4-H STEM Toolkit

The Sky's the Limit: **Activity 5: Design and Build a Solar Car**

5

Time: This lesson should take approximately 90 – 120 minutes minutes to complete.

Learning Targets

- Understand how solar panels convert electrical energy from the sun to mechanical energy in a motor.
- Design and construct a working solar car.
- Use your experiences to create the fastest car.

Essential Questions

1 What elements can impact the speed of a solar car?

Enduring Understandings

- How solar panels capture light/electrical energy from the sun.
- Some car designs are faster than others.
- The engineering design process is an effective way to find a solution to a problem.

NGSS Standards

- 3-5-ETS1-1, 1-2, 1-3
- 4-PS3-2, 4-PS3-3
- MS-PS3-3, ETS 1-2, 1-2, 1-3, 1-4

Background for Facilitator

This activity has youth construct a solar-powered car. These cars use solar photovoltaic systems to power them. Solar photovoltaic systems convert sunlight into electricity. Solar photovoltaic (PV) devices, or solar cells, change sunlight directly into electricity. Small PV cells can power calculators, watches, and other small electronic devices. Arrangements of many solar cells in PV panels and arrangements of multiple PV panels in PV arrays can produce electricity for an entire house. Some PV power plants have large arrays that cover many acres to produce electricity for thousands of homes.

- The two main benefits of using solar energy are: Energy systems do not produce air pollutants or carbon dioxide. Solar energy systems on buildings have minimal effects on the environment.
- The main limitations of solar energy: The amount of sunlight that arrives at the earth's surface is not constant. The amount of sunlight varies depending on location, time of day, the season of the year, and weather conditions.
- The amount of sunlight reaching a square foot of the earth's surface is relatively small, so a large surface area is necessary to absorb or collect a useful amount of energy.

While templates are provided for the cars to start, youth should have the opportunity to engage in the engineering design process and modify their design if they choose.

View either video:

- **Video: Maine 4-H Solar Energy Project with RLC Engineering 5422** (YouTube) youtu.be/H23iWucMDeM
- **The Engineering Design Process: A Taco Party** (YouTube) youtu.be/MAhpfFt_mWM

As the facilitator, it will be especially important to ask purposeful questions about their designs, such as why they chose a certain modification and what the function of that modification might be. Encourage youth to explain why they are making design choices. If a design does not work how they expect, what might they change? This will encourage independence and discovery.

Safety Consideration: *Youth should be told not to look directly at the sun or any area where the rays are concentrated.*

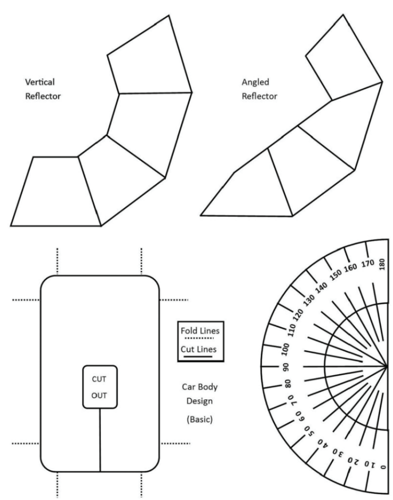
Vocabulary List

- **Thermal Energy:** heat energy
- **Radiant Energy:** light energy
- **Reflection:** bouncing energy back without absorbing it
- **Absorption:** take in heat energy
- **Solar panel:** collect sunlight and change radiant energy into electricity
- **Engineering Design:** a series of steps to create a product, including ask, imagine, plan, create, improve
- **Chassis:** The frame that holds the body and motor of an automobile together.
- **Axle:** The supporting shaft on which the wheels revolve.
- **Transmission:** The part of the car that transfers the power from the motor to the wheels.
- **Aerodynamics:** design of car to allow air to flow smoothly and quickly around it to decrease drag and increase speed

Materials

- Mini Solar Cars
- **Solar Car Design Template (PDF)** (to download and print)
- Copies of Car Design (best on cardstock)
- Scissors
- Meter stick
- Stopwatch
- Colored Filters
- Protractor
- Double Stick Tape
- Reflector Outlines
- Aluminum Foil
- Flashlight
- **Solar Cars Data Sheet Template, Part A (PDF)** (to download and print), view sample below.

