Simple Solar Tracker

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DESCRIPTION: Students will be shown a working example of a solar tracker and asked to replicate the design based on their observations. The design incorporates four solar cells arranged in two arrays with each array reverse biased such that they generate a voltage that opposes the other. Whichever array receives the most light will generate more voltage thereby driving a motor one direction or another. As the tracker rotates, the light incident upon each array equalizes. This circuit will be used as a springboard for discussion into the engineering design process, solar tracking and basic electricity and circuits.

GRADE LEVEL(S): 4, 5, 6, 7, 8, 9, 10, 11, 12
This lesson can be modified to target a large range of grade levels.

SUBJECT AREA(S): Physics, electronics, solar power, engineering, engineering design process

ACTIVITY LENGTH: 2 hours

LEARNING GOAL(S):
1. Students observe and replicate a simple solar tracker.
2. Students will learn basic electric circuits and terminology.
3. Students will reflect on possible improvements for solar tracker.
4. Students will reflect on how the engineering design process is used daily.

STANDARDS MET:
Common Core:
- CCSS.ELA-Literacy.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

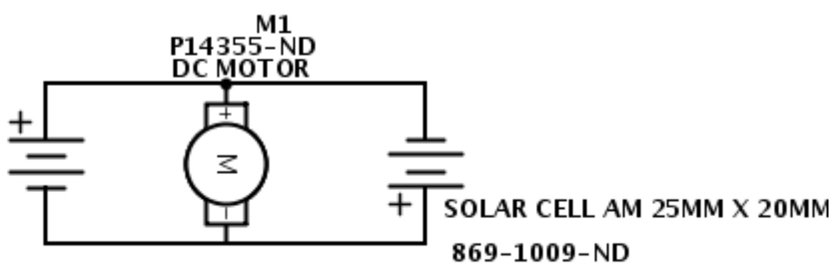
Next Generation Science Standards:
- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Student Background:

Very little prior background knowledge is required. Being familiar with solar cells is helpful but not required. This activity centers on student observations and any misconceptions they may have about electricity.

Educator Background:

A rudimentary level of understanding of electricity and solar panels is required. Understanding the engineering design process is important. Below, Circuit 1 is the diagram for the simple tracker. Part numbers are from Digi-Key's website, but you can use any source. I've found that the motors with attached gearboxes work best. These types are listed in the materials. Notice that the solar cells are reverse polarized. This means that the cells that get more incident light will drive the current against the other making the motor turn. The reverse happens when the other cell receives more light. If the cells are mounted on a superstructure (which is on top of the motor) and allowed to rotate, then this simple device will track a light source.



Circuit 1: Simple Solar Tracker

Figure 1, below, is a top view of how to arrange the cells on their superstructure. The varying angle allows for different cells to receive variable sunlight. Thus, in the morning the sun will come up on the extreme left of the tracker. This light will hit the left rear cell, causing the tracker to rotate counterclockwise.

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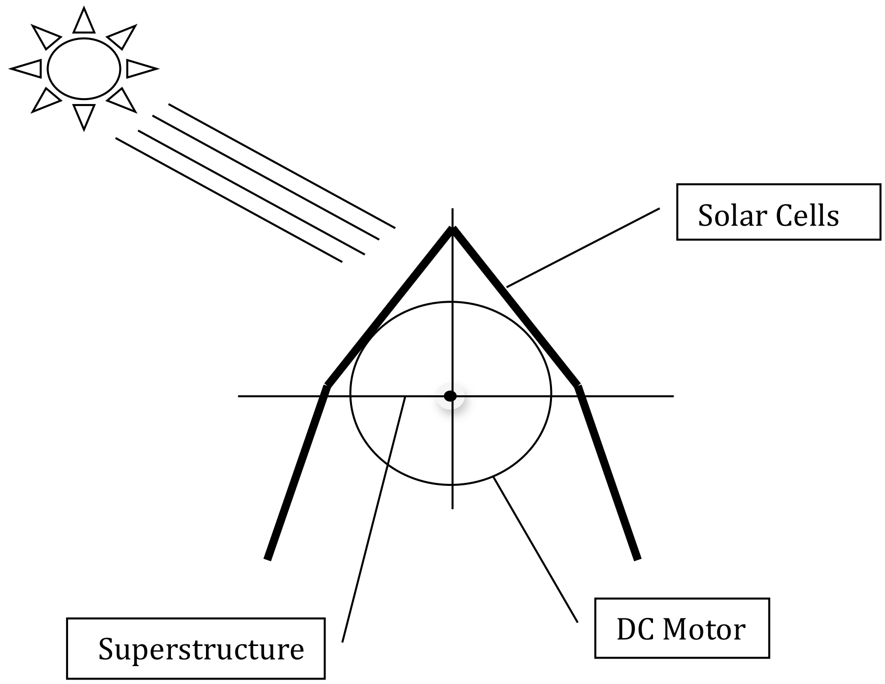

