Build and Test a Sun-Tracking Solar Panel

Experimental Procedure

This project follows the Scientific Method. Review the steps before you begin.

Before you begin: Review How to Use an Arduino Tutorials 1-3.

Assemble Your Circuit

Before you build and test your complete tracking system, follow the steps in this section to assemble your circuit as shown in Figures 5 and 6. You can also access a Tinkercad Circuits simulation of the circuit here. For now, you can put parts like the photoresistors directly in the breadboard, without using male-female jumper wires as extension cables to connect them to the tracker.

1. Connect the servo motor. Assuming you have an SG90 servo motor with orange, red, and black wires (if not, you will need to look up the connections for your motor):
    a. Orange wire to Arduino pin 9
    b. Red wire to breadboard power bus
    c. Black wire to breadboard ground bus
2. For each photoresistor:
    a. Connect one leg to the power bus
    b. Connect the other leg to one side of a 10kΩ resistor
    c. Connect the other side of the resistor to the ground bus
    d. Connect one of the Arduino's analog input pins to the middle connection between the photoresistor and fixed resistor
3. If you purchased a solar panel with 5V or less output:
    a. Connect the negative (black) wire to the ground bus
    b. Connect the positive (red) wire to one of the Arduino's analog inputs
    c. If you purchased a solar panel with more than 5V output, **do not connect it to your Arduino**. You can use a multimeter to measure its output instead.
4. Connect power from your Arduino:
    a. 5V pin to breadboard power bus
    b. GND pin to breadboard ground bus