Goal: Have students go through the engineering design process to create a solar car that utilizes alternative energy.



Solar Car Design Template is included in the PDF link under the "Materials" list.

Solar Cars Data Sheet Template: Part A: Calculating Speed

Speed = distance/time	Speed = 1 meter/ X seconds
Trial 1: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 1 is:	1 meter/ ______ seconds = ______ speed
Trial 2: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 2 is:	1 meter/ ______ seconds = ______ speed
Trial 3: My car took _______ seconds to travel 1 meter. The speed my car traveled at for trial 3 is:	1 meter/ ______ seconds = ______ speed

Figure 5.1: Solar Car Materials
(UMaine Extension 4-H Photo, Sarah Sparks)

Methods

Engage

Tell the youth that today they are going to become engineers and build a car powered by the sun.

Begin by brainstorming with young people what they already know about solar power and the engineering design process.

Explore

- Ask youth to explain what they already know about solar energy.
- Facilitator note: focus on how sunlight is captured and transferred into usable energy.
- Reflect on some of the activities youth have already done related to solar energy. How can the heat of the sun be captured?
- How can engineers capture energy from the sun and what might impact the amount of energy they capture?
- How can solar energy be used? Can youth think of examples you have seen locally?
- What limits exist for solar energy?
- What do youth know about engineers and what they do?
- What role do youth think engineers play in relation to solar energy?
- Why would it be a good idea to build a solar car?

Explain to participants that today you are going to look at different factors that affect a solar-powered car. In order to do that, everyone will become an engineer for the day. Watch this video as a group, as a way to introduce the engineering design process:

Video: The Engineering Design Process: A Taco Party, KQED QUEST (YouTube): youtube.com/watch?v=MAhpfFt_mWM

Explore

Be sure to be in the sunlight (or a high-power spotlight) when testing.

The purpose of this activity is to maximize the use of solar energy, using engineering design to move a small car. Briefly discuss how we will know we have achieved this goal? Begin by showing youth the materials they will use to construct a basic car. Facilitators should decide if youth will work independently or with a small group. Each youth/group will have a mini solar car, a template, and scissors. Model how to construct the car and then give youth the materials to build their own cars. They will cut out the car body design provided and place it on the mini car chassis.

Once cars are built, identify a safe place to take the group outside and test the cars. You may want to set up a runway or test track. Masking tape on the pavement is one way to do this. Have youth work with a partner or small group and begin gathering data about their cars. They should:

- Measure the time it takes for the car to travel over a 1-meter distance while in the sun or using the flashlight.
- Calculate the speed; 1 meter divided by the time in seconds. Use the Solar Cars Data Sheet part A to help aid in this (provided as an appendix in this curriculum).
- Discuss the results before moving on. What did the youth find during this testing phase?

After collecting some baseline data, it's time to use the creative part of being an engineer. Challenge them to do one of the following:

- Create a different shape for the front end of the car and test the speed.
- Create another shape for the front end of the car and test the speed.
- Create another shape for the body and test the speed.

Before testing, discuss as a group if there are any other data we should be collecting before we test? Refer to the **Solar Cars Data Sheet Template, Part B (PDF)** if needed. If a whiteboard or flipchart are available, this would be a good time to generate a group datasheet, where collective results are displayed. Test the modified designs and measure the time and speed again.

Explain

Have youth share their modified car design. They can do this in small groups, or with the whole group as time allows. What changes did they make to the original design? What impact did their modification have on how their car worked? As a whole group, some themes will likely emerge (such as aerodynamics). Explain that now that the group's car designs are complete, we are going to add some other factors to our designs and see how they can impact the movement of the cars. A summary of factors that influence the function of these solar cars is below. During the discussion, encourage youth to use evidence to support their claims. As these themes emerge, help guide youth into understanding the science behind their discoveries.

