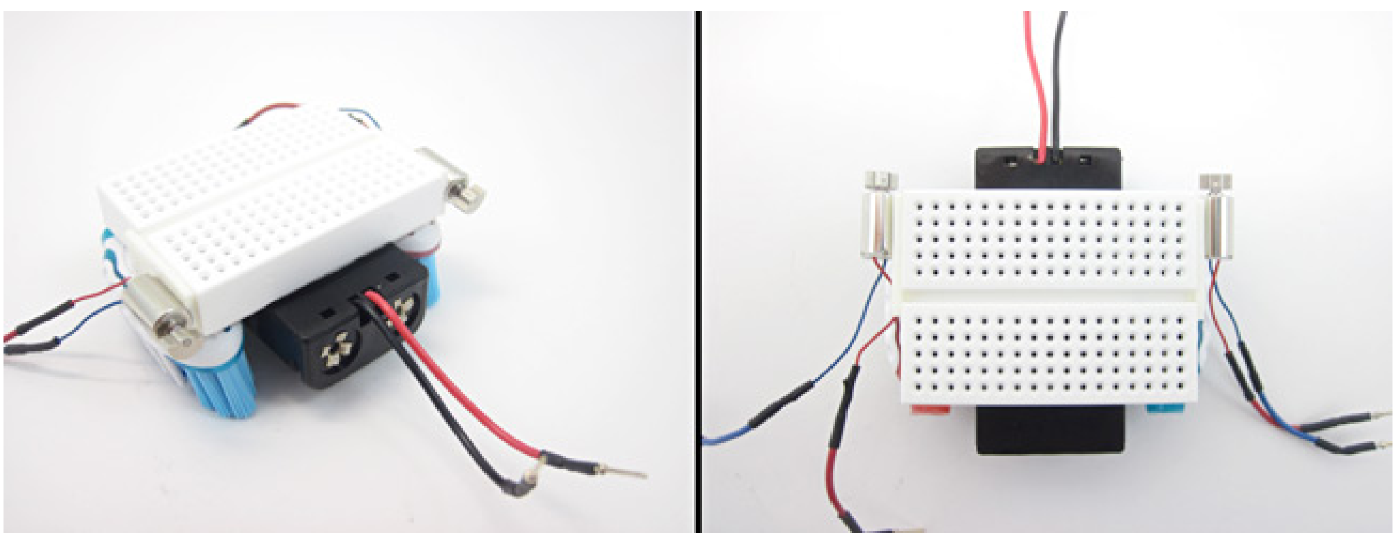


Figure 9. Attach the second motor to the other side of the breadboard using double-sided tape.

Assembling Your Circuit

1. Before you start building your circuit, you need to know a little bit about how breadboards work. Here is a

shortened version of the information that will be useful in this project.

a. **Breadboards** make it very easy for complete beginners to build circuits because they allow you to *temporarily* connect wires together. If you make a mistake, want to start over, or want to take your robot apart to do a completely different project, you can just pull the wires out of the breadboard.
b. Breadboards are divided into rows and columns. When you hold the breadboard vertically—as shown in Figure 10—the rows run left to right, and the columns run up and down.
c. The mini breadboard you are using in this project has 17 rows and 10 columns. We will refer to the rows by number (1–17) and the columns by letter (A–J). The breadboard does *not* have labels printed on it, so you will have to count spaces on the breadboard (for example, column C is the third column from the left).
d. An individual hole on the breadboard can be referred to by its column letter and row number. For example, "hole B3" means the hole in the third row of the second column from the left. The instructions will tell you exactly where to place things on the breadboard, based on hole naming.
e. Orient your robot body so that it is like the one in Figure 10. This will help you to easily refer to the breadboard diagrams while assembling your circuit.

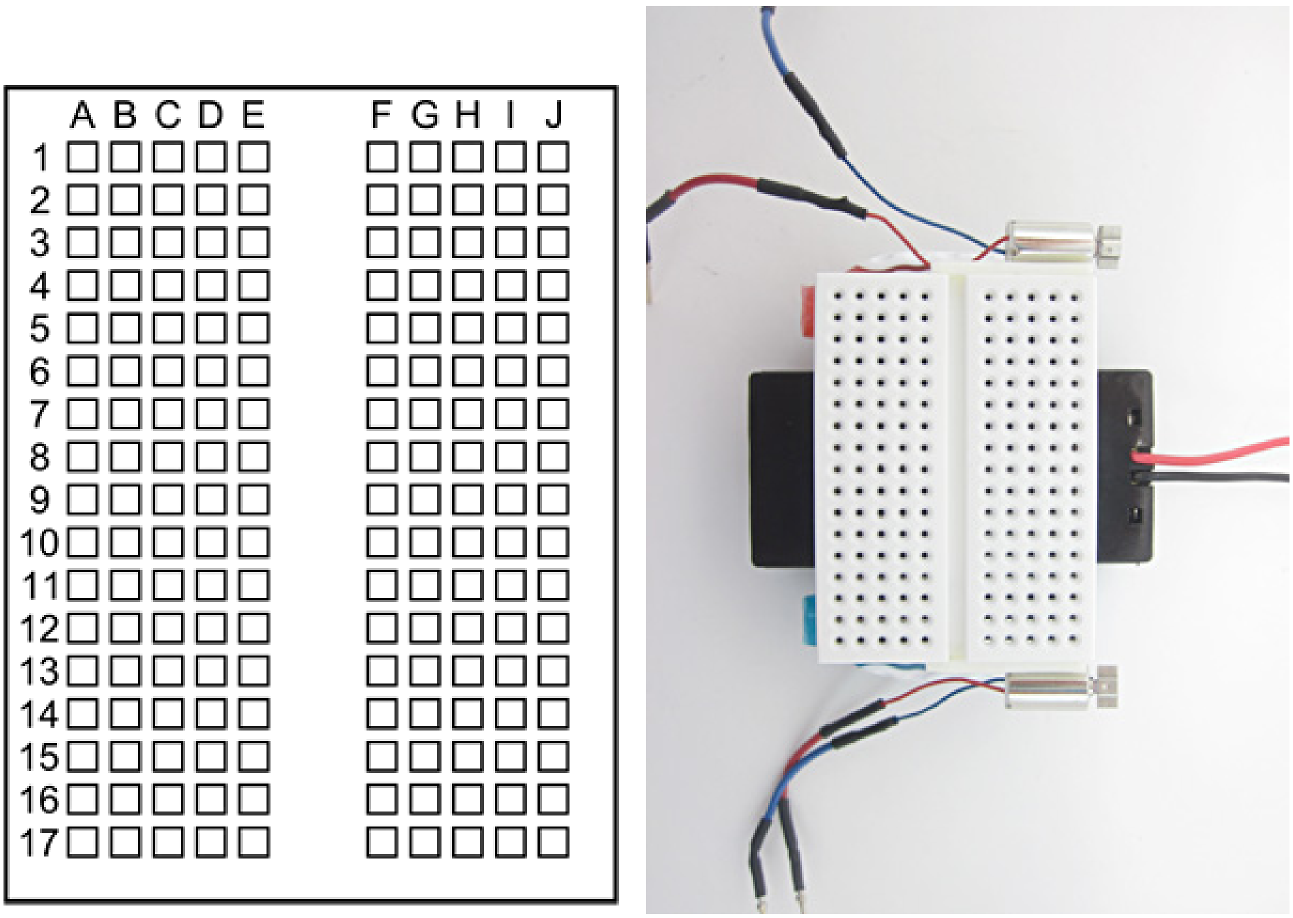


Figure 10. A computer diagram of a blank breadboard is shown on the left, with rows labeled 1–17 and columns labeled A–J. Notice how the physical breadboard, on the right, does *not* have labels printed on it, so you will have to count spaces. (*Note:* the battery holder and motors are not shown in the diagram on the left.)

2. Connect the power switch, as shown in Figure 11.
   a. The power switch has three metal pins sticking out of the bottom. Press these pins into holes J8, J9, and J10 (the orientation of the switch does not matter).
   b. The plastic body of the switch actually takes up *five* rows on the breadboard, even though it only has three pins. Be sure you press the pins into the correct holes.