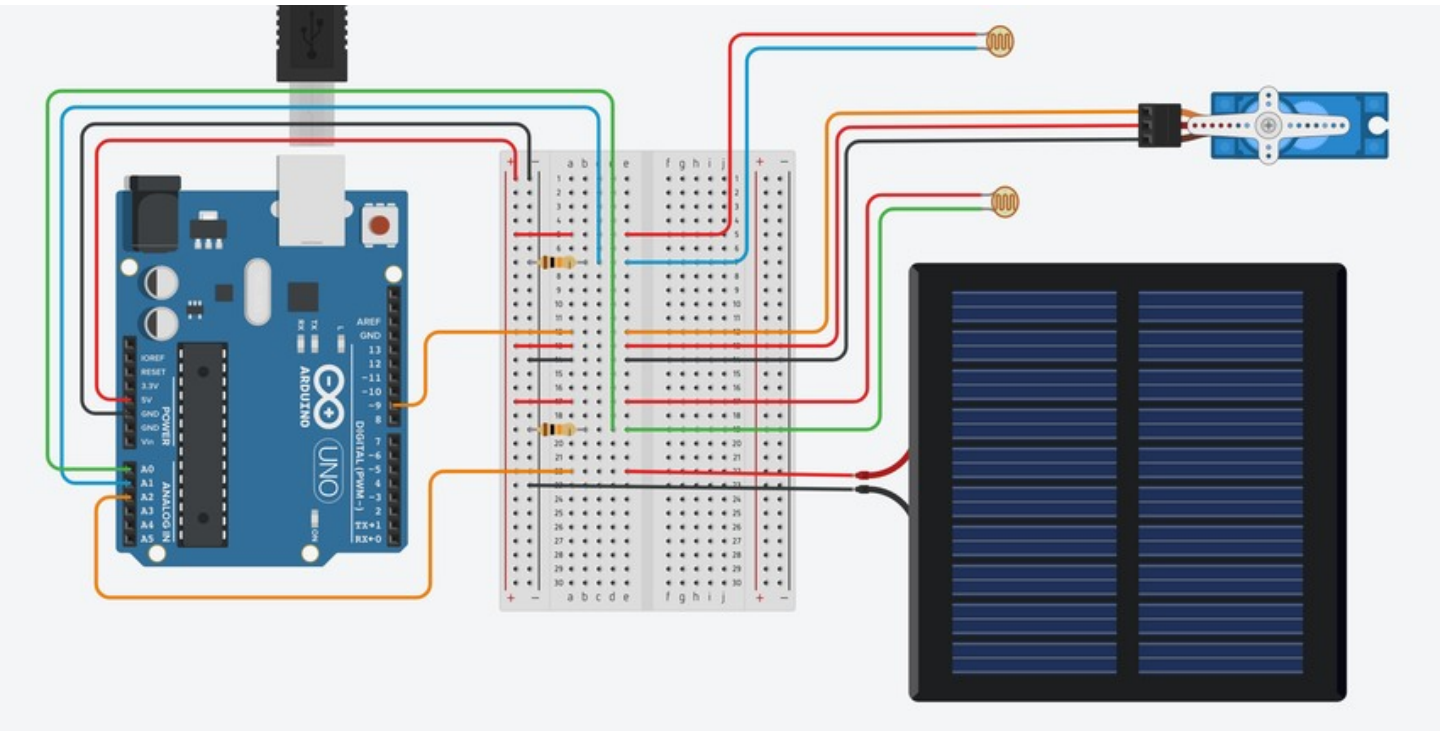

Image Credit: Ben Finio / Science Buddies

Figure 5. Breadboard diagram for Arduino solar tracker.

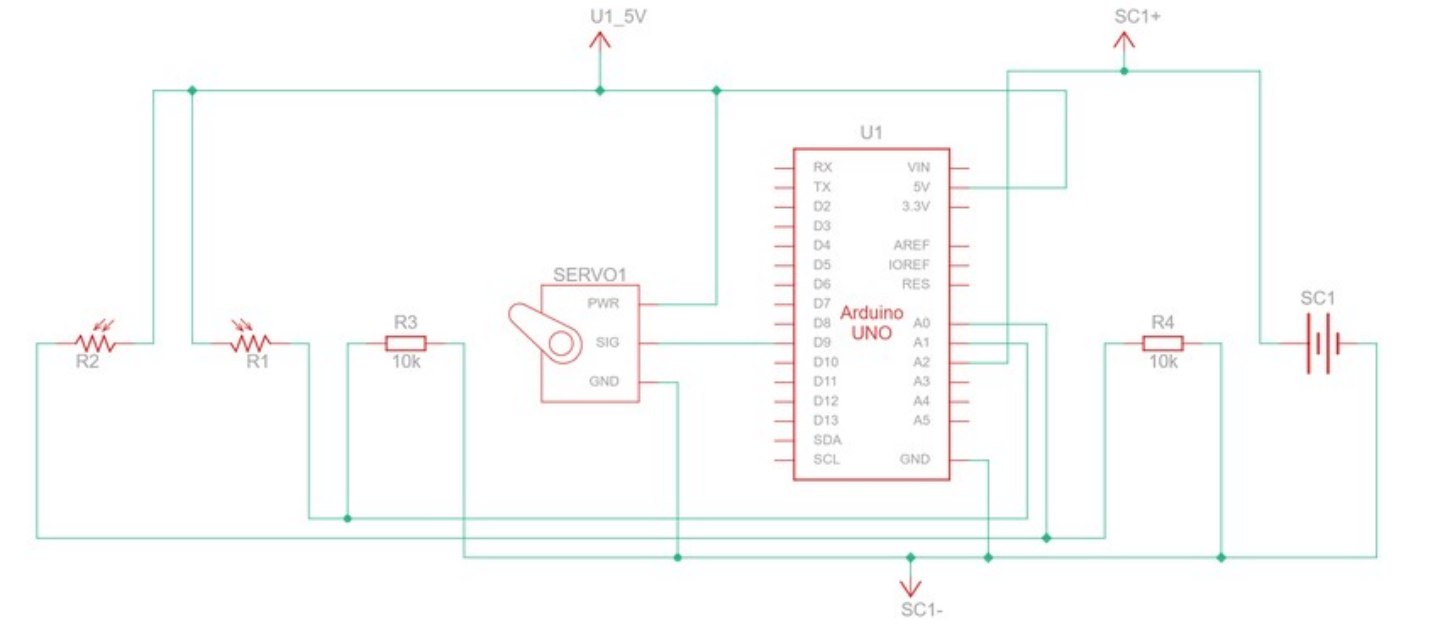

Image Credit: Ben Finio / Science Buddies

Figure 6. Circuit diagram for Arduino solar tracker.

Test Your Circuit

Before you build the support structure for your motor and solar panel, you should test your circuit to make sure that everything works properly.