Figure 1: Top View of Simple Solar Tracker

Science Kit Materials List:

- (4) Individual Solar Modules, 2-Volt, 500 mA

Other Materials List:

- Student handout "Simple Solar Tracker Reflection Questions"
- "Engineering Design Notebook"
- Halogen lamp or other shop light
- DC gearhead motor
- (6) paper clips
- Foam board or some other structural element (set amount for each group)
- Red/Black braided wire with striped ends (one 5" strip/group)
- Hot glue gun and glue
- Copper wire (for bus)
- Popsicle sticks
- (Optional) wood blocks

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Vocabulary:

- Solar cell
- Polarity
- Engineering Design Process
- Iteration
- Design Constraints
- Engineers Notebook/Journal

Lesson Details:

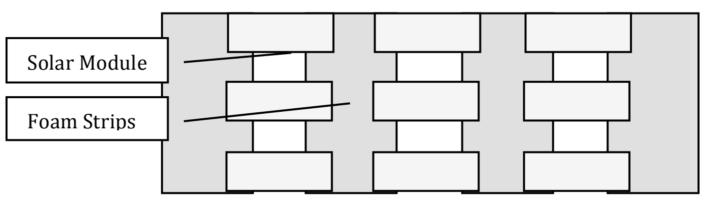
Planning/Prep

Have one simple tracker made prior to class. Using care to construct the model, it should take approximately one half an hour to complete and test. A motor with an attached gear assembly is the easiest to use.

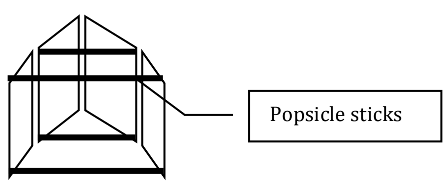
Following are sample assembly instructions for the teacher.

1. Using foam board, cut 9 pieces ¼ inch by 3 inches. Compress the middle section of each piece to promote flex.

2. Lay the 4 solar modules face down on a table with about ¼ inch of space between them on the long edge. Hot glue the foam board strips at the top, middle and bottom sections between each module.



3. Place the now attached modules on end in such a way that it models a "v" as shown below and in the pictures that follow. Hot glue a popsicle stick between the two ends of the "v" to help hold the "v" shape. Turn over the modules and repeat.



3. Add more popsicle sticks to support the overall structure as needed. Be sure to include a stick that has the center of mass located on it. This will be the attachment point for the gear assembly from the motor.

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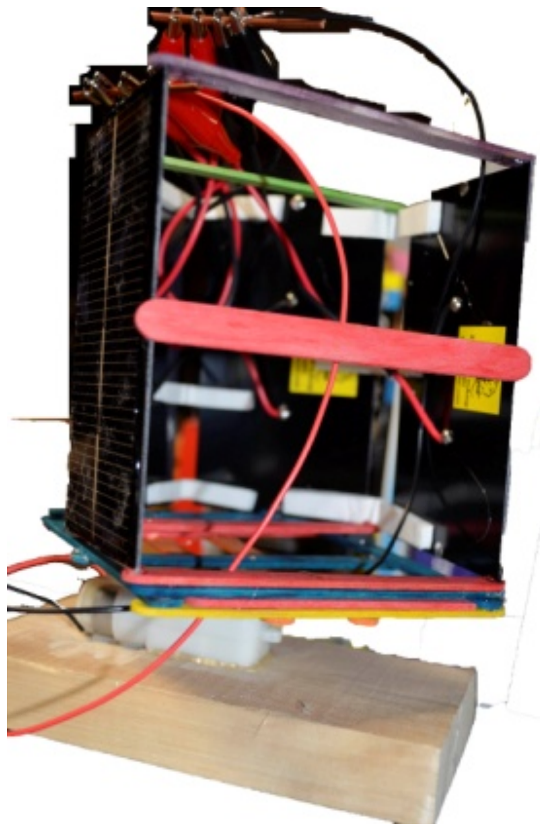
5. Fit the motor onto a base such as a section of foam board or a wood block, as in the pictures, using hot glue. Ensure that the gear axis is vertical and has room to operate.