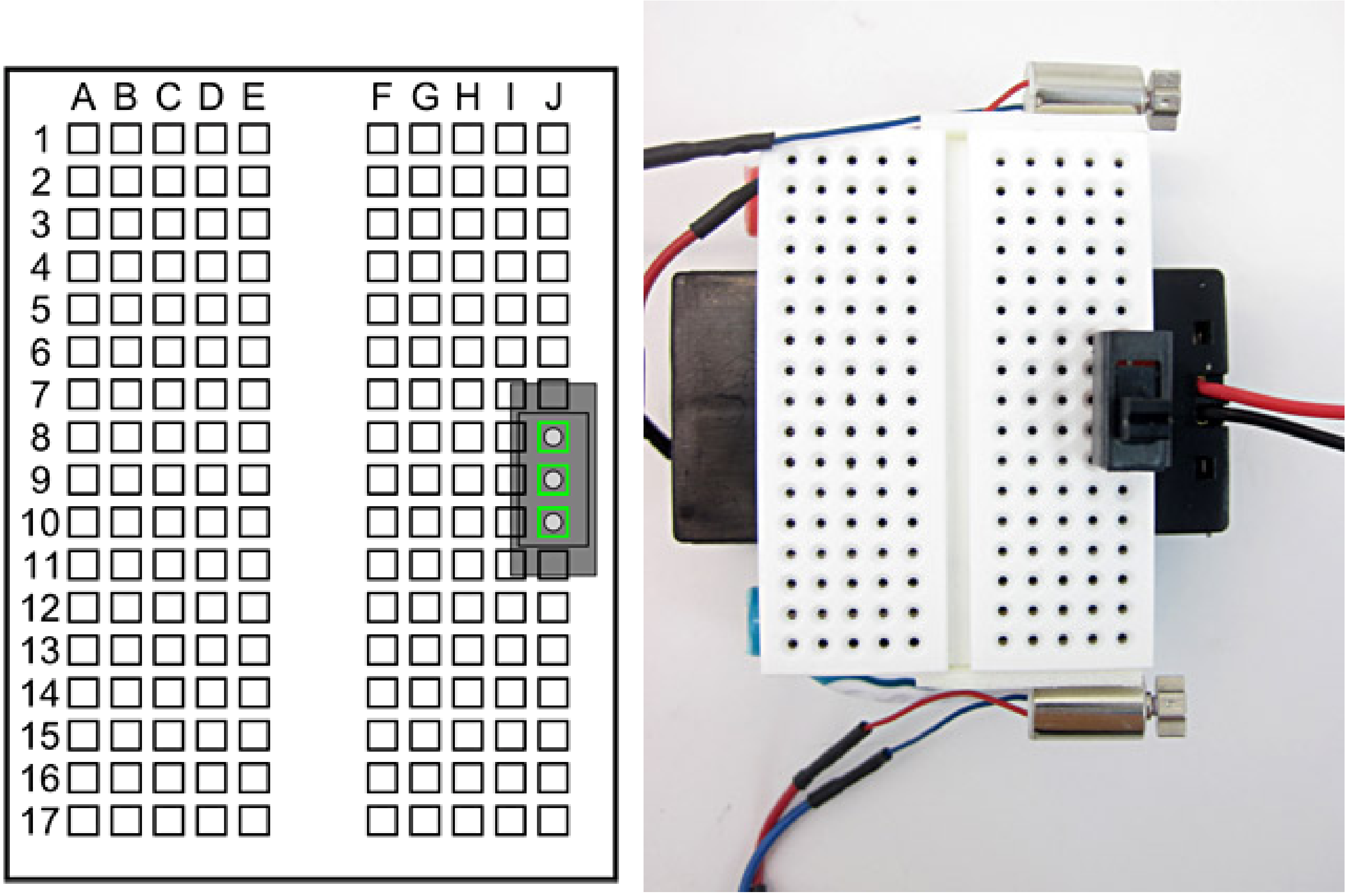
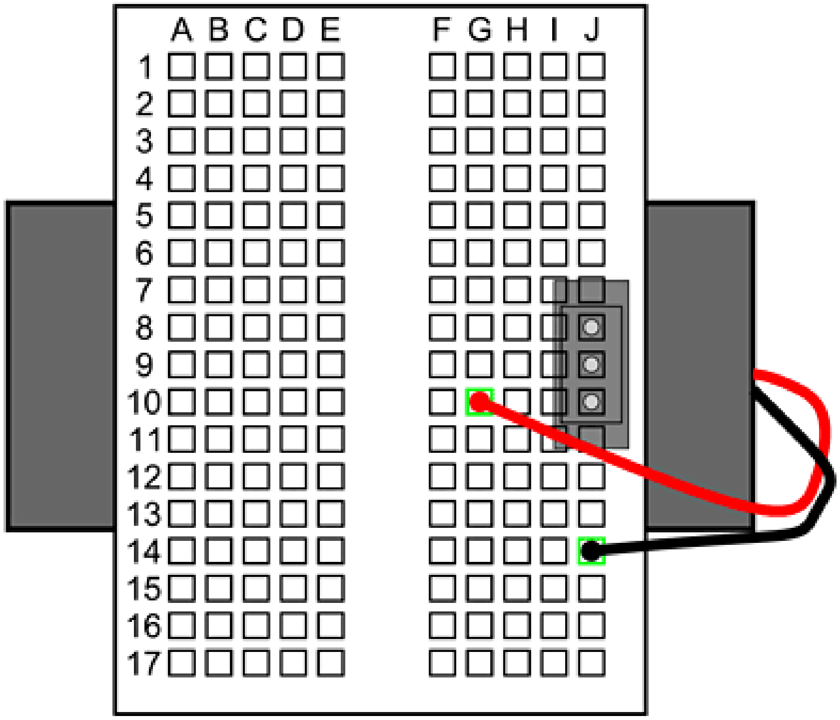


Figure 11. Insert the power switch into holes J8, J9, and J10 (new connections are highlighted in green in the diagram on the left).

3. Connect the wires from the battery holder, as shown in Figure 12.
    a. Push the end of the red wire into hole G10.
    b. Push the end of the black wire into hole J14.



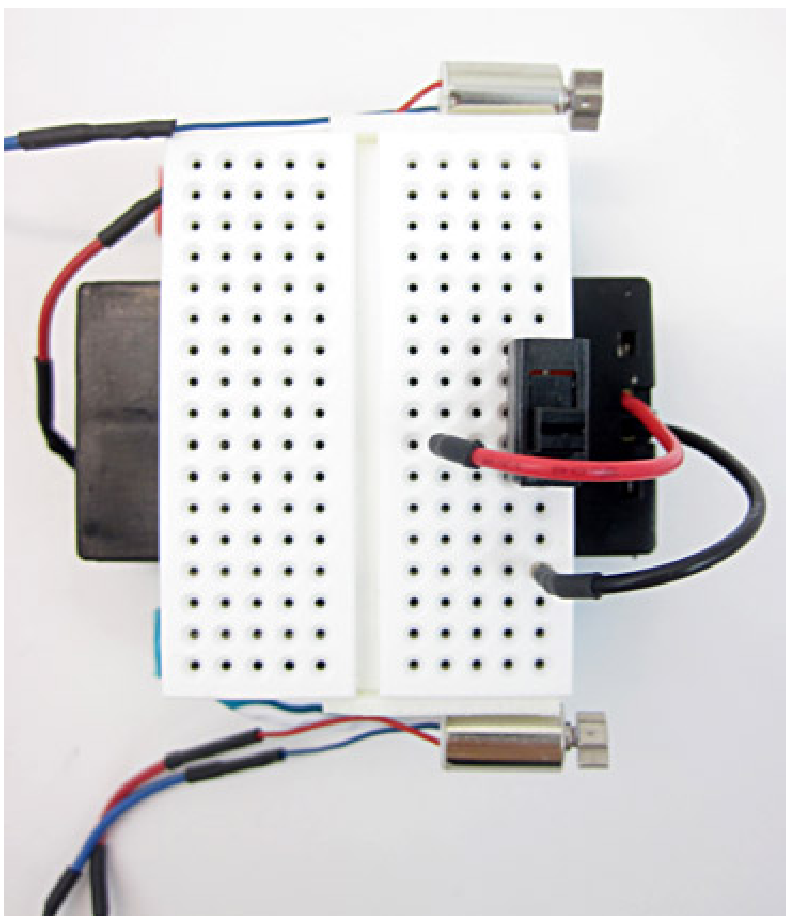
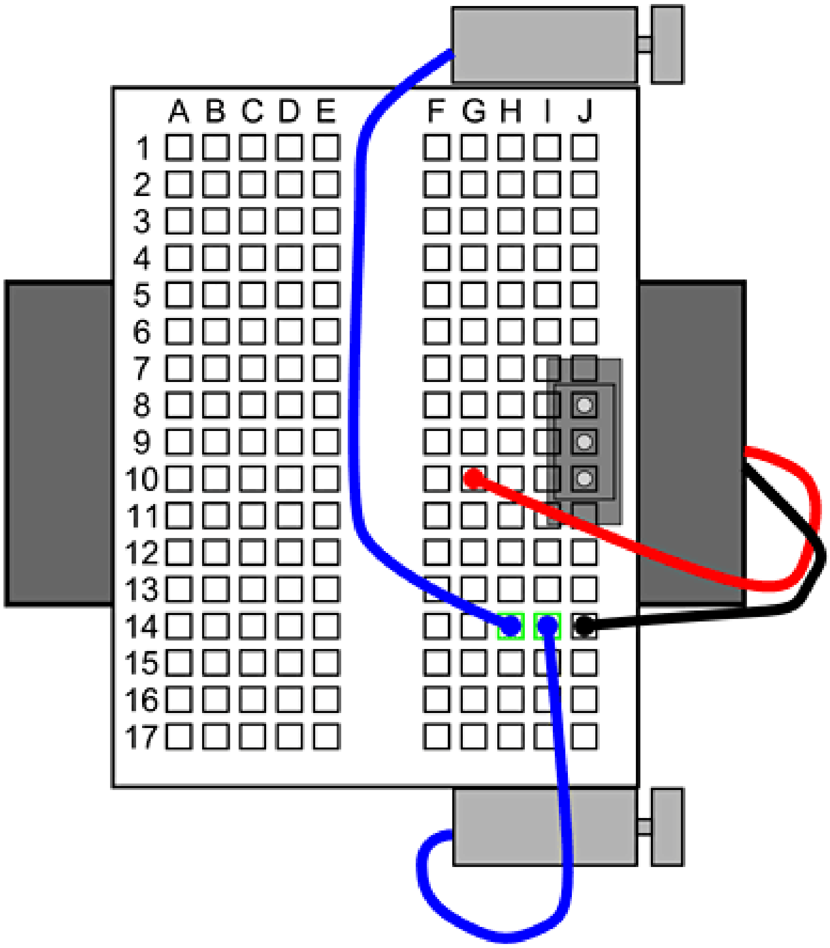