1. Download solar_tracker.ino.
2. Read through the commented code so you understand how it works.

3. Upload the code to your Arduino.
4. Open the serial monitor (Tools→Serial monitor).
5. Watch the numbers in the serial monitor. Try covering one of the photoresistors with your finger. The value for that sensor should go down.
6. By default, when the difference between the two sensor readings is greater than 50, the servo motor should rotate.
7. If possible, take your Arduino outside in direct sunlight while it is connected to your computer with a USB cable. If this is not possible, find a window with exposure to direct sunlight indoors.
8. Continue watching the serial monitor and try covering the sensors with your finger one at a time. Write down the sensor readings in direct sunlight and when shaded with your finger.
9. You may need to make adjustments to the `margin` variable in the code and/or change the default 10kΩ resistor values to get your circuit to work properly. It will depend on how strong the sun is in your area at the time of year you are doing the project and on the photoresistors you purchased (photoresistors can have a wide resistance range). Here are some tips:
    a. If your sensor values seem "saturated" (they are always very close to 1000 and do not change much when you cover them with your finger), try swapping out the 10kΩ resistors for *smaller* resistors.
    b. If your sensor values seem saturated in the other direction (they are always close to zero and do not change much), try swapping out the 10kΩ resistors for *bigger* resistors.
    c. If the sensor values change when you cover one with your finger, but do not change enough to make the motor spin, try decreasing the `margin` variable from the default value of 50.
    d. If the motor moves too easily because the sensor values fluctuate too much, try increasing the `margin` variable.
10. Your goal is to adjust your system so that the motor holds still when both photoresistors are directly facing the sun, and the motor rotates when one photoresistor is shaded. Continue adjusting your system as needed to achieve this behavior.

Build Your Tracker

Once you have your circuit working on a breadboard, you need to build a tracker with your solar panel and photoresistors mounted on a servo motor so they can rotate, as shown in Figures 7-12.

1. Disconnect the photoresistors, servo motor, and solar panel from the breadboard.
2. Cut a piece of cardboard to serve as a secure base to attach everything (Figure 7).

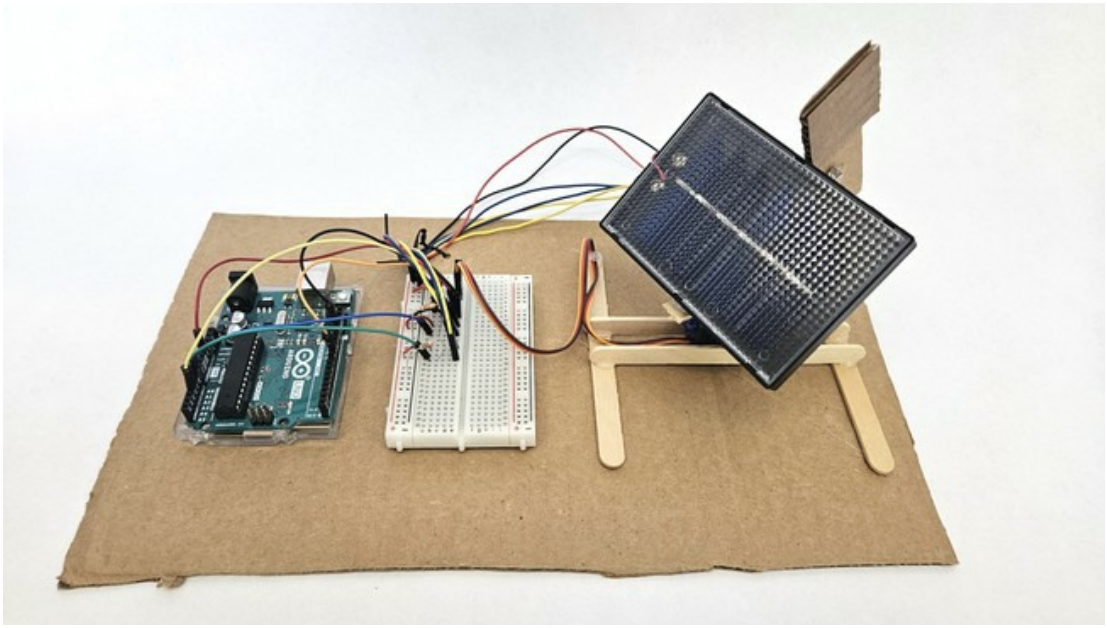

Image Credit: Ben Finio / Science Buddies

Figure 7. Solar tracker mounted on a cardboard base.

