



## Green Technology: Build an Electronic Soil Moisture Sensor to Conserve Water

[https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water](https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water) ([http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water](http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water))

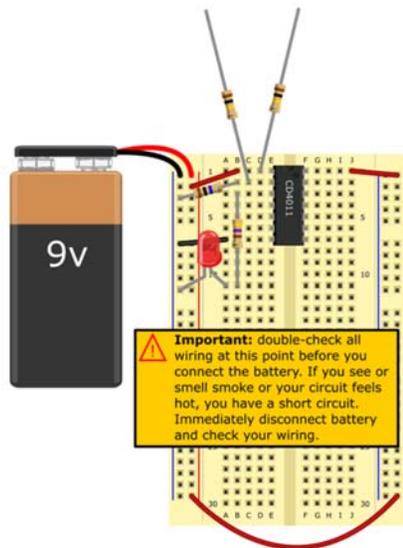
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### Experimental Procedure

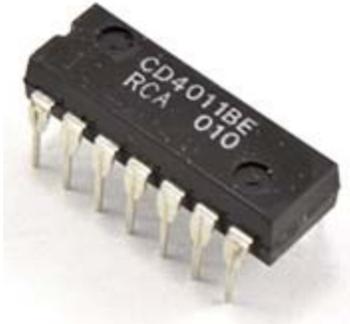
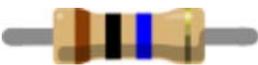
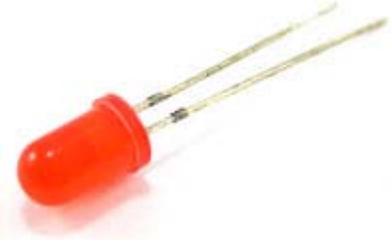
**Note:** This engineering project is best described by the **engineering design process**, as opposed to the **scientific method**. You might want to ask your teacher whether it's acceptable to follow the engineering design process for your project before you begin. You can learn more about the engineering design process in the Science Buddies [Engineering Design Process Guide](http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml) (<http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml>).

### Assembling the Circuit

If this is your first time using a breadboard, refer to the Science Buddies resource [How to Use a Breadboard](http://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-breadboard) (<http://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-breadboard>). Assemble your soil moisture sensor circuit on a breadboard, as shown in the slideshow and described in Table 1. For advanced students, see the [Help \(#help\)](#) section for a circuit schematic and detailed description of how the circuit works.



Slideshow with step-by-step instructions viewable online.

Part	Picture	Breadboard Symbol	Location
4011 NAND gate			Rows 1–7, straddling the middle of the breadboard, with semicircular notch facing up
10 MΩ resistor			B2 to (-) bus
470 Ω resistor			B3 to B11
Red LED			Long lead to A11 Short lead to (-) bus
100 kΩ resistor			C2, other lead free