1 **Aerodynamics:** the lower the air resistance, the faster the car. Prior discussion may have introduced this vocabulary term. If it has not already been discussed and named, now is the time. What does it mean to be aerodynamic? What factors maximize aerodynamics in our car designs? Use evidence to support claims related to car design.

Solar Cars Data Sheet Template: Part B: Collected Data

Variables	Time	Speed	Star the Fastest
Square Original			
Design 1			
Design 2			
Design 3			
Red Filter			
Orange Filter			
Yellow Filter			
Green Filter			
Blue Filter			
Purple Filter			
10 Degrees			
30 Degrees			
60 Degrees			
90 Degrees			
120 Degrees			
150 Degrees			
Vertical Reflector			
Angled Reflector			
Our Designed Reflector			

Describe the fastest car based on design, filter, sun angle, and reflector shape.

As a group, discuss which design created the fastest car? When answering this question, youth should use evidence to support their claims. Refer to the group and/or individual data sheets during this discussion. What patterns did you see? What differences did you see?

2 **Filters**: only certain colored light can be converted into mechanical energy in the panel. While filters are not used in real practice with solar panels, they can simulate real-world scenarios that impact the light absorbed by the panels. Filters hold radiant wavelengths out and the color is different radiation frequencies. Explain that filters can reduce the radiance, or energy, reaching the panel.

Colored filters can mimic real-life scenarios. For example, shade from a cloud or surrounding tree or structure would still allow indirect light to reach the panel but would limit the direct sunlight. Another example might include light reflected off snow or grass, which is absorbed differently by solar panels than the direct rays of sunlight. The science behind which filters mimic which can be complex. The key here is to determine which color filter impacts their cars going faster or slower. Additional resources are provided at the end of this lesson with more information about filters.

3 **Angles**: the more directly the sun hits the panel, the faster the car.

4 **Reflectors:** by concentrating the sun energy onto the panel, the faster the car.

Elaborate

Reflecting at 90 degrees, with respect to the sun, is best; ask participants to explain this. Use a flashlight to create a model of the sun at various angles in relation to the reflector. Regardless of how you point it, the flashlight is always producing the same amount of light. Draw a circle around the area the beam is lighting up. Now move the flashlight to a lower angle and outline the area, repeat. Now draw a square in the first circle about the size of the circle; this represents a solar cell that is collecting all the power the flashlight is producing. Now compare the situation when the angle is 45 degrees. The solar cell is only covering half of the area that light is shining on. Therefore it must be collecting less than half the power of the flashlight. At the lowest angle, the beam is covering a huge area but the solar cell is only catching a small portion of the light.

The straight version, of the reflector, is good for noon sun directly overhead. The tilted one is good when racing towards a low sun. The ideal reflector angle and size direct all the light coming in the opening towards the target.

Explain to the youth that the first test we will perform is with color filters. There are several colored filters. The key here is to determine which color filter impacts their cars going faster or slower. Ask everyone to predict a color they think will make the car go faster, and a color they think will go slower. Ask youth to explain why they predict that color will make that difference.

After making predictions, have youth test the color filters with their cars. As a group, make sure that all the colors are tested at least once. If time allows, everyone could test all the colors. If limited in time, testing can happen as a whole group, using only the fastest car design.

Place the red filter over the panel and calculate the speed (measure the time it takes for the car to travel over a 1-meter distance).

1 Repeat for each colored filter.

2 Did any filter make the car faster? Use data and evidence to support your claim.

3 Which color reduced the speed the most? Use data and evidence to support your claim.

Be sure to remind youth that they can use data collected in past trials as evidence in making comparisons. Thinking about the types of data that are needed and how to capture data is an important skill. If time allows, and materials are available, as a group generates their own (or group) datasheet. Use the **Solar Cars Data Sheet Template, Part B (PDF)** to continue to collect data if needed.