3. Mount your Arduino and breadboard to the cardboard using double-sided foam tape.
4. Build a support structure using hot glue and popsicle sticks to hold your servo motor vertically (Figure 8). Make sure the supports are securely glued to the cardboard base.

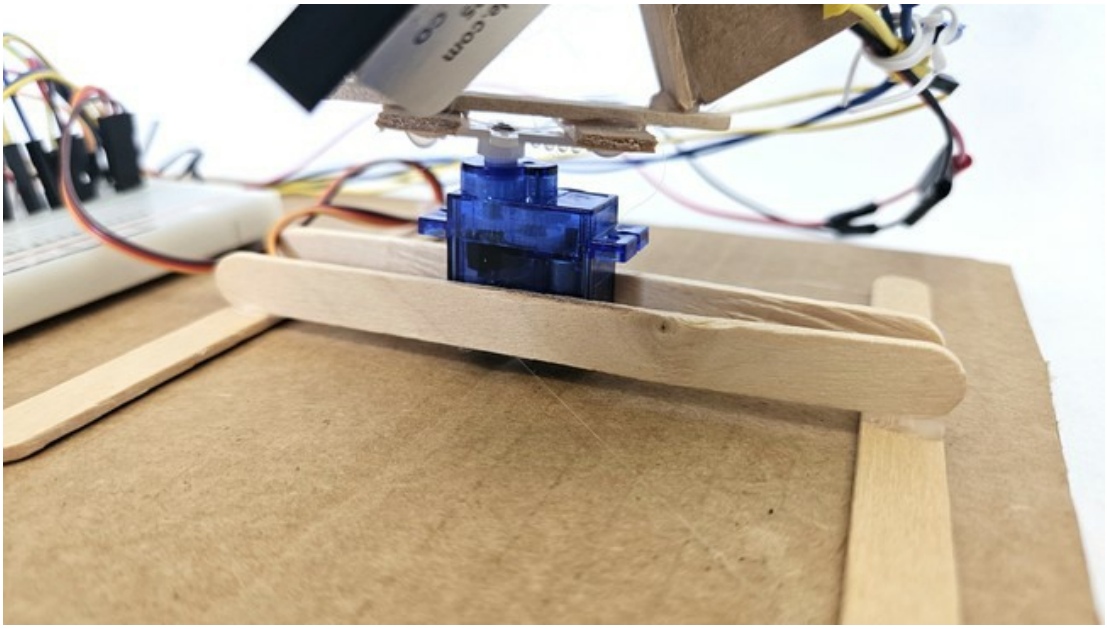

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Figure 8. Popsicle stick supports for servo motor.

5. Make sure your servo is centered at 90 degrees. You can do this by temporarily modifying your program to manually set the angle to 90 degrees with the command `servo1.write(90);`.
6. Attach the servo horn to the servo.
7. Use popsicle sticks and hot glue to create a support structure for the solar panel and attach it to the servo horn (Figure 9).