Figure 12. Insert the red wire from the battery holder into hole G10, and the black wire into hole J14.

4. Connect the blue wires from the motors, as shown in Figure 13.
    a. Push the end of one motor's blue wire into hole I14 (it does not matter which motor you pick).
    b. Push the end of the other motor's blue wire into hole H14.



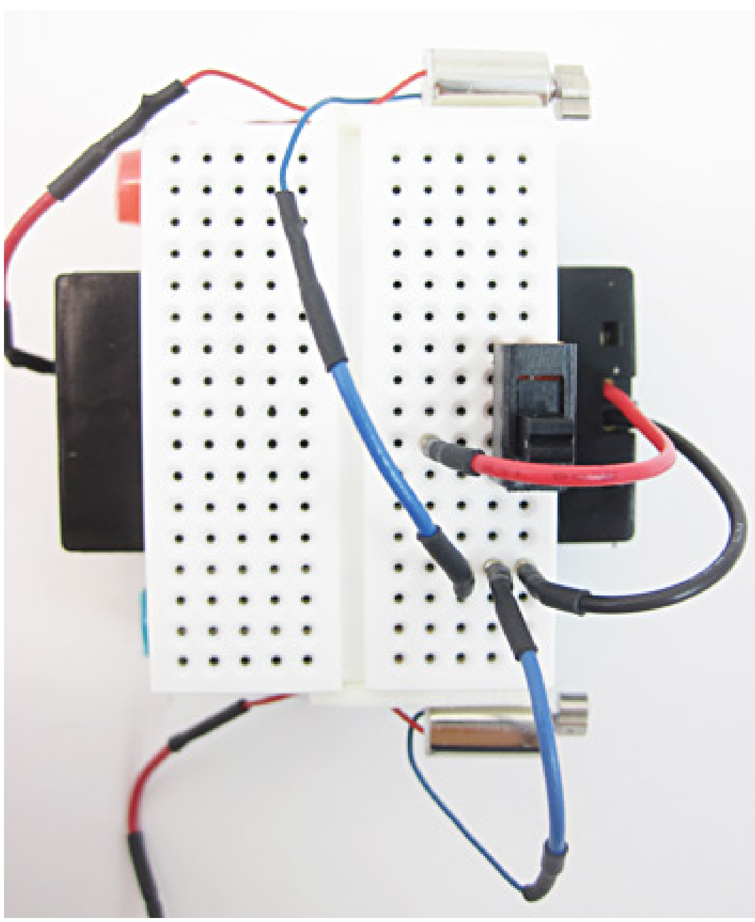
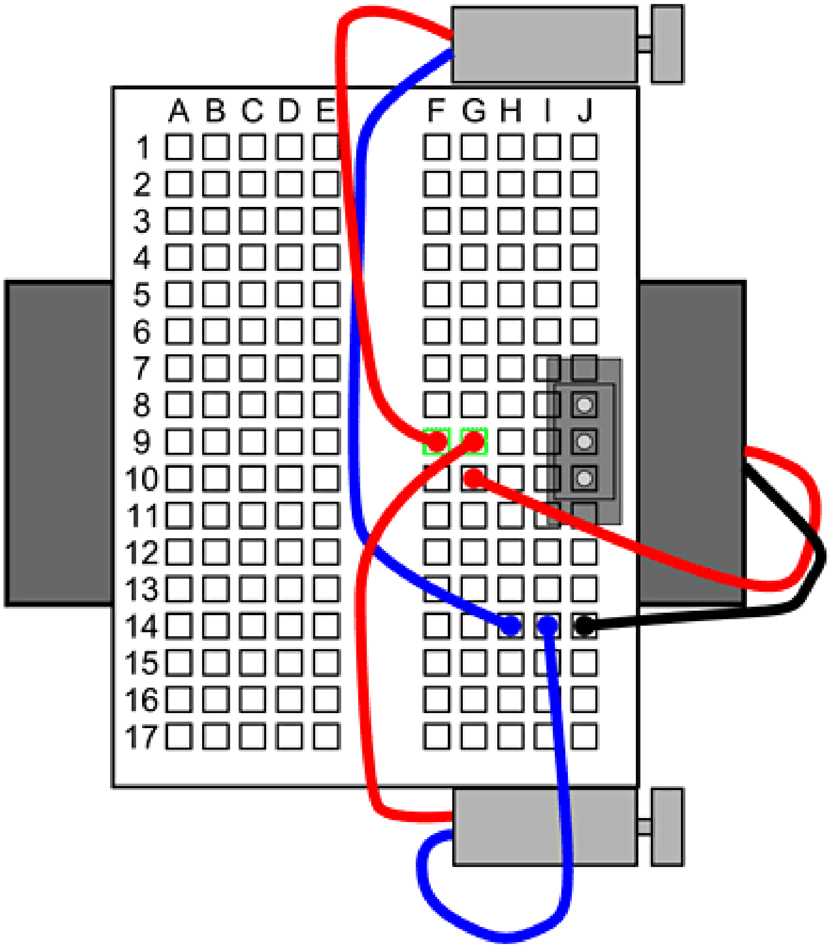


Figure 13. Insert one motor's blue wire into hole I14, and the other motor's blue wire into hole H14.

5. Connect the red wires from the motors, as shown in Figure 14.
    a. Make sure the power switch is pushed "up" (toward row 1 of the breadboard, according to the orientation in Figure 14). This will prevent your motors from turning on during this step.
    b. Connect one motor's red wire to hole F9 (it does not matter which motor you pick).
    c. Connect the other motor's red wire to hole G9.



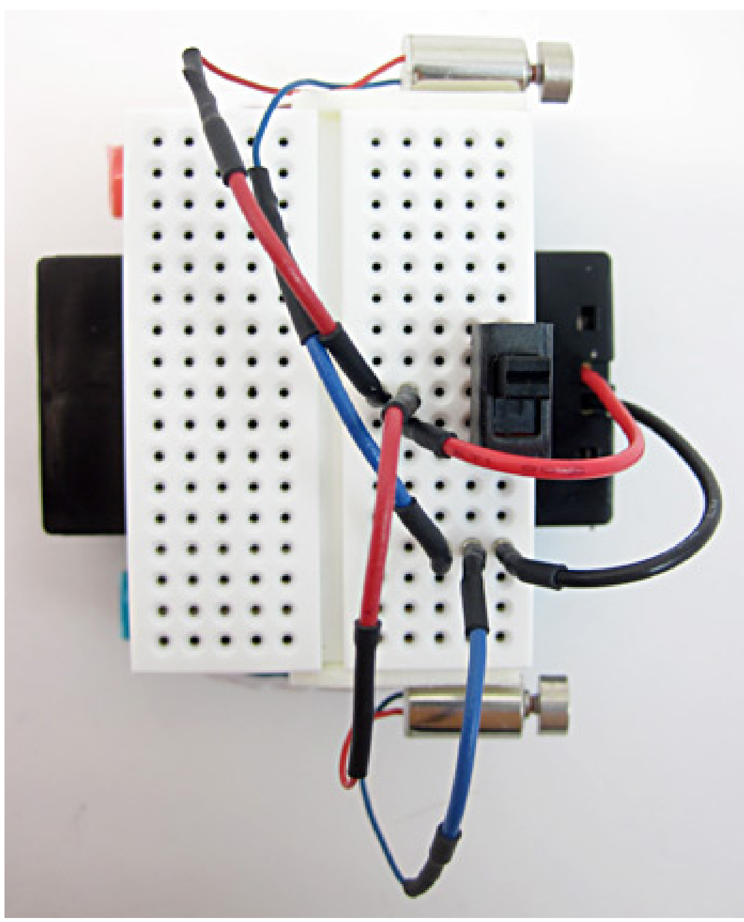


Figure 14. Insert one motor's red wire into hole F9, and the other motor's red wire into hole G9.