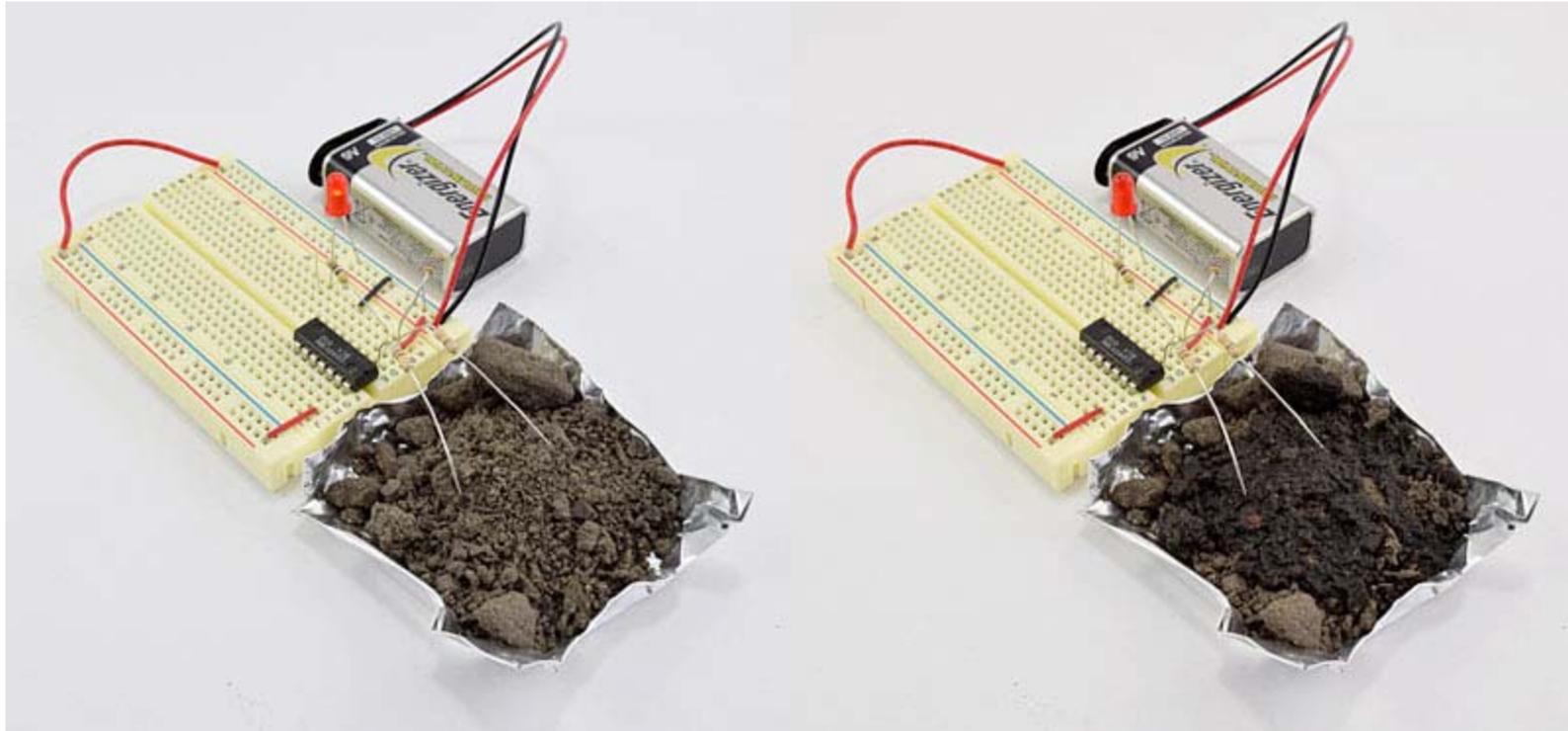
Part	Picture	Breadboard Symbol	Location
100 kΩ resistor			D1, other lead free
9 V battery and snap connector			Red lead to (+) bus Black lead to (-) bus
Jumper wires (4)			B1 to (+) bus J1 to (+) bus A7 to (-) bus Left (+) bus to right (+) bus

**Table 1.** List of circuit components and their locations.

## Testing Your Circuit

The circuit works by "detecting" the resistance between the two free 100 kΩ resistor leads. If the resistance is very high (like with dry soil), the LED will turn on to indicate that the plants need to be watered. If the resistance is very low (like with wet soil), the LED will turn off, and stay off until the soil dries out again. You can easily check to make sure your circuit is working:

1. Make sure the free 100 kΩ resistor leads are not touching each other. The LED should be on, because the resistance between the leads is very high (electricity would have to travel through air to get between them, and air is not a good conductor).
2. Touch the two free leads directly to each other. This should cause the LED to go out, because the resistance between the leads is zero. Electricity can flow easily from one lead to the other.
3. Put a small pile of dry soil on a plate. Touch both resistor leads to the soil at the same time. The LED should turn on, because the resistance of the dry soil is very high.
4. Slowly add drops of water to the soil and watch as the soil gets wet. Eventually the LED should turn off, because the wet soil has a low resistance. See Figure 2.
5. You can also try testing the circuit with your hands. Try touching both resistor leads to your palm at the same time. If your hands are slightly damp or sweaty, the LED should turn off.
6. If you cannot get your circuit to work, see the [Help](#) (#help) section for troubleshooting information.