The facilitator should explain after cars have been tested that white light is composed of all colors mixed together but we don't see them separately. A rainbow (or rainbow diffraction stickers) splits the white light into its colors so you can see different kinds of light there. Objects can absorb and reflect the light of different colors. If an object is white it means it is reflecting all the colors equally, if it is red that means that it is reflecting back only red light but is absorbing the others. A black object is absorbing all colors equally. The filters work the same way except the filter is transparent. A red filter lets red light through but blocks all other colors. A blue filter makes the red colors behind disappear. Colored filters will block some light so unfiltered light is always the strongest. Solar cells are sensitive to the color (wavelength) of light they are exposed to; it doesn't work very well below 450 nm which is blue to violet light. Note to facilitator: filters closest to the color of natural light generally work best (ex. yellow and red), while those similar to darkness achieve fewer results (ex. blue).

Now it's time to test light angles. Use the white from the protractors provided to reflect light onto the car's solar panel. The facilitator can determine if this is best done as a whole group, or in small groups.

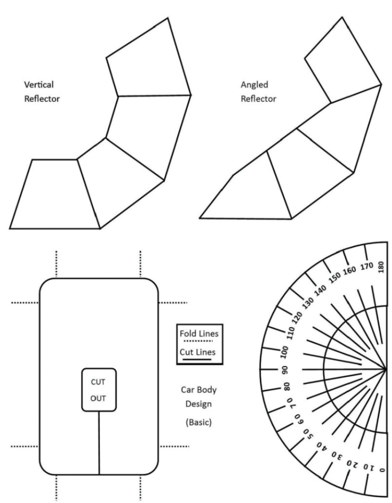
1 Using a protractor shine light on the solar panel at a 10-degree angle, have youth test the speed over a 1-meter distance.
2 Repeat for the following angles: 30, 60, 90, 120, and 150.
3 Ask participants as they are testing, which angle of light produces the fastest car? Ask youth to use data and evidence to support their claim.

The final phase is to build reflectors onto the cars. Use the templates in **Solar Car Design Template (PDF)** designed to attach reflectors. Everyone should test at least one type of reflector. The following directions should be explained to youth participants.

1 Put out the vertical reflector and put it on the car.
2 Test the speed over a 1-meter distance.
3 Repeat with the angled reflector.
4 If time allows, add aluminum foil to the inside of the reflector.
5 Ask participants, which type of reflector affected the speed of the car the most? Ask youth to use data and evidence to support their claim.

Ask the group why do solar arrays change positions instead of being stationary?

In this discussion, tie in concepts of energy transfer when answering these questions. For example, "I know my car is going the fastest because…." Or "My car is using the following factors to generate energy…"



Solar Car Design Template is included in the PDF link under the "Materials" list.

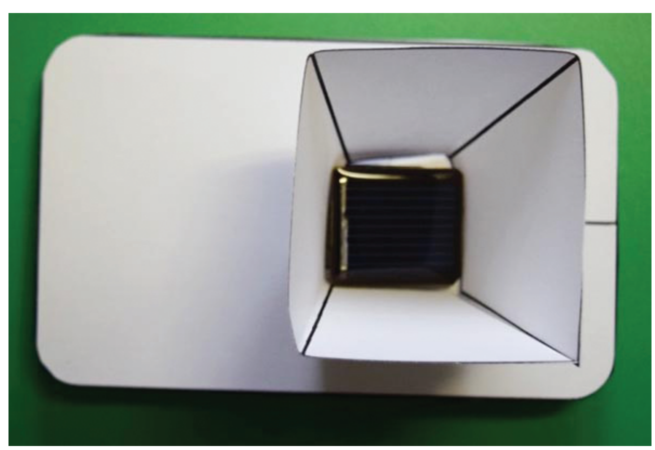


Figure 5.2: Example of a mini solar car with vertical reflector attached. (UMaine Extension 4-H Photo, Sarah Sparks)

Evaluate

Using observations and data collected on their **Solar Cars Data Sheet Template, Part A (PDF)** and **Solar Cars Data Sheet Template, Part B (PDF)**, engage in a group discussion on these topics. Encourage participants to use evidence when making their claims in response to the following questions.