6. Connect the mini solar panels, as shown in Figure 15.
    a. Connect the first solar panel's orange wire to hole C1.
    b. Connect that solar panel's black wire to hole C9.
    c. Connect the second solar panel's orange wire to hole D9.
    d. Connect that solar panel's black wire to hole C17.

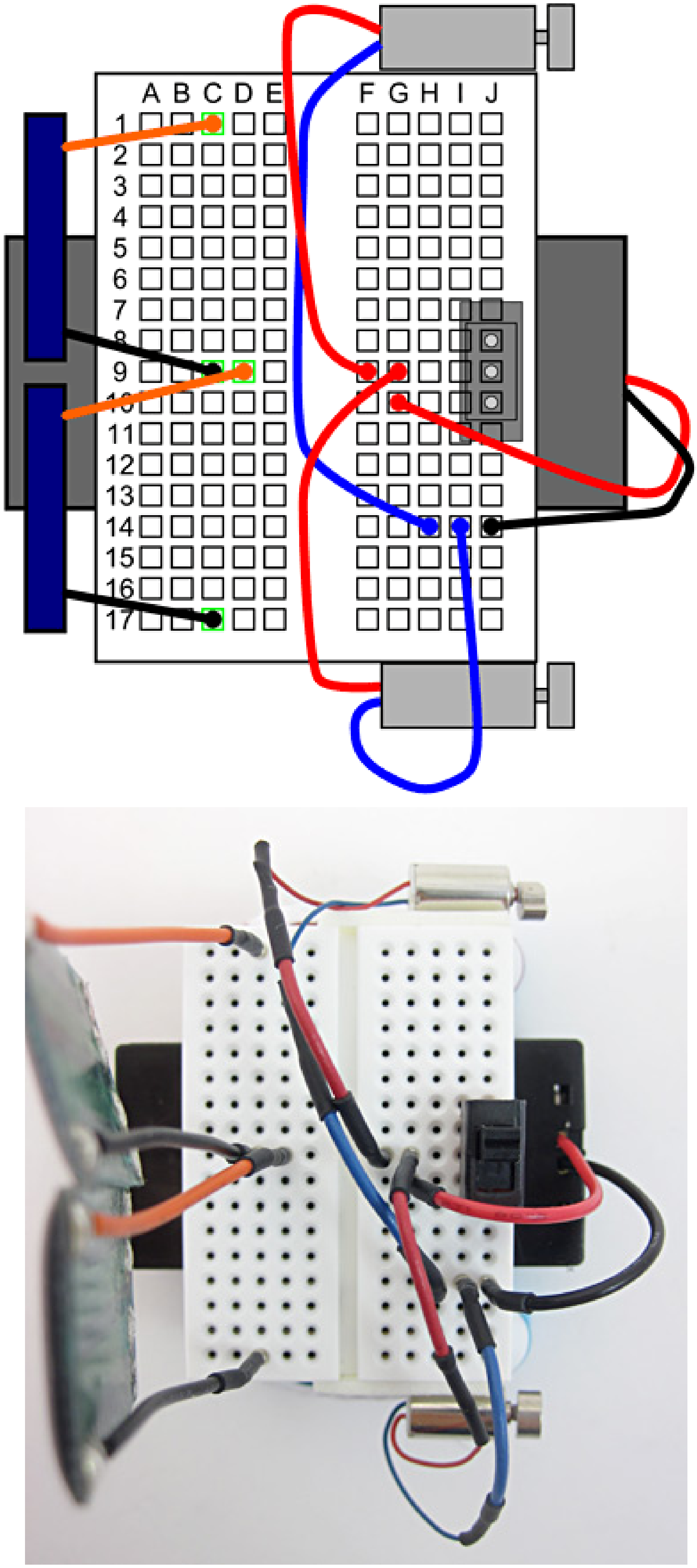
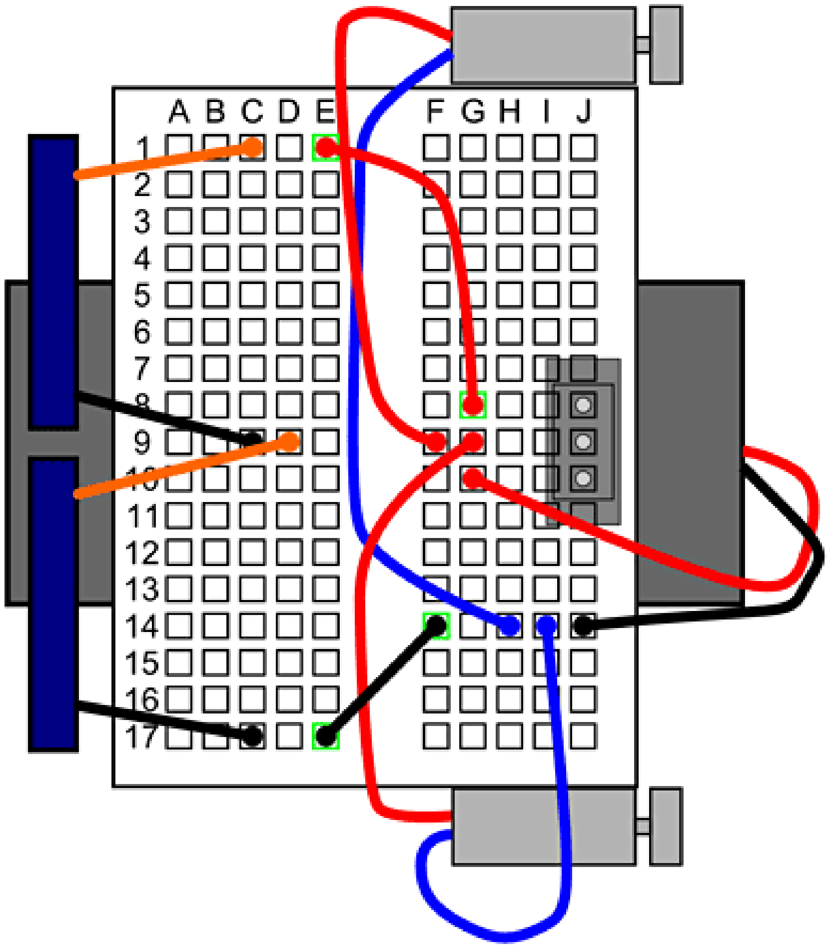


Figure 15. Insert one solar panel's orange and black wires into holes C1 and C9, respectively. Insert the other solar

panel's orange and black wires into holes D9 and C17, respectively.

7. Use jumper wires to connect the solar panels to the rest of the circuit, as shown in Figure 16.
    a. Use a red jumper wire to connect hole E1 to hole G8.
    b. Use the black jumper wire to connect hole E17 to F14.
    c. *Note*: Different-colored jumper wires are just used to help organize circuits and know which wires go where. The different colors all work the same. There is no difference between a red or a black wire on the inside (they are some type of metal, usually copper); they are just coated in different colors of plastic on the outside.