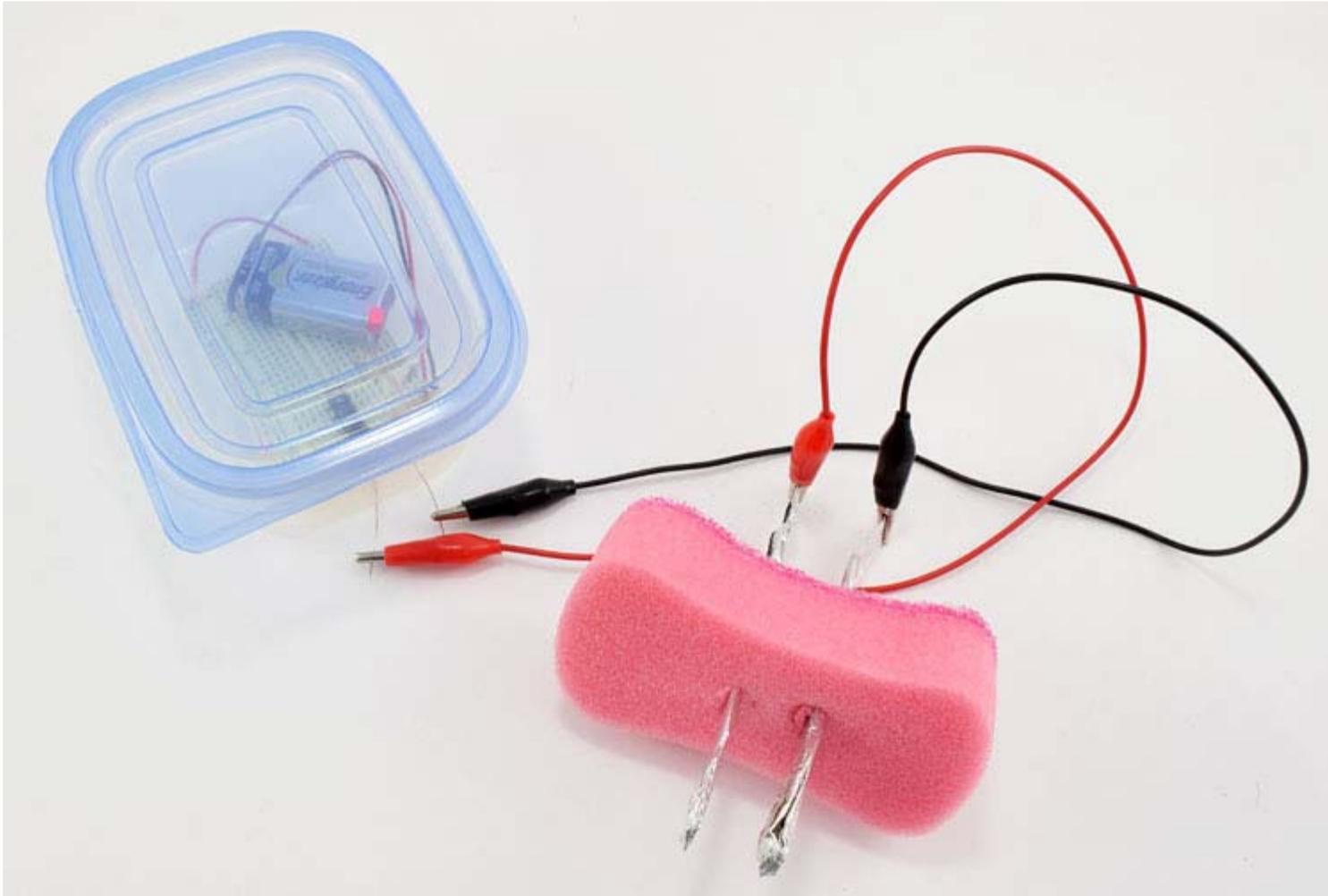
**Figure 2.** The LED stays on when the resistor leads touch dry soil (left) and turns off when the leads touch wet soil (right). So, if the LED is off, that indicates that the soil is already wet and you do not need to water your lawn or plants.

### Designing and Building a Case for Your Soil Moisture Sensor

Now you should have a working soil moisture sensor circuit. However, you have probably noticed that this circuit is not very practical for everyday use, because it is rather fragile. What if you wanted to leave the circuit in your garden, or carry it around your house to check on different potted plants? Here are a few problems you could run into:

- The circuit has loose parts dangling off the breadboard, like the 9 V battery, that could fall out easily as you carry it around.
- The resistor leads are very small and flexible. It is difficult to insert them into soil at the same distance repeatedly (remember from the introduction that it is important to keep the distance between the probes the same, because the soil's resistance depends on this distance).
- The circuit is not covered or protected at all. If you took it outside, the breadboard holes could get clogged with dirt or the entire circuit could be damaged by rain.

