# Make a Working Solar Cell

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**Lesson Title:** **Make a Working Solar Cell**

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**Grade Level:** **High School**

**Prerequisites:** **Students should be able to list and briefly describe the basic particles that compose the atom. Students will read <http://www.colorado.edu/physics/2000/quantumzone/photoelectric.html>**

**Learning Objective(s):** **Students will construct a working solar cell, and measure the output of that cell under various lighting intensities. A light meter will be used to determine the intensity. Students will link their solar cells together in series and parallel under the same lighting conditions, measuring total solar cell system output and voltage with the micro-ammeter or multimeter as appropriate. Data will be recorded by the student in a logbook.**

## Ohio Core Content Indicators:

**Demonstrate that waves (e.g., sound, seismic, water and light) have energy and waves can transfer energy when they interact with matter.**

**Draw conclusions from inquiries based on scientific knowledge and principles, the use of logic and evidence (data) from investigations.**

## Materials/Resources:

1. **A sheet of copper flashing from a hardware store if money is not a problem. If money is a problem (and it almost always is), consider asking local contractors for scraps of copper flashing left over from roofing jobs. It took nearly four months for a local contractor to respond, but his generosity saved us a bundle (about $5.00 per square foot of copper).**

2. **Two alligator clip leads of approximately 12” in length for each solar cell. You want to leave enough slack in the clips so that connections can be made without tipping the solar cell. Remember to inventory all alligator clips at the end of class. This may prevent you from a bit of irritation later if a stolen clip is found blackened, corroded, and clipped to a sun visor in the student parking lot.**

3. **A sensitive micro-ammeter that can read currents between 10 and 50 microamperes. The local Radio Shack does not carry these meters, nor are they listed in their current catalog. If you buy retail, it could cost you $30.00 easily. I recommend purchasing surplus analog ammeters from C & H Sales < http://aaaim.com/CandH/> for around $5.00 each. They are accurate to**

**about 0.1 of an ampere. The digital ammeters are even more accurate, but I prefer the price of the analog meters.**

4. **An electric hotplate or stove rated above 1000 watts, the kind that has a spiral resistance coil upon which you can place the copper sheets. Remember never to plug these hotplates into a non-GFI receptacle, nor walk away from them while they are heating. Place the hotplate on a stable surface away from flammable items, and with the cord so that it cannot get tangled up with human arms and legs.**

5. **A large clear plastic 2-liter bottle that you can cut the top off of to leave a cylinder in which the salt solution can be contained. Glass jars will also work, but I prefer not to have the worry of broken glass in my lab unless necessary.**

6. **Two tablespoons of table salt, preferably NaCl reagent grade. I haven't had the chance to compare regular table salt with reagent grade salt in its effect on solar cell output. Common table salt has minute quantities of NaI and glucose mixed with the NaCl for stabilizing the NaI.**

7. **A source of tap water**

8. **Fine grit sandpaper (00)**

9. **Sheet metal sheers to cut the copper sheeting into the size you need for the solar cell. Our carpentry students volunteered to cut our sheeting for us, thereby saving us the need for sheers.**

## Procedure for Teaching:

1. **Cut two pieces of copper sheeting to match the size of the burner. Caution your students about handling the sharp edges of their copper sheets. Wearing safety goggles through the entire process, wash your hands of any grease or oil, and then wash the copper sheets with soap to clean them as well. Use a sheet of sandpaper to clean off any light corrosion or sulfide.**

2. **Before using the burner, make certain that the drip plate is clean of any chemical residue. Place one clean dry copper sheet on the burner, and turn the burner to its highest setting. You will notice oxidation patterns form, as oranges, purples, and reds begin to cover the copper.**

3. **As the copper gets hotter, the oranges, purples and reds will be replaced by an ugly black coating of cupric oxide. When the burner is finally glowing red-hot, the copper sheet will be coated with the black cupric oxide coat. Continue to cook it for 30 minutes, to get a thick coating.**

4. **After the 30 minutes of heating, turn the burner off and leave the hot copper sheet on the burner to cool slowly. The copper will shrink as it cools, as will the black cupric oxide. Fortunately for our purposes, they shrink at different rates so the black cupric oxide flakes off with enough force to propel them a few inches from the burner.**