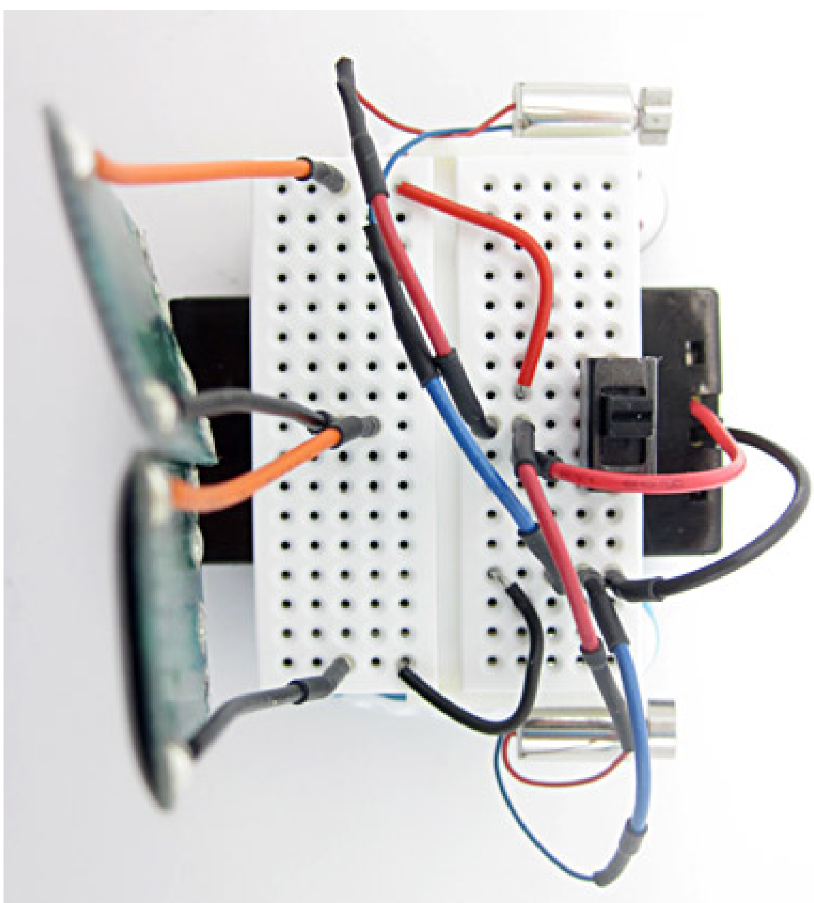


Figure 16. Use the red jumper wire to connect holes E1 and G8, and the black jumper wire to connect holes E17 and

F14.

8. Congratulations! You just built your first robot. Your robot should now look like the one in Figure 17.
    a. *Optional:* You can decorate your robot if you would like. Decorate your robot by adding googly eyes, pipe cleaners, or other arts and crafts materials. *Note:* Be careful not to damage your circuit; for example, do not get glue in or stick a pipe cleaner end into any of the breadboard holes.
    b. If you want to learn more about the robot's circuit, including a circuit diagram, see the Help (#help) tab.

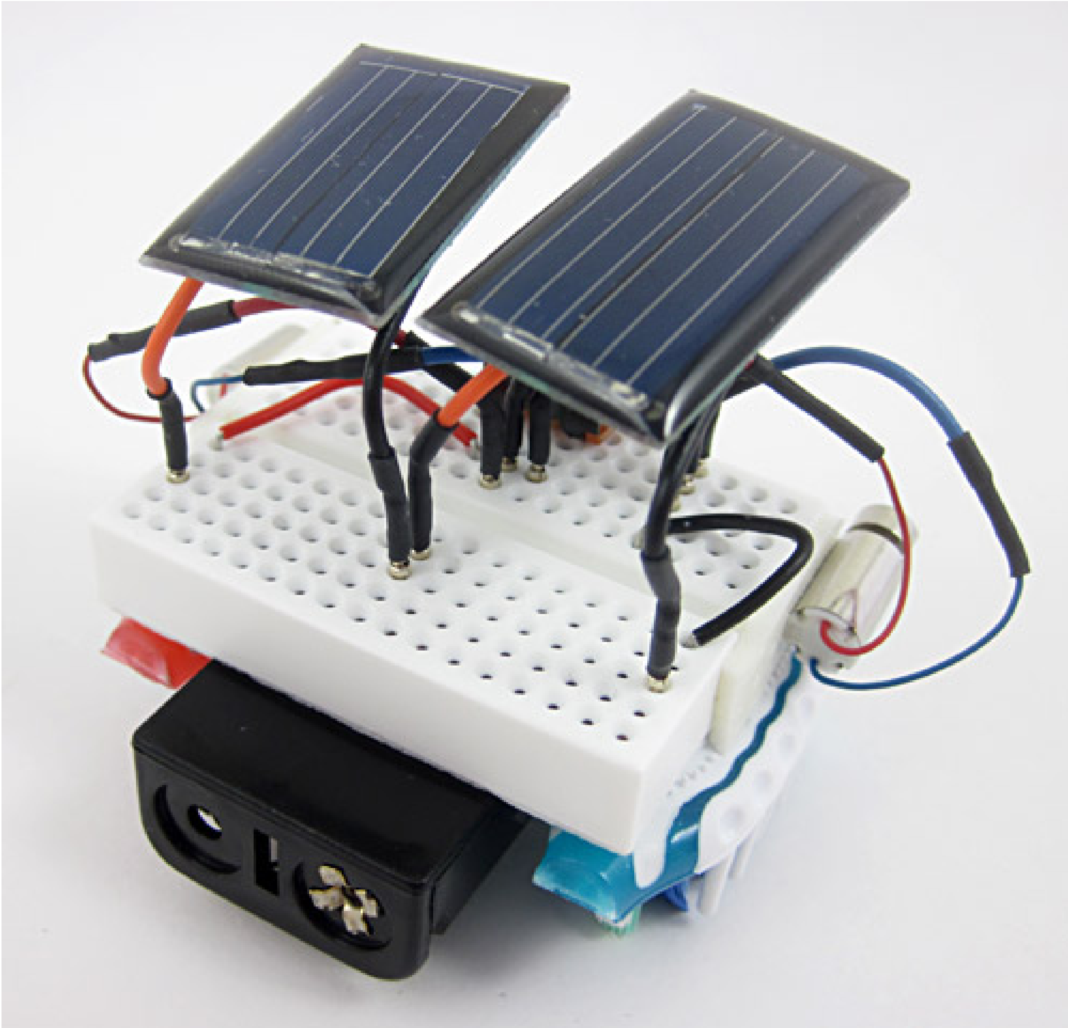


Figure 17. The completed solar bristlebot.

9. Test your robot before you move on to the next section to do your experiment.
    a. Slide the power switch "down" (toward row 17 of the breadboard). This will switch the robot to battery power, and the motors should immediately start spinning. If the motors do not spin at all, see the Help (#help) tab for troubleshooting information.
    b. Put the robot down on a smooth surface, and it should move forward! If the robot does not go straight, but curves sharply off to one side or spins in circles, see the Help (#help) tab for troubleshooting information.
    c. Now, slide the power switch "up" (toward row 1 of the breadboard). This will switch the robot to solar power.
    d. Take the robot outside and place it in direct sunlight. The motors should start to spin, and the robot should move if you put it down on a flat surface. If the motors do not spin at all on solar power, refer to the Help (#help) tab.

Comparing Solar and Battery Power

1. Before you start testing your robot, you will need to set up a "course" so you can measure the robot's speed. You can improvise the course using household materials.
    a. Remember that you will need a flat, smooth surface for the robot to drive on. The toothbrush bristles will get stuck on rough surfaces.
    b. Your robot might curve slightly in one directly instead of driving perfectly straight. This is okay, but it means you might need to build two walls for your course to help guide the robot on a straight path. You can use common household objects for walls, like books or rulers.
    c. Figure 18 shows an example course made from a plastic storage container and two rulers.