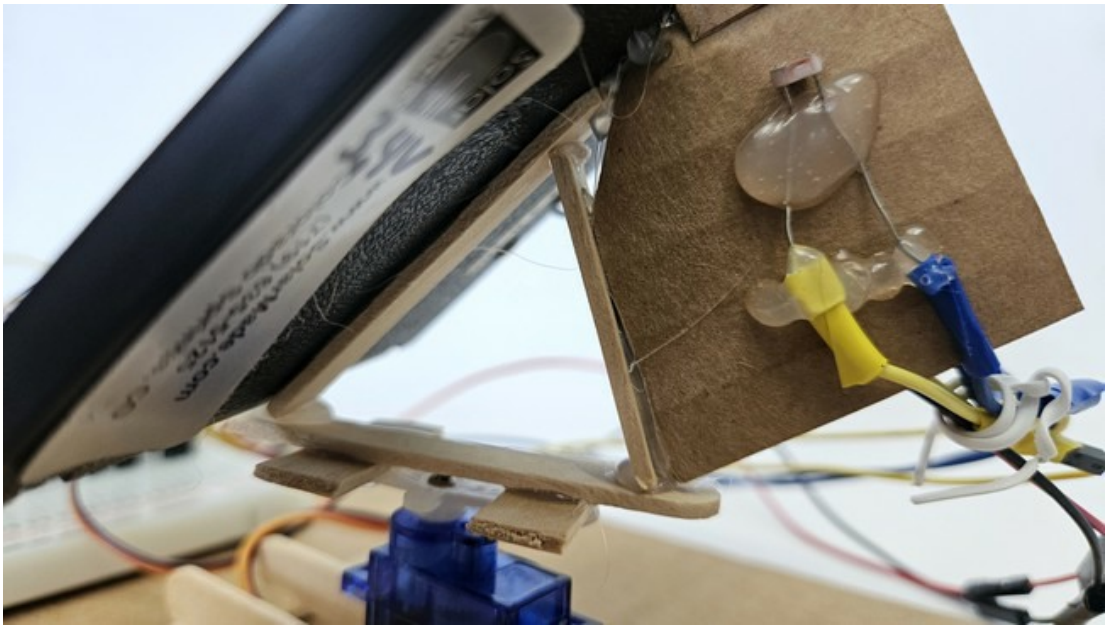

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Figure 9. Popsicle stick support structure for solar panel.

8. Cut a small piece of cardboard and mount it vertically above the solar panel (Figure 10).

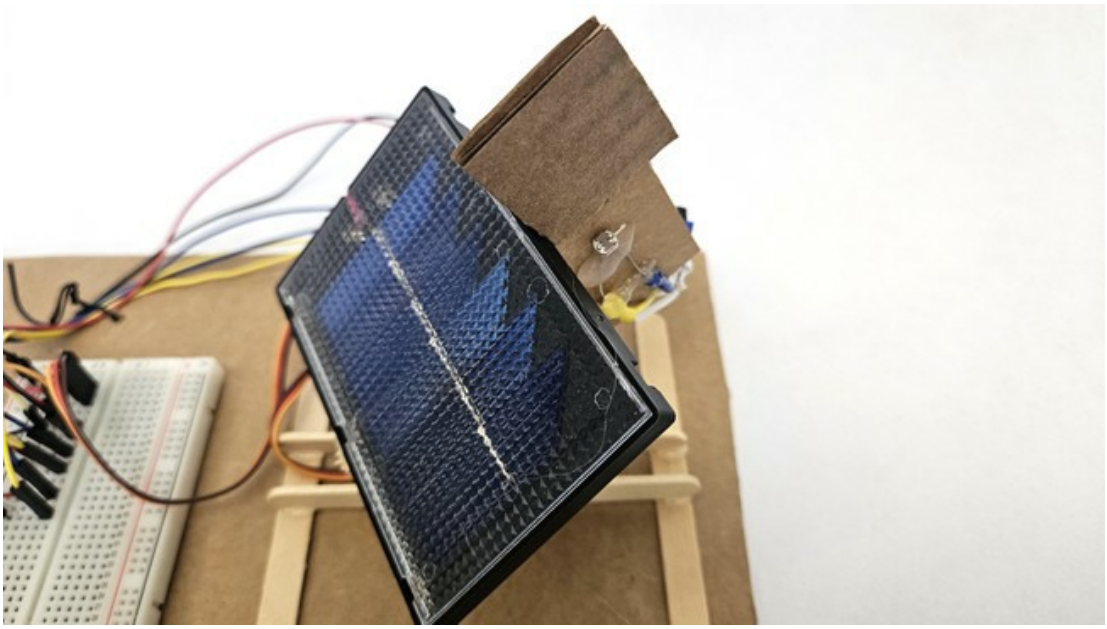

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Figure 10. Side view of the piece of cardboard mounted vertically above the solar panel. Only one photoresistor is visible from this angle, and the other is behind the piece of cardboard.