- How did it feel when you were testing your car?
- What did you think would happen when you tested your car the first time?
- What did you think would happen when you added color filters? Reflectors?
- How did you design your car?
- What challenges did you have in building and/or testing your car?
- What design seemed to work the best? Why do you think that was? Use data and evidence to make your claim.
- What did you learn about solar energy? What are some of the limitations for solar energy? What design for a solar car might be used as evidence to support this claim?
- What did you learn about car design? How can you connect this to engineering design?
- How might you use what you learned today and apply it to future possibilities?
- Based on data and evidence collected today, what can we infer the perfect car to be?

Extension Ideas

1 Using your fastest car based on design, filters, angles, and reflectors, race the cars over a 2-meter track, 3 at a time. Continue to race until the fastest car is determined.

2 Test the cars on a full sun, partial sun, and overcast day.

3 Have students create Junior Solar Sprint cars.

Additional information: Students can participate in the University of Maine Junior Solar Sprint competition in June. More information about the solar sprint is available at the end of this curriculum.

Additional Resources

- **Teacher Guide for SunDawg Bag Lessons, Teacher Edition (PDF)** (Clean Energy Institute, University of Washington)
- **SunDawg Bag, Bring Solar to the Classroom, Mini-Cars and Lessons, Youth Edition (PDF)** (Clean Energy Institute, University of Washington)
- **Renewable Solar, Solar basics** (energyKIDS U.S. Energy Information Administration website) eia.gov/kids/energy-sources/solar/
- **Junior Solar Sprint: An Introduction to Building a Model Solar Car – Student Guide to Junior Solar Spring Competition (PDF)** (NREL website)
- **Education, Junior Solar Sprint** (Florida Solar Energy Center website) fsec.ucf.edu/en/education/k-12/energywhiz_olympics/jss/rules.htm
- **Teacher Guide for SunDawg Bag Lessons (PDF)** (Clean Energy Institute, University of Washington website)