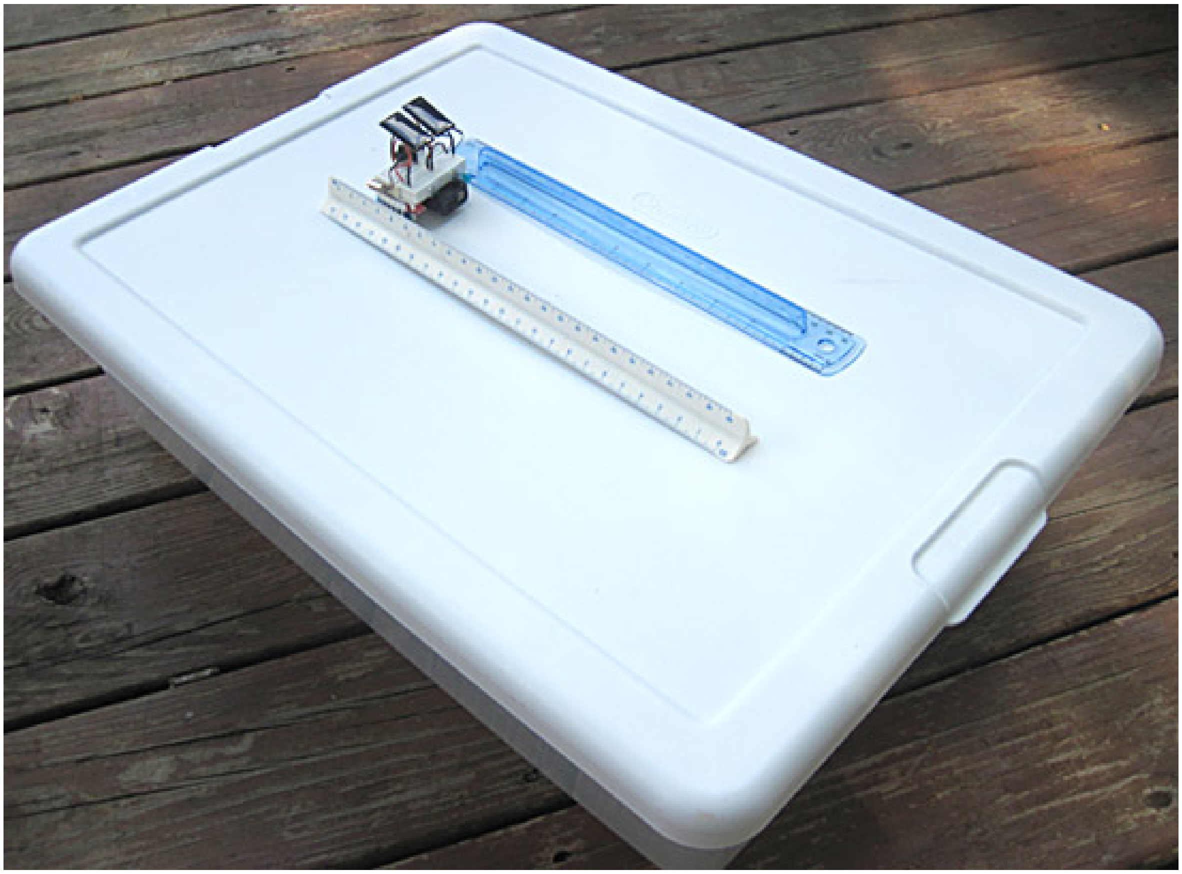


Figure 18. An example "course" for the robot to drive on. The lid of the plastic container provides a smooth, flat surface, and the rulers act as walls to help the robot go straight.

2. In your lab notebook, set up a data table like Table 1. You will use the data table to record how long it takes the robot to go from one end of the course to the other in seconds (sec).
    a. The exact weather conditions you are able to test may depend on the time of year and the climate where you live.
    b. The order in which you do the following steps might also depend on the weather. For example, if you build your robot on a cloudy day, you can do the cloudy day trials first, and then the sunny day trials later.

Power Source	Weather Conditions	Trial 1 (sec)	Trial 2 (sec)	Trial 3 (sec)	Average (sec)
Battery	Full sunlight				
Battery	Cloudy				
Battery	Nighttime				
Solar panels	Full sunlight				
Solar panels	Cloudy				
Solar panels	Nighttime				

Table 1. Example data table to record how fast your robot can drive through the course.

3. Take the robot and your test course outside on a sunny day.
    a. Get your stopwatch ready.
    b. Slide the power switch "down" (toward row 17 of the breadboard) to set the robot to battery power.
    c. Set the robot down on one end of your course. As soon as you do, start the stopwatch.
    d. Watch your robot as it goes down the course. If it gets stuck against one wall, quickly give it a gentle nudge to knock it loose. If your robot consistently turns sharply to one side and always gets stuck as a result, see the Help (#help) tab for suggestions.
    e. As soon as the robot reaches the other end of the course, stop the stopwatch.
    f. Record the time in your data table in the row for "battery power" and "full sunlight".
    g. Repeat step 3 two more times and record the data in the appropriate trial columns.
4. Switch the robot to solar power by sliding the power switch "up" (toward row 1 on the breadboard).
    a. **Important**: Make sure the robot's solar panels are aimed directly at the sun, as shown in Figure 19. This will ensure that they receive the maximum amount of solar power possible. The wires connected to the solar panels are flexible, so you can bend them slightly to aim the panels toward the sun.

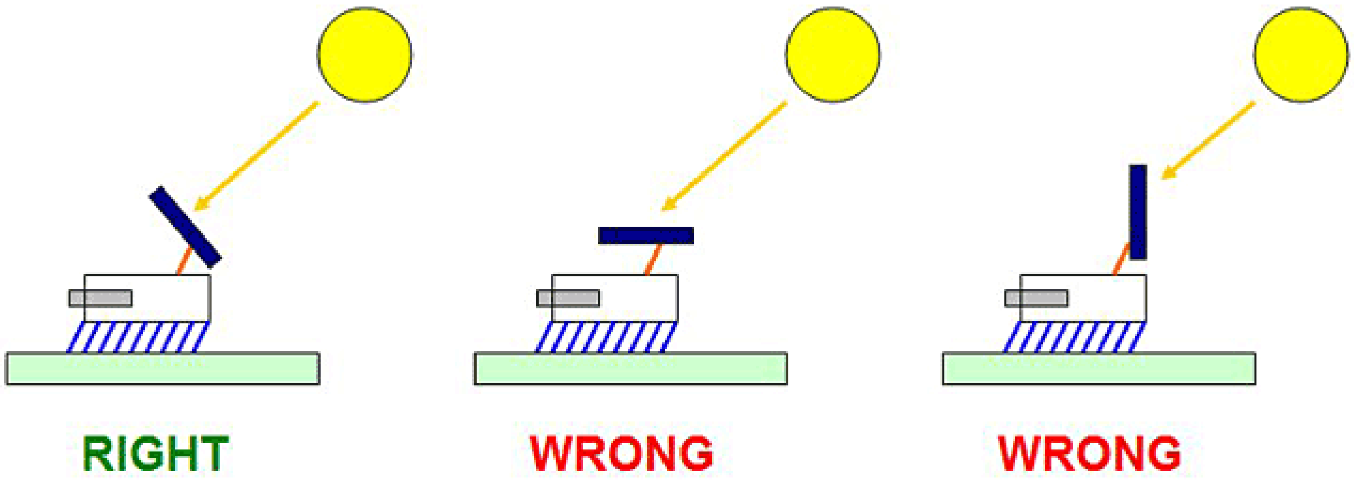


Figure 19. Make sure the solar panels are pointed directly toward the sun.

5. Repeat step 3 with the robot set to solar power instead of battery power.
6. Wait for a cloudy day, and repeat steps 3–5.
    a. Optional: If you live in an area with a lot of sunlight during certain times of the year, it might not be feasible for you to wait for a cloudy day. Instead, try doing your test very early in the morning or very late in the evening, when the sun is low in the sky and not as strong as it is during the middle of the day. Adjust the labels of your data table if necessary (for example, from "cloudy" to "early morning").
    b. Do your best to aim the solar panels directly at the sun through the clouds. You can guess where the sun is based on the time of day (ask an adult if you need help).
    c. Make sure you record all your results in the appropriate row of your data table.
    d. If the robot does not move at all, write "did not move" in the appropriate cell of the data table.
7. Take your robot and test course outside at night, and repeat steps 3–5. Remember to record all your results in your data table and write "did not move" if the robot does not move at all.
8. Analyze your data.
    a. For each row of your data table, calculate an average for the three trials. For example, if the trials were 8 s, 10 s, and 12 s, the average would be (8 + 10 + 12) / 3 = 10 s.
        i. Do not include "did not move" data points in an average, since they do not have a numerical value. If the robot did not move for all three trials, also write "did not move" for the average.
    b. Make a graph for the battery-powered data with the weather condition on the x-axis (horizontal axis) and the average time to complete the course on the y-axis (vertical axis).
    c. Make a second bar graph for the solar-powered data with the weather condition on the x-axis (horizontal axis) and the average time to complete the course on the y-axis (vertical axis).
        i. If the robot did not move for all three trials for a certain data set, write "N/A", which stands for "not applicable," meaning you could not record any times.
    d. Answer the following questions:
        i. Did weather impact the robot's speed using solar power? If so, in which weather condition did the robot move fastest? What about slowest?
        ii. Did weather impact the robot's speed using battery power? If so, in which weather condition did the robot move fastest?
        iii. What are the advantages and disadvantages of running the robot on solar power compared to with the battery?
    e. Now, it might be tempting to think about which power supply is "better" just based on the results of your experiment, but remember, there are some other factors to consider.
        i. Which power supply is renewable? (*Note:* You did not use *rechargeable* batteries in this project, but

even if you did, such batteries are not considered renewable because they need electricity from a wall outlet to be charged, and that electricity likely came from a power plant using fossil fuels.)

ii. What challenges would you need to overcome to use different energy sources at night or when it is cloudy? Could you build a robot with rechargeable batteries that can store energy for later use? See the Make It Your Own (#makeityourown) tab for more details.

iii. In this project, you are restricted to using the solar panels and battery pack that comes with the kit, but do you think you could use larger solar panels or battery packs to make the bristlebot run faster? How could this change your results?

