

Lesson 10: Solar Car Race

Adopted/Revised From

NREL Model Car Competition (http://www.nrel.gov/education/jss_hfc.html)

Grade Level

6-12

Objectives

- Analyze the relationship between voltage, amperage, and load
- Measure the voltage output of multiple solar panels wired in series and in parallel
- Experiment to find the wiring configuration that delivers the most power to the motor
- Apply concepts of tilt and azimuth to create a solar car that optimizes its use of the sun's rays

Overview

Students will experiment with solar panels and motors to produce a car that can run on solar power. They will explore different wiring schemes and different panel angles.

Materials (per group)

- One copy of Benham's disk (see below)
- One cereal box and corrugated cardboard
- One 1.5 volt motor
- One 0.5 V and one 1.0 V solar panels, wire, and alligator clips
- Multimeter
- Protractor
- New pencil and a pencil sharpener
- Glue, tape, scissors, compass, and a hole puncher

Estimated Cost of Materials

\$30 per group

Computer Required?

No

Duration

2 class periods (one to build, one for race)

Primer References

1.1 Forms of Energy
1.3 Units of Energy
3.1 Solar

Related Articles

N/A

Engagement

- How do you use solar panels to achieve maximum power output?
- How is *load* like resistance?

Investigation

Part One:

1. Divide students into small groups with the materials listed.
2. Have students read the Exploratorium's "Benham's Disk" description (below). They will learn that the black and white disk will create different colors when it is spun.
3. Have students cut out the disk and glue it to a piece of cardboard. Poke a small hole in the center of the disk and glue it carefully to the axle of the motor. The students will use both panels to power the motor and look for colors on the spinning disk. They will note how the colors change with greater speed.
4. Go outdoors to a sunny spot. (**Safety Note: Do Not Look Directly At The Sun!**) Wire one solar panel to the motor by attaching the wires from the panel to the terminals of the motor. Observe how fast the disk spins. Pivot the panel to different angles with respect to the sun's rays. How is the speed of the motor affected?

Electric Circuits

An electric circuit consists of the various conductors that lead from the negative to the positive terminal of a source of electricity. The various parts of a typical house circuit include a fuse or circuit breaker, wires, switches, wall outlets, and light sockets and bulbs.

A circuit through which electricity is flowing is said to be closed. The circuit can be opened, or broken, by turning off a switch or by removing a fuse, pulling out a plug, or disconnecting the wires. A circuit generally contains a load - a device such as a lightbulb or appliance that provides resistance in the circuit. If a current is allowed to flow from one terminal to another with very little resistance, a short circuit exists. Unless such a current is quickly stopped by a fuse or circuit breaker, the wires may heat up enough to start a fire.

There are two basic methods of wiring a circuit—in series and in parallel. In the series circuit the current flows through one device (such as a lightbulb) to reach the next. In the parallel circuit the current enters and leaves each device separately. Devices connected in series each carry the same amount of current; devices connected in parallel are each subjected to the same voltage. Many electrical applications use a combination of these two types of circuits.

Excerpted from HowStuffWorks, <http://science.howstuffworks.com/electricity-info5.htm>.

5. **Parallel Circuits:** Students should read the box above about electrical circuits. Now have the students add another panel in parallel with the first panel by attaching both of the positive leads from the panels (red) to one of the motor terminals and both of the negative leads (black) from the panels to the other motor terminal. How is the speed affected?
6. **Series Circuits:** Have the students try wiring the panels in series. Disconnect all the wires. Using two panels, connect the positive lead of one panel to the positive terminal of the motor. Connect the negative lead of that panel to the positive lead of a second panel and attach the negative lead to the other motor terminal. How is the speed affected? Ask the students if they think they should wire the panels in parallel or in series to produce the fastest speed.

Part Two:

1. The students should understand that wiring the panels in series will produce the greatest voltage and the fastest rotational spin. Now they are ready to build their car, using the photos below and template provided after this lesson plan or by creating their own designs.



2. Students should mount their panels on their cars using what they know about tilt and azimuth from the "Watt's Your Angle" lesson plan. They can experiment with one 0.5V panel and one 1.0V panel to see how the load of the car affects the performance of the motor. Set the time and date of the race so students will have the information they need to create their solar panel mount for the race.
3. Create a race track that runs due north with start and finish lines. Make sure the race track is relatively smooth and located in a sunny spot. At the agreed upon time, start the race. Assign a record keeper to time the cars. Record car characteristics and results in the activity sheet for this lesson.