9. Glue one photoresistor to each side of the piece of cardboard, facing upright (Figure 11).

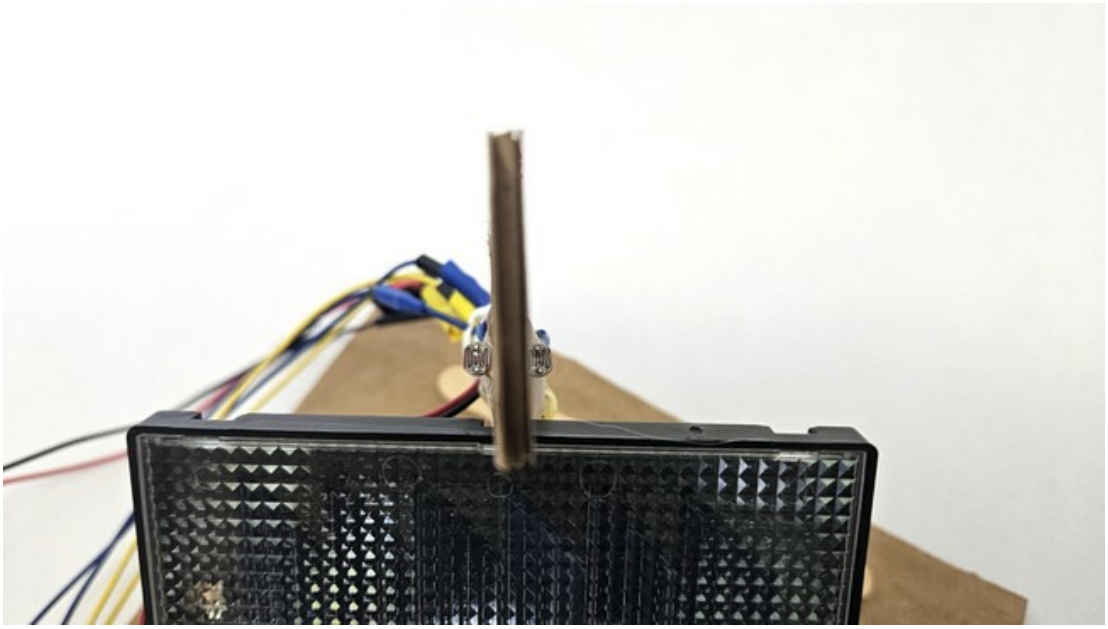

Image Credit: Ben Finio / Science Buddies

Figure 11. An edge-on view of the piece of cardboard with one photoresistor visible on each side.

10. Reconnect all circuit components to the breadboard using male-female jumper wires. If you have a soldering iron available, you can solder for stronger connections.
11. Secure the wires so they do not pull loose as the servo motor rotates:
    a. Connect the wires near the breadboard to the cardboard base using zip ties, twist ties, or hot glue (Figure 12).
    b. Connect the wires near the solar panel to the popsicle stick frame.
    c. Leave a long, flexible section of wire between the two connection points.