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Variations

- How does the robot's speed change if you change the angle of the solar panels relative to the sun (e.g. to the positions labeled "wrong" in Figure 19 (#figure19))?
- How does the robot's speed change if you test the solar panels at different times of day, or different times of year? Does this have to do with the sun's position in the sky?
- Look up the difference between *series* and *parallel* circuits. In the circuit for this project, you connected the solar cells in series. What happens if you connect them in parallel? Does the robot's speed change?
- Can you make a *rechargeable* solar-powered bristlebot? The goal is to make a circuit with solar panels and rechargeable AAA batteries. In direct sunlight, the solar panels can run the motors and charge the batteries. When sunlight is not available, the robot can run on backup battery power. This eliminates the need to manually select one of the two power supplies with a switch. See this page (http://www.robotroom.com/Solar-Recharging.html) for a circuit design (requires extra components not included in your Advanced Bristlebots Kit).
- What happens if you remove the batteries from the robot to make it lighter, and only run it on solar power? Does that make the robot faster?
- Can you build a larger solar-powered robot? For example, check out the Build a Brushbot (http://www.sciencebuddies.org/hands-on-activities/brushbot) home science activity or the Art Bot: Build a Wobbly Robot Friend that Creates Art (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_p014.shtml) science project. You will need to purchase bigger solar panels to build a bigger robot.
- Use a multimeter to measure the *open-circuit voltage* and *short-circuit current* of both the AAA battery pack and the solar panels. How do the two power supplies compare in terms of the maximum voltage and current they can provide? How do the supplied voltages and currents change when they are "under load" (driving the motors)? Refer to the Science Buddies Multimeter Tutorial (http://www.sciencebuddies.org/science-fair-projects/multimeters-tutorial.shtml) if you need help using a multimeter.
- How long does it take for your batteries to die if you leave the robot on continuously? Do an online search to look up the prices of AAA batteries and tiny solar panels. Use that information to calculate the *payback period* for the solar panels, or the amount of time it takes you to start saving money if the solar panels are initially more expensive than the batteries.

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Frequently Asked Questions (FAQ)

If you are having trouble with this project, please read the FAQ below. You may find the answer to your question.

- Why are my motors not spinning on battery power? (#question1)
- Why are my motors not spinning on solar power? (#question2)
- Why does my robot always turn to one side? (#question3)
- Why does my robot not go forward at all? (#question4)
- What is the circuit diagram for this robot? (#question5)

Q: Why are my motors not spinning on battery power?
A: If your motors do not spin when you push the power switch "down" to set the circuit to battery power, check the following items. For an overview of some other common mistakes you can make when using a breadboard, see the Common Mistakes (http://www.sciencebuddies.org/science-fair-projects/breadboard-tutorial#common-mistakes) section of the breadboard tutorial.

- Make sure you properly inserted the two AAA batteries into the battery holder, so the "+" symbols on the batteries line up with the "+" symbols inside the battery holder. Refer to Figure 4 (#figure4) in the Procedure.
- Make sure the red and black wires from your battery pack are pressed all the way into the correct holes of the breadboard, as shown in Figure 12 (#figure12) in the Procedure.
- Make sure the red and blue wires from your motors are pressed all the way into the correct holes of the breadboard, as shown in Figure 14 (#figure14) of the Procedure.
- Make sure the spinning weights on the ends of the motors are not getting stuck against the double-sided tape.
- If you try all of the previous steps and your motors *still* do not spin at all, follow these steps to see if the problem is with your power switch:
  - Remove the power switch from the breadboard, flip it around, and put it back into the same breadboard holes (J8, J9, J10). If you are confused about which way to rotate the switch, see this video (https://youtu.be/zkGBW5JSqls).
  - Slide the power switch to the "down" position (when the robot is oriented as shown in Figure 16) to toggle the robot to battery power, and try testing your robot again. If your robot works after making this change, but did not work with the switch in its original position, you have a faulty power switch that only works in one direction. You can continue with the project, but will have to flip the switch around each time you want to toggle between battery and solar power (or remove the switch entirely and connect/disconnect individual wires, see next point). Please contact us at scibuddy@sciencebuddies.org (mailto:scibuddy@sciencebuddies.org?subject=Solar%20bristlebot:%20switch%20works%20when%20flipped) to let us know this happened.
  - If your robot still does not work after flipping the power switch around, remove the power switch from the breadboard entirely. Connect the battery pack's red lead to hole H9 (instead of hole G10). This connects the battery pack directly to the motors. To turn the robot off again, you will have to temporarily disconnect this wire.
  - Now, re-try testing your robot. If your robot works, you can continue with the project, but please contact us at scibuddy@sciencebuddies.org (mailto:scibuddy@sciencebuddies.org?subject=Solar%20bristlebot:%20switch%20did%20not%20work%20in%20either%20direction) to let us know the switch did not work in either direction. To switch your robot to solar power, you will need to disconnect the battery pack's red lead first, then move the red jumper wire from hole G8 to hole H9.
  - If your robot still does not work, even after you have tried the previous steps (flipping the power switch

around; and removing it entirely and putting the battery pack's red lead in hole H9), the problem is elsewhere in your circuit and not with the power switch. If you are having trouble figuring out what is wrong with your robot, you can ask a question in our Ask an Expert (http://www.sciencebuddies.org/science-fair-projects/ask-an-expert-intro) forums.

Q: Why are my motors not spinning on solar power?

A: If your motors do not spin when you push the power switch "up" to set the circuit to solar power, check the following items. For an overview of some other common mistakes you can make when using a breadboard, see the Common Mistakes (http://www.sciencebuddies.org/science-fair-projects/breadboard-tutorial#common-mistakes) section of the breadboard tutorial.

- Make sure you are outside in direct sunlight, with the solar panels pointed toward the sun.
- Make sure the orange and black wires from your solar panels, and the red and black jumper wires, are pressed all the way into the correct holes of the breadboard, as shown in Figure 15 (#figure15) and Figure 16 (#figure16) of the Procedure.
- Make sure the red and blue wires from your motors are pressed all the way into the correct holes of the breadboard, as shown in Figure 14 (#figure14) of the Procedure.
- Make sure the spinning weights on the ends of the motors are not getting stuck against the double-sided tape.
- If you try all of the previous steps and your motors *still* do not spin at all, follow these steps to see if the problem is with your power switch:
    - Remove the power switch from the breadboard, flip it around, and put it back into the same breadboard holes (J8, J9, J10). If you are confused about which way to rotate the switch, see this video (https://youtu.be/zkGBW5JSqls).
    - Slide the power switch to the "up" position (when the robot is oriented as shown in Figure 16) to toggle the robot to solar power, and try testing your robot again. If your robot works after making this change, but did not work with the switch in its original position, you have a faulty power switch that only works in one direction. You can continue with the project, but will have to flip the switch around each time you want to toggle between solar and battery power (or remove the switch entirely and connect/disconnect the wires each time, see next point). Please contact us at scibuddy@sciencebuddies.org (mailto:scibuddy@sciencebuddies.org?subject=Solar%20bristlebot:%20switch%20works%20when%20flipped) to let us know this happened.
    - If your robot still does not work after flipping the power switch around, remove the power switch from the breadboard entirely. Disconnect one end of the red jumper wire from hole G8 and move it to hole H9. This connects the solar panels directly to the motors. To turn the robot off again, you will have to temporarily disconnect this wire.
    - Now, re-try testing your robot. If your robot works, you can continue with the project, but please contact us at scibuddy@sciencebuddies.org (mailto:scibuddy@sciencebuddies.org?subject=Solar%20bristlebot:%20switch%20did%20not%20work%20in%20either%20direction) to let us know the switch did not work in either direction. To switch your robot to battery power, you will need to disconnect the red jumper wire from hole H9, and then connect the battery pack's red lead to hole H9 instead.
    - If your robot still does not work, even after you have tried the previous steps (flipping the power switch around; and removing it entirely and moving the red jumper wire from hole G8 to H9), the problem is elsewhere in your circuit and not with the power switch. If you are having trouble figuring out what is wrong with your robot, you can ask a question in our Ask an Expert (http://www.sciencebuddies.org/science-fair-projects/ask-an-expert-intro) forums.