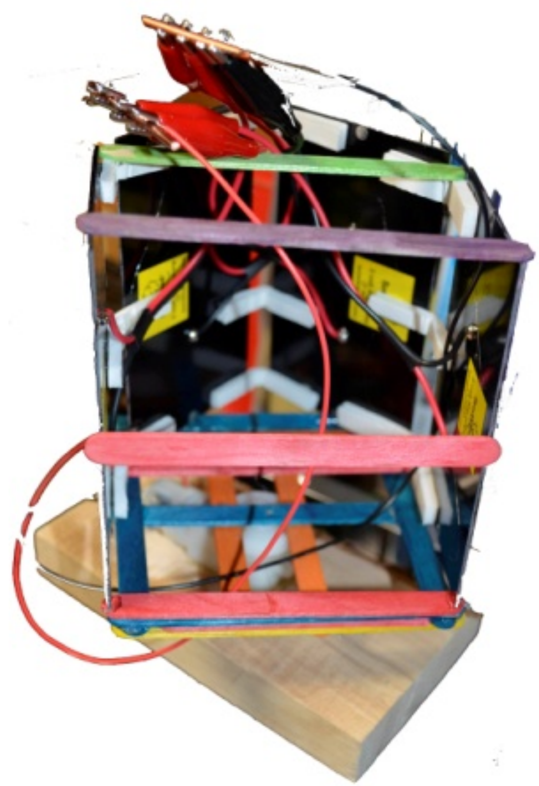
6. Using hot glue, attach the gear assembly to the center of mass of the support structure. Below are some pictures of a finished assembly.

***Note: foam board hinges, arrangement of popsicle sticks and the positive/negative connections to a Copper bus in the following pictures.*



Picture 1

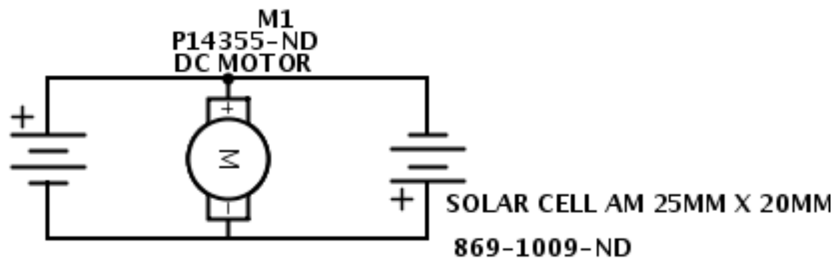
Picture 2



Picture 3

Background Information/Circuit Diagram

Below is the Circuit 2 diagram for the simple tracker. Part numbers are from Digi-Key's website, but you can use any source. Notice that the solar cells are reverse polarized. This means that the cells that get more incident light will drive the current against the other, making the motor turn. The reverse happens when the other cell receives more light. If the cells are mounted on a superstructure, which is on top of the motor, and allowed to rotate then this simple device will track a light source.



Circuit 2: Simple Solar Tracker

Figure 2 shows a top view of how to arrange the cells on their superstructure. The varying angle allows for different cells to receive variable sunlight. In the morning the sun will come up on the extreme left of the tracker. This light will hit the left rear cell causing the tracker to rotate counterclockwise.