This is where the **engineering design process** (<http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess>) becomes important. How could you improve the circuit to solve these problems? The engineering design process is open-ended, meaning there is no single "right answer." A design that works well for somebody who wants to leave the sensor in his or her yard might not work for somebody who wants a portable sensor to check on potted plants, and vice versa. Figure 3 shows *one* possible design to improve the usability of the circuit, but how you modify the circuit is up to you. You could do something totally different!



**Figure 3.** An example of a modified soil moisture circuit. The breadboard is placed in a plastic container with a sealable lid to make it waterproof (the removable lid ensures that you can still change the battery). Two small holes are drilled in one side of the container to allow the 100 k $\Omega$  resistor leads to poke through. The resistor leads are connected with alligator clips (included in your kit) to two popsicle sticks covered in aluminum foil. These popsicle sticks serve as sturdier probes that are easier to handle than the tiny resistor leads. Note that the outer surface of the probes must be an electrically conductive material, and most metals are conductors. The probes would not work if they were *just* wooden popsicle sticks. Finally, the popsicle sticks are inserted through slots cut in a sponge, which keeps them at a fixed distance from each other. Remember, this is just *one* potential way to improve the circuit—you could do something totally different with different materials!

If you are new to the engineering design process and need help getting started, these steps will help walk you through it for this project. You can also refer to the resources about the engineering design process in the [Bibliography](#) (#bibliography).

1. **Define the problem:** From reading this far, you already know that the general idea of this project is to build a soil moisture sensor, and use it to conserve water by indicating whether soil is already wet when watering plants. But that is not specific enough. Where will the sensor be used and who will use it? Will it be used indoors or outdoors? Will it remain in one place or does it need to be portable? Define a specific problem, such as "Design a weatherproof soil moisture sensor that can be left outside."

2. **Do background research:** You have already started this research if you read the **Background** (#background) section and the **Bibliography** (#bibliography) of this project. You may need to do additional research, depending on the problem you define in step 1. You could also interview potential "customers" for your soil moisture sensor (for example, interview your parents if they do most of the gardening at your house).
3. **Specify requirements:** Come up with specific requirements based on your problem statement and background research. For example, if you intend to leave the circuit outside, one requirement could be "the circuit needs to be waterproof." If you want the circuit to be portable, a requirement could be "You must be able to pick the circuit up and move it without any of the parts falling out." Many engineering design projects also specify a budget, so you could put a limit on the total cost of all your materials.
4. **Brainstorm, evaluate, and choose a solution:** This is where the engineering design process becomes totally open-ended. Remember that there is no single "right answer" to your problem. Use your lab notebook to write down and sketch ideas. Try to come up with as many ideas as you can for now, and do not worry about ideas being "wrong." For example, how many different ways can you think of to make the circuit waterproof? What materials will you need to build your design? Once you have thought of multiple solutions, evaluate them based on the requirements you came up with in step 3. Which one meets your requirements the best?
5. **Develop and prototype solutions:** Build a **prototype** (or an early model) of your best solution. You do not have to stick to exactly what you drew in your lab notebook. You can tweak the design as you build it if you find out that part of your idea will not work.
6. **Test solution:** once you have a prototype built, it is time to test it! First, test your circuit with wet and dry soil to make sure the LED still lights up properly. Then, test your circuit to make sure it meets all your other requirements. For example, if the circuit is supposed to be waterproof, you can leave it outside in the rain (or, if it is a sunny day, run it under a faucet) and then check to see if it still works.
7. **Does solution meet your requirements?** If not, do not worry! Engineers rarely get things perfect on the first try. Now it is time to **iterate**, or go back through some steps of the engineering design process to refine your solution. If your prototype did not work, go back to step 4. Maybe you can make some small changes to your existing design, or maybe you should go with a totally different solution. There is nothing wrong with iterating through the steps multiple times until you arrive at a final solution.
8. **Communicate results:** Once you have a final solution, you are ready to write the report for your science project. Be sure to take lots of pictures of the device you built!

## Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at [https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water#help](https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water#help) ([http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water#help](http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p066/electricity-electronics/build-an-electronic-soil-moisture-sensor-to-conserve-water#help)).