Class Review

1. Discuss the results of the race. What characteristics did the winning vehicle have? What was the most crucial factor that led to its being successful?
2. Likewise consider the slowest car. What were the characteristics that led to its lack of success?
3. Use all class results to graph the relationship between voltage and velocity (also graph milliamps and milliwatts with velocity if applicable).
4. What was your car able to do when you had just the 0.5 V panel attached to the motor? The 1.0V panel? Both panels? Discuss what you observed in terms of the concept of load. (Note: see shaded box above.)
5. How can you reduce the load of your car in order to maximize speed?
6. How can you increase the solar radiation to your panel(s) to maximize the speed?

Elaboration

1. Ask students how they can modify their cars to make them faster. Consider load, aerodynamics, number of panels, friction and weight.
2. Now that they have experienced this activity, ask the students how load is like resistance.
3. If milliamps were detectable, how important was this factor compared to voltage? Why?
4. What are the limitations of solar vehicles?

Instructor Notes

- Some multimeters will not be able to detect milliamps generated from such small panels. If your multimeters can detect milliamps, have your students record this data in their activity sheets to calculate milliwatts (power).
- A finish line should be set a reasonable distance from the start for the race. This is likely going to be 5-10 feet from the start.

Extensions and Variations

1. Build more sophisticated cars using gears, rubber wheels, bigger panels, etc.
2. Consider how to use solar power with other types of transportation.
3. Research solar transportation and create a display.
4. Check out M.I.T.'s Solar Electric Vehicle Team's website: <http://solar-cars.scripts.mit.edu/>.

References/For More Information

Three great resources from the National Renewable Energy Laboratory for investigating different aspects of your solar car –

<http://www.nrel.gov/docs/gen/fy01/30826.pdf>

<http://www.nrel.gov/docs/gen/fy01/30828.pdf>

<http://www.nrel.gov/docs/gen/fy01/30830.pdf>

Here is the Exploratorium's Snack Site where you can read about Benham's Disk -

http://www.exploratorium.edu/snacks/benhams_disk/index.html

Learn about the nature of light by building your own spectroscope -

<http://solar-center.stanford.edu/activities/cots.html>

Solar Car Race

Race Date:

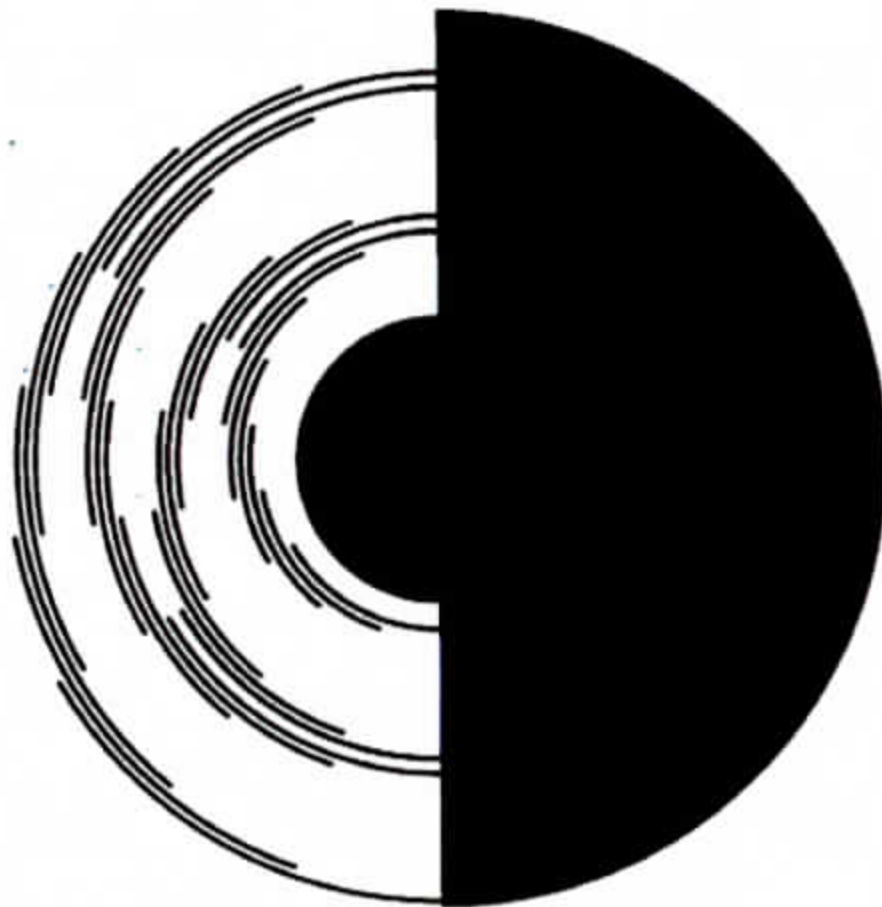
Race Time:

Description of Solar Car	Mass of Car (oz.)	Number of Panels	Series or Parallel (if applicable)?	Tilt of Panels (degrees)	Voltage of Panels	milliAmps of Panels (if detectable)	milliWatts of Panels (if possible)	Distance to Finish Line (ft.)	Time to Finish Line (sec.)	Velocity (feet/sec.)

Questions

1. What would you do to improve your car's design to make it run faster and/or straighter next time?
2. If you were running this race over the course of a few hours, would you set all your panel angles the same? Why or why not?
3. What would be the effects of adding an additional motor to your solar car?

Benham's Disk



Different people see different intensities of colors on this spinning disk. Just why people see color here is not fully understood, but the illusion involves color vision cells in your eyes called cones.

There are three types of cones. One is most sensitive to red light, one to green light, and one to blue light. Each type of cone has a different latency time, the time it takes to respond to a color, and a different persistence of response time, the time it keeps responding after the stimulus has been removed. Blue cones, for example, are the slowest to respond (have the longest latency time), and keep responding the longest (have the longest persistence time).

When you gaze at one place on the spinning disk, you are looking at alternating flashes of black and white. When a white flash goes by, all three types of cones respond. But your eyes and brain see the color white only when all three types of cones are responding equally. The fact that some types of cones respond more quickly than others -- and that some types of cones keep responding longer than others -- leads to an imbalance that partly explains why you see colors.

The colors vary across the disk because at different radial positions on the disk the black arcs have different lengths, so that the flashing rate they produce on the retina is also different.

The explanation of the colors produced by Benham's disk is more complicated than the simple explanation outlined above. For example, the short black arcs that are on all Benham's disks must also be thin, or no colors will appear.

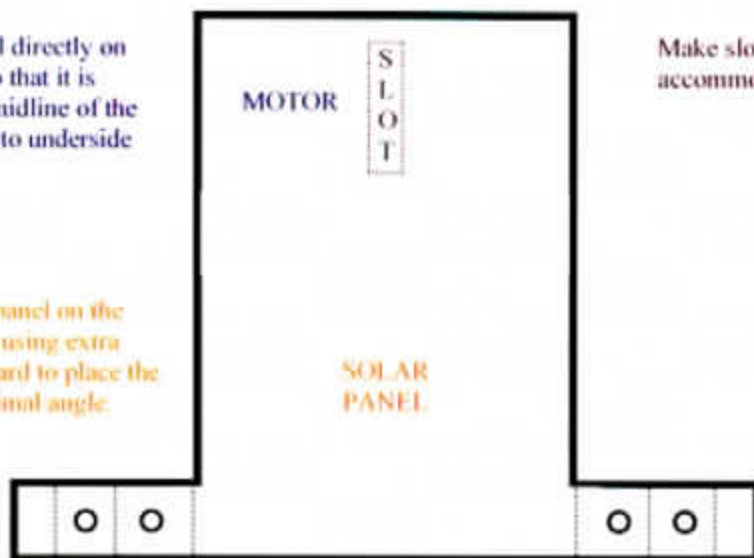
http://www.exploratorium.edu/snacks/benham's_disk/index.html

Solar Car Race: Suggested Template for Solar Car

Use cereal box cardboard for the body of the car and the solar panel stand, and corrugated cardboard for the wheels. Use dimensions that accommodate the solar panels and the motor.

Place front wheel directly on the motor axle so that it is centered on the midline of the car. Tape motor to underside of cardboard.

Place the solar panel on the back of the car, using extra strips of cardboard to place the panel at the optimal angle.



Make slot big enough to accommodate the wheel

Side view of bearing: Fold side tabs under into triangles as shown to support back axle. Punch holes at circles. (You may need to punch holes several times to make them big enough.)



Make three wheels out of corrugated cardboard: Using a protractor, draw a circle with a radius slightly larger than the radius of the motor housing. Attach one wheel to the axle of the motor using a strong glue (like Gorilla Glue), taking care not to get any in the motor housing. Using a pencil that has been sharpened at both ends for an axle, attach the other two wheels in the rear bearing.