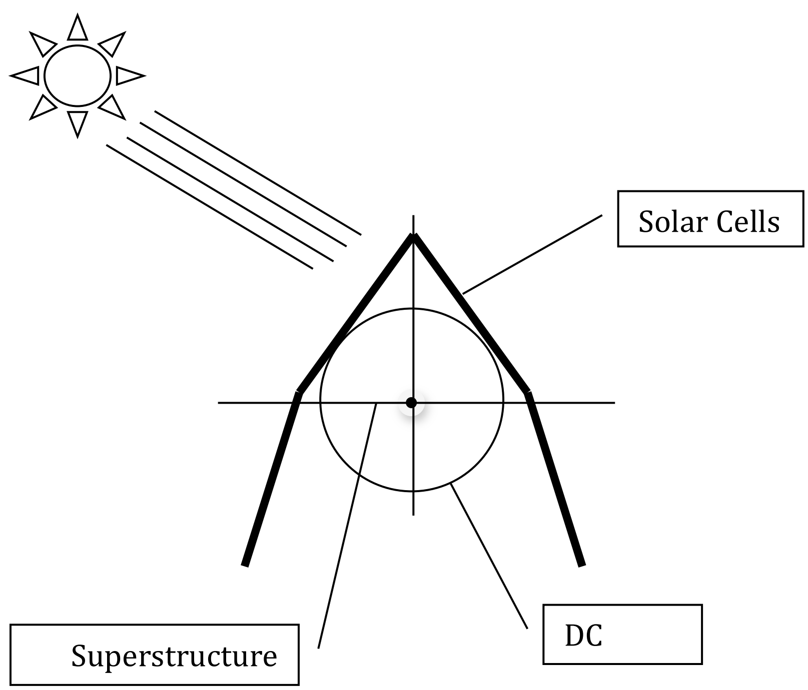


Figure 2: Top View of Simple Solar Tracker

Class Sequence

- This lesson should take a full period, possibly two, depending on the class.
- Divide students into groups of three if possible using whatever method you prefer. Try to get an academic stratification within each group.
- Show students a completed simple solar tracker and use a light source to demonstrate the tracker operation.
- Instruct students that they are to build a working model with the materials you are handing out. *Place masking tape on the back of solar modules where hot glue is to be applied. This allows you to remove the glue later for reuse in subsequent years.*
- Resist the urge to show them how to complete the tracker. In this activity students are to work together in deciding how to get the tracker to work. There is a built-in discrepant event with regard to the circuit hook up. Most students will likely hook all the positive leads (red) together and the negative leads (black) together. This will allow the motor to turn in one direction only. They must figure out to reverse the polarity from each side of the tracker in order to get the motor to move in both directions. There are not many permutations of ways to hook things up so this shouldn't take long. Paper clips can be used to make mechanical connections between wires.
- Make sure their motor tracks the light source in both directions.
- Once each group has a successful tracker, guide the class through a reflection of the process they used in their respective groups. One way to do this is using a T-Chart graphic organizer with one side filled in after the groups observe the sample tracker and the other side filled in after constructing a successful design. The first side would have a list of what facts they already know about the design such as: *four modules are used*; *the motor has two wires coming from it; the wires all connect to the alligator clips.* The second side would be what facts they learned. Tie their comments into the engineering design process and elaborate on electrical ideas that the students throw out.

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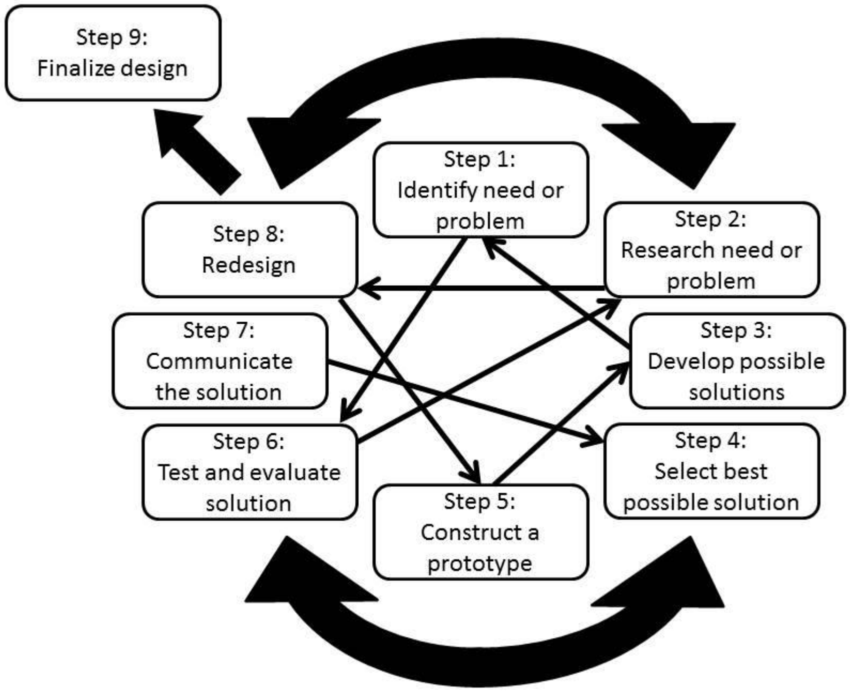

Figure 2: Engineering Design Cycle. This figure is from the National Center of Engineering and Technology Education report Householder, D. L., & Hailey, C. E. (Eds.). (2012). "*Incorporating engineering design challenges into STEM courses*."

- Guide students in a discussion of how to make the tracker better. What limitation can the group see with their design? Most classes should come up with limitations such as cloudy days, night, vertical tracking in addition to horizontal, etc. Discuss with students that as design constraints grow in both complexity and number that having a "brain" helps to sort things out. Have students answer the reflection questions included in the student materials.

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