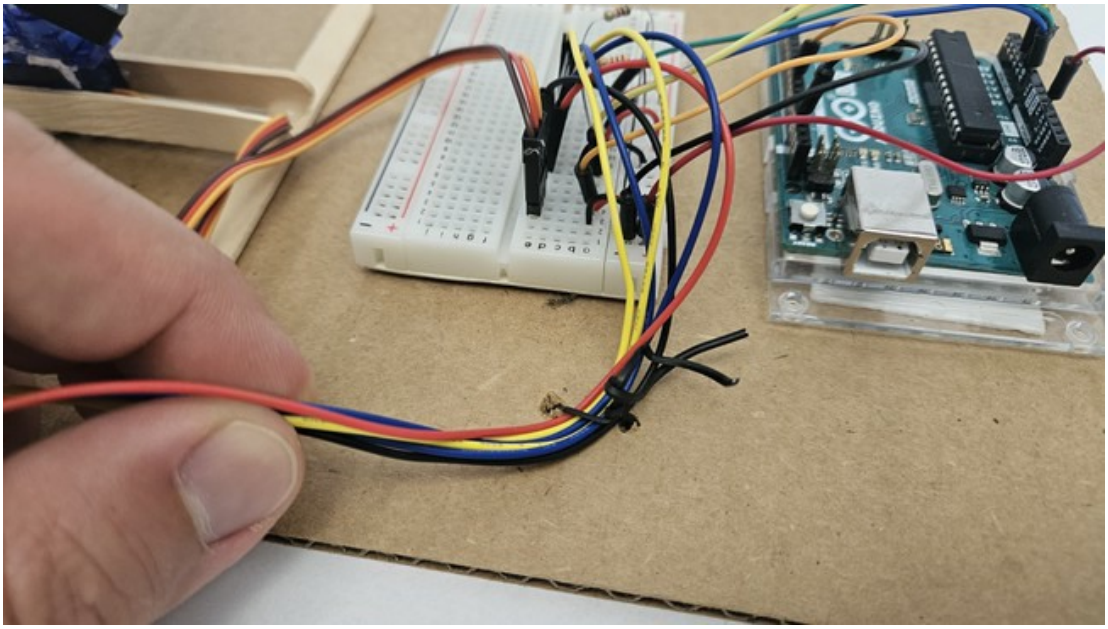

Image Credit: Ben Finio / Science Buddies

Figure 12. Wires near the breadboard connected to the cardboard base with a twist tie. This way, the wires are not pulled out of the breadboard when the motor rotates.

12. Make sure your motor can rotate without any of the wires coming loose.
    a. You can do this using the Arduino sweep example code, which rotates the servo motor back and forth through its complete range.
    b. First, test the sweep program and watch to make sure that none of the wires physically come loose.
    c. Modify the sweep example code to print out the sensor values and solar panel voltages (you can copy the relevant code from solar_tracker.ino).
    d. Run the code again and watch the serial monitor values. Make sure the readings all change if you cover the panel or one of the sensors. If any readings are constant and do not change, you may have a loose connection.
        i. Even if a wire is not visibly loose, it may not have a good electrical connection. Unplug your Arduino and make sure all connections are secure. Use additional tape or glue if necessary.
        ii. The photoresistors have thin leads that may not securely into the female ends of male-female jumper wires. Make sure they are pushed in firmly. Optionally, use needle-nose pliers to crimp their leads to the male end of a jumper wire, or solder the connections if you have a soldering iron available.
    e. Confirm that all your connections are secure before you continue. It will be frustrating if a wire comes loose partway through your experiment!
13. Make sure your tracker works with a flashlight or by manually rotating the piece of cardboard to make the panel track the sun. Make sure the photoresistors are properly shaded by the piece of cardboard when not aimed directly at the sun. Adjust their position if needed.

Test Your Solar Tracker

1. Plan when and where you will conduct your experiment.
    a. Ideally, this experiment should be conducted outdoors in full sunlight. If weather conditions do not permit this, you can conduct the experiment indoors from a sunny window, or use a high-wattage incandescent light bulb (100W or greater) to simulate the sun.
    b. You will need to test your solar tracker system on multiple different days as close together as possible to avoid seasonal variation in the sun's position in the sky. If you have to wait a few days for more sunny weather, that is OK, but you should not wait weeks or months between data collection days.
    c. Avoid leaving your Arduino or other electronics out in the rain.
    d. You will need access to your Arduino and a computer to record the solar panel voltage throughout the day. If you do not want to leave a computer outside, you can power your Arduino with a wall adapter and use a multimeter to measure the solar panel's voltage.
2. Create a data table like Table 1. Modify the rows and columns based on the times of day and number of days where you can collect data.
3. To collect data for a fixed solar panel, you can simply unplug your servo motor, or modify the code to manually set the servo motor angle to 90 degrees instead of changing it based on the photoresistor readings.
4. To collect data for your solar tracker, run your solar_tracker.ino code (with any modifications you made in previous sections).
5. Make a graph of your data with voltage on the y-axis and time on the x-axis.
6. How does voltage produced for your tracking system compare to the fixed solar panel? Do you think the added complexity of the tracking system is worth it? There are many other things you can do with this project - see the Variations section for more ideas.

	Voltage (fixed panel)				Voltage (tracking panel)			
Time of day	Day 1	Day 2	...	Average	Day 1	Day 2	...	Average
8:00 AM								
9:00 AM								
10:00 AM								
...								

Table 1. Table for recording solar panel voltage.

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