MAINE 4-H FOUNDATION

RLC ENGINEERING

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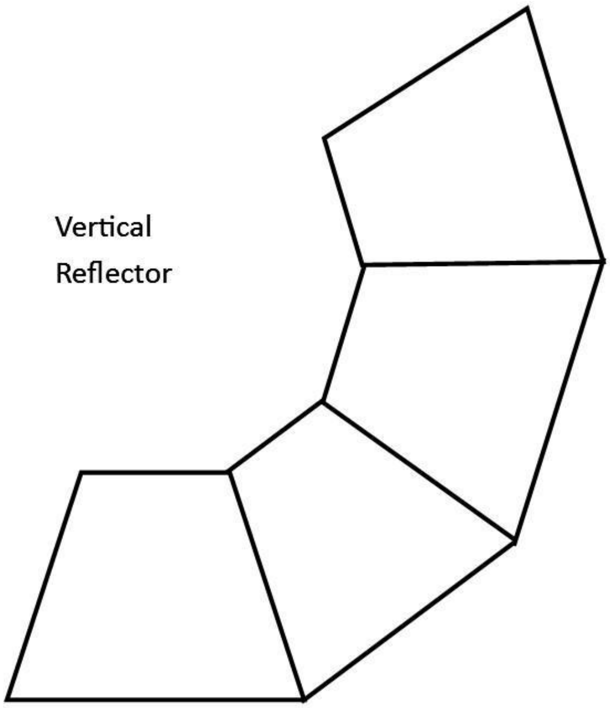
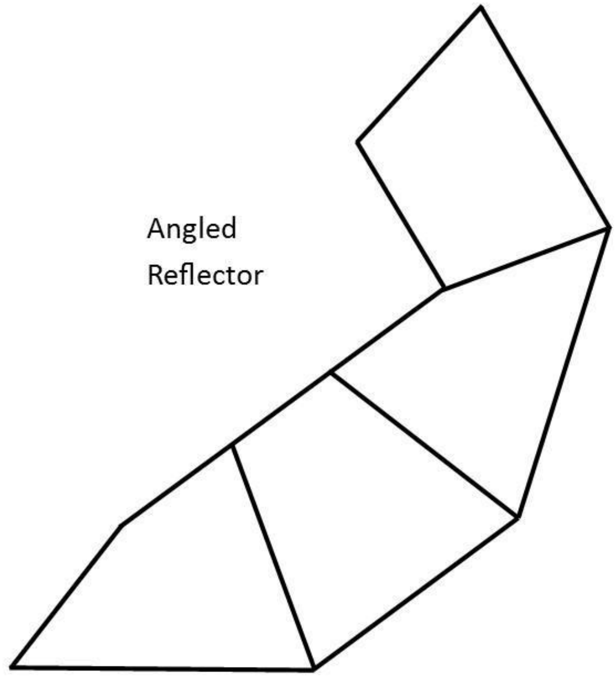
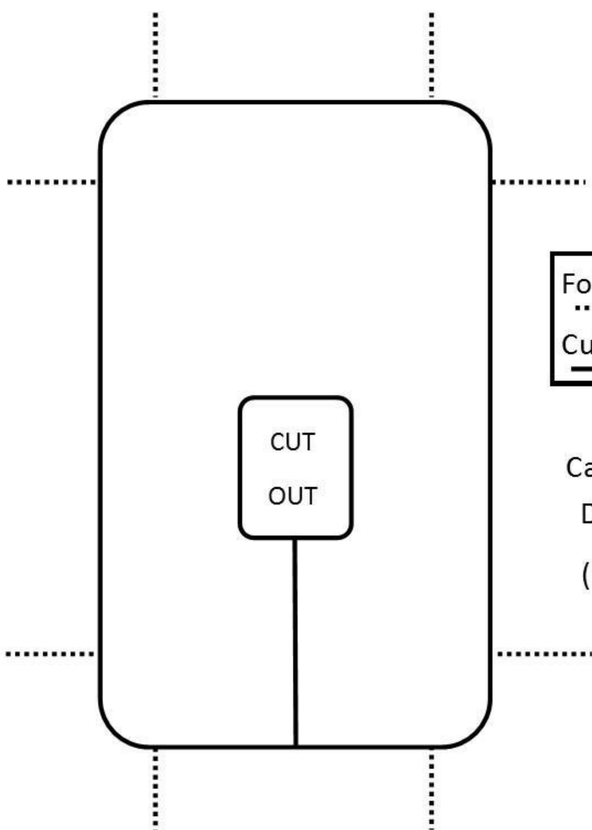
Car Design Template

Vertical
Reflector



Angled
Reflector

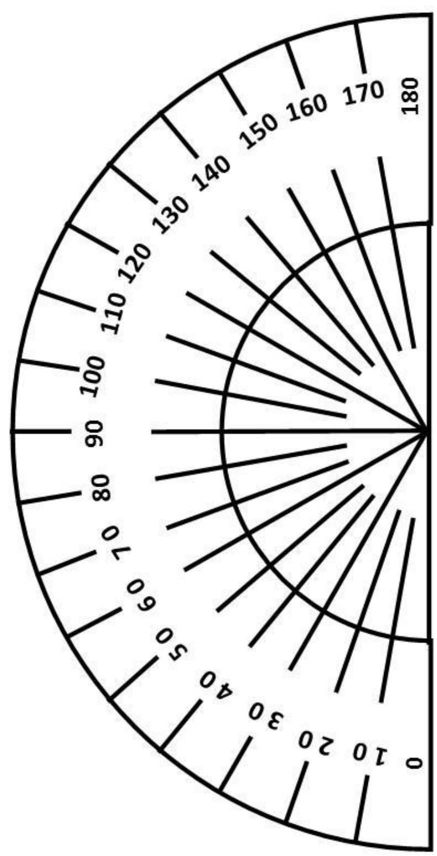




Fold Lines

Cut Lines

Car Body
Design
(Basic)



Solar Cars Data Sheet

Part A: Calculating Speed

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Part B: Collected Data

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