Q: Why does my robot always turn to one side?

A: Since the robot does not have a "brain" to help it steer left and right, it may tend to drift off in one direction. This is normal and does not mean there is anything wrong with your robot. It is actually pretty difficult to build a robot that will drive *perfectly* straight, due to small misalignments when you attach parts like the toothbrush heads and motors. For your experiment, you can use walls to help guide the robot along a straight path, as shown in Figure 18 (#figure18) of the Procedure.

If your robot turns *very sharply* to one side, check the following:

- Make sure the battery holder is *centered* under the breadboard, as shown in Figure 6 (#figure6) of the Procedure. If the battery holder is too far off to one side, this could cause the robot to turn excessively.
- Make sure the two toothbrush heads are mounted straight and parallel to each other, as shown in Figure 7 (#figure7) of the Procedure. If one or both toothbrush heads are crooked, this can cause the robot to turn to one side.
- Make sure you are using two identical toothbrushes. If you use two different toothbrush heads, this could cause the robot to always turn to one side.
- Make sure both motors are spinning. If only one motor is spinning, this can cause the robot to drive in very tight circles.

Q: Why does my robot not go forward at all?
A: If your robot does not move forward *at all*, meaning it just goes sideways or even backwards, this is likely caused by the type of toothbrush head you used. It is very important to use a toothbrush where the longest bristles are all slanted in one direction. If you used toothbrushes with straight bristles, or toothbrushes with bristles slanted in both directions, the robot will not be able to drive straight. See Figure 3 (#figure3) in the Procedure for an example.

Q: What is the circuit diagram for this robot?
A: *Note*: This question is intended for advanced users who are already familiar with circuit diagrams.

The circuit for this robot is relatively simple. The circuit diagram is shown in Figure 20, below. The two motors are connected in parallel. A single-pole double-throw (SPDT) switch lets you toggle between solar power or battery power. The two power supplies are never connected at the same time, and the solar panels do *not* charge the batteries (for ideas on making a rechargeable solar circuit, see the Make It Your Own (#makeityourown) tab).

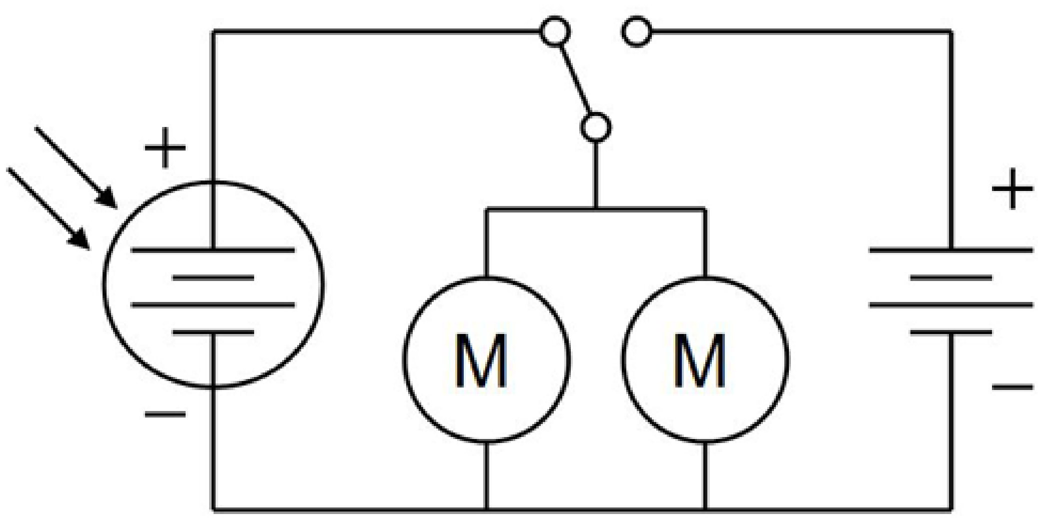

Figure 20. Circuit diagram for the solar-powered bristlebot.

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Ask an Expert **(http://www.sciencebuddies.org/science-fair-projects/ask_an_expert_intro.shtml)**

Contact Us

If you have purchased a kit for this project from Science Buddies, we are pleased to answer any question not addressed by the FAQ above.

In your email, please follow these instructions:

1. What is your Science Buddies kit order number?
2. Please describe how you need help as thoroughly as possible:

   Examples

   Good Question *I'm trying to do Experimental Procedure step #5, "Scrape the insulation from the wire. . ." How do I know when I've scraped enough?*
   Good Question *I'm at Experimental Procedure step #7, "Move the magnet back and forth . . ." and the LED is not lighting up.*
   Bad Question *I don't understand the instructions. Help!*
   Good Question *I am purchasing my materials. Can I substitute a 1N34 diode for the 1N25 diode called for in the material list?*
   Bad Question *Can I use a different part?*

Contact Us **(mailto:help@sciencebuddies.org?subject=Build%20a%20Solar-Powered%20Bristlebot)**

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- Other Ideas Like This (http://www.sciencebuddies.org/science-fair-projects/search.shtml?v=solt&pi=Robotics_p026)
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If you like this project, you might enjoy exploring these related careers:

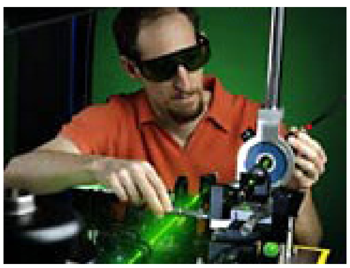
Robotics Engineer

Have you watched "The Transformers" cartoon series or seen the "Transformers" movies? Both shows are about how good and evil robots fight each other and the humans who get in the middle. Many TV shows and movies show robots and humans interacting with each other. While this is, at present, fantasy, in real life robots play a helpful role. Robots do jobs that can be dangerous for humans. For example, some robots defuse landmines in war-stricken countries; others work in harsh environments like the bottom of the ocean and on the planet Mars. At the heart of every robot is a robotics engineer who thinks about what a robot needs to do and works with several engineering disciplines to design and put together the perfect piece of equipment. Read more (http://www.sciencebuddies.org/science-engineering-careers/engineering/robotics-engineer)

Solar Energy Systems Engineer

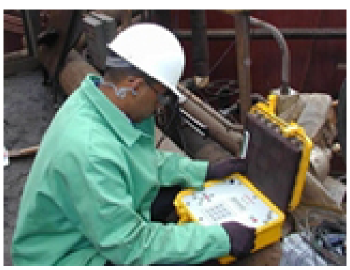
Does the idea of harvesting the enormous power of the sun interest you? If you find this exciting, then you should think about installing solar photovoltaic panels on your house to collect free electricity from the sun. But how energy efficient is your home already? Can it get better? How many panels would your house need? What would the system look like? You can get the answers to these questions and more from your local solar energy systems engineer. These engineers help their residential and commercial clients save on their electric bills and reduce their carbon footprint by performing energy audits and picking and designing the right solar energy system for them.

Read more (http://www.sciencebuddies.org/science-engineering-careers/engineering/solar-energy-systems-engineer)



Electrical & Electronics Engineer

Just as a potter forms clay, or a steel worker molds molten steel, electrical and electronics engineers gather and shape electricity and use it to make products that transmit power or transmit information. Electrical and electronics engineers may specialize in one of the millions of products that make or use electricity, like cell phones, electric motors, microwaves, medical instruments, airline navigation system, or handheld games. Read more (http://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-electronics-engineer)



Energy Engineer

How much energy do you think all the houses and buildings in the United States consume? It turns out they eat up 40% of all the energy that the U.S. uses in a year. The figure is high because all those houses and buildings need to be heated, cooled, lit, ventilated, and supplied with heated water and electricity to run all sorts of electrical devices, appliances, and computers. Energy efficiency engineers help reduce the energy that houses and buildings use. This saves families and businesses money, and lowers the emissions of greenhouse gases that contribute to global warming. Read more (http://www.sciencebuddies.org/science-engineering-careers/engineering/energy-engineer)

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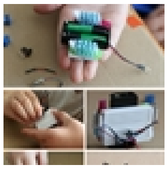

Building a Solar-powered Bristlebot (http://www.sciencebuddies.org/news/article?id=127786), *Science Buddies Blog*, April 17, 2015

How to Do Robotics at Home with Your Kids (http://www.sciencebuddies.org/news/article?id=131212), *Science Buddies Blog*, April 28, 2015

Family Robotics: Toothbrush Bots that Follow the Light (http://www.sciencebuddies.org/news/article?id=97712), *Science Buddies Blog*, December 12, 2013

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