5. **When the copper has cooled to room temperature (approximately 20 minutes), most of the black oxide will be gone. Light scrubbing with your hands under running water will remove most of the remaining black bits. Be careful not to try and remove all of the black spots because that could damage the red cuprous oxide layer needed for the solar cell to work.**

6. **Take both the burnt copper sheet and the clean copper sheet and bend both pieces gently so they will fit inside the plastic bottle without touching each other. Face the cuprous oxide outside, as it has the smoothest and cleanest surface.**

7. **Attach the two alligator clip leads, one to the clean copper plate and the other to the cuprous oxide coated plate. Connect the lead from the clean copper plate to the positive terminal of the ammeter. Connect the lead from the cuprous oxide plate to the negative terminal of the ammeter.**

8. **Still wearing the safety goggles, mix two tablespoons of salt into some hot tap water and stir the solution until all the salt dissolves. Then carefully pour the saltwater into the bottle, avoiding getting the clip leads wet. Leave about an inch of copper plate above the water so you can move the solar cell around without getting the lead clips wet.**

9. **The meter will usually show a few microamps even in the dark, because the solar cell is a battery. A few students were not convinced, so the solar cell had to be covered completely in a lightproof box in order to read the ammeter without any light striking the solar cell.**

10. **A light meter is needed to determine the intensity of light striking the surface of the solar cell.**

11. **Wiring solar cells in series will increase the voltage but will not increase the amps. Wiring solar cells in parallel will increase the current, but will not increase the voltage. Use additional alligator clips to wire in series and in parallel.**

**Student Product:** **Students will keep a journal of solar cell construction project, and provide a working model of a primitive solar cell.**

**Assessment:** **Students will construct a working solar cell, and use a light meter to determine the intensity of light striking the solar cell surface. Students will use the multimeter to take a voltage reading in their working solar cell circuit, and will use**

**the microammeter to take an amperage reading in the solar cell circuit. Students will wire a specific number of solar cells in series and then wire the same number in parallel to report the voltage and/or amperage differences between the two ways of connecting solar cells. They will report the implications of their experimental findings with regard to the relation between light intensity, series wiring, parallel wiring, and solar cell output.**

**Extensions:** **Students will create solar cells with larger surface areas to investigate the relation between solar cell surface and output. Students will use various colored filters to determine what wavelengths of light hitting the solar cell surface are most efficient at producing current as an investigation into the nature of light and the concept of wave-particle duality.**

**http://lectureonline.cl.msu.edu/~mmp/kap28/PhotoEffect/photo.htm**

**http://galileo.phys.virginia.edu/classes/252/photoelectric_effect.html**

**Reflection:** **The solar cell construction seemed to capture my students' interest immediately, perhaps because they were escaping the confines of a classroom by testing the newly created solar cells in the late summer sunshine. I am considering several introductions I can offer for this particular activity, but it worked very well as presented. There seems to be a much stronger connection by my students with this activity than many of the labs we have performed in the past, and I believe that is because the experiment they are performing with the solar cell is not far removed from the original conditions under which the discovery was made. In short, they were allowed to follow the process of inquiry without interference and without the obfuscation of underlying principles that often accompanies a mature technology. Although this is not the first time I have attempted to have students construct a solar cell, this one was more successful as compared to my other efforts. A possible reason is that this activity does not require soldering skills, nor does it have students run the risk of accidental burns from the soldering iron. Now seems like a good time to attack Ohm's Law. <http://jersey.uoregon.edu/vlab/Voltage/>**

**My students now want to vary the concentration of the salt solution used in their primitive solar cell to see what results can be found. They are also interested in varying the angle of incidence that the light striking the solar cell incurs, to see whether or not a solar cell would have to be oriented differently for maximum output according to the seasons. Noting that a part of my assignment as an IRET in Thailand was to determine the angle at which a solar cell panel would provide maximum output at the South Pole, I will make them aware that seasons are only the tip of the iceberg when it comes to the factors impacting on solar cell output. http://eospso.gsfc.nasa.gov/index.php**