Solar Energy, Kit #6A: Efficiency of Solar Cells

Solar Energy, Kit #6B: Solar Extension Activities
Contents:

Topic Template ........................................3
Introduction: ..............................................5
   Photovoltaic Cells: How can we maximize their efficiency? ....................................5
Lab Protocol: .............................................7
   Investigating Factors That Impact Power Of Photovoltaic Cells .................................7
Lab Analysis .............................................10
Lab Protocol: Building a Solar Car ............................................12
Topic Template ........................................14
Elaborate: ..............................................12
   Modeling Global Conditions To Enhance PV Efficiency ........................................12
STEM Connection: .......................................22
   Investigating Factors that Influence Solar Panel Power Output ................................22
Performance Task: What’s Your Angle? ..............................................23
Extension: ..............................................29
   Investigations with Solar Trackers and Solar Battery Chargers .................................29
Photos of Kit Components ..................................34
### Topic Template

<table>
<thead>
<tr>
<th>Topic</th>
<th>Photovoltaic Cells: How can we maximize their efficiency?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associated Curriculum</td>
<td>Solar Energy</td>
</tr>
<tr>
<td>Associated Content</td>
<td>Sunlight =&gt; Energy; Photovoltaic Cells; Circuits; Electricity</td>
</tr>
<tr>
<td>Materials Required</td>
<td></td>
</tr>
<tr>
<td>• 2.0 V silicon solar cells</td>
<td>• Different Sizes of Drinking Cups</td>
</tr>
<tr>
<td>• lead wires with alligator clips</td>
<td>• 8½” x 11” piece of cardboard</td>
</tr>
<tr>
<td>• small motor</td>
<td>• Various sizes of rubber bands</td>
</tr>
<tr>
<td>• small (1 W) light bulb</td>
<td>• Various sizes of spools or similar</td>
</tr>
<tr>
<td>• light bulb base</td>
<td>• Scotch Tape</td>
</tr>
<tr>
<td>• 60 W light bulb</td>
<td>• Solar Cell and Motor</td>
</tr>
<tr>
<td>• Drinking Straws</td>
<td>• Ramp</td>
</tr>
<tr>
<td>• Bamboo Skewers (2 sizes if possible)</td>
<td>• Scissors</td>
</tr>
</tbody>
</table>

| 5E Learning Cycle | | |
| **Engagement** | • Turn on a light bulb using only a battery, a bulb, and a wire. Expand on this with more bulbs and wires. |
| **Exploration** | • What are the different parts of a circuit and how do they function together to produce work? |
| **Explanation** | • How does the intensity of light affect a photovoltaic cell? |
| **Elaboration** | • Why do solar cells not function as well on cloudy days? |
| **Evaluation** | • Design a car that is powered using solar cells. Design a circuit with a battery and light bulbs that functions in series and in parallel. |

| Related NGSS Standards | | |
| **MSPS2-3.** | Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. |
| **MSETS1-2.** | Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. |
| **MSETS1-3.** | Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. |

| Background/Why | Photovoltaic cells do not produce much energy on their own, they need to be connected in a circuit. In order to understand this, the concept of circuits is explored here. |

| Model 1 (Essential) | Electric Symbols (When drawing circuits, it’s important to understand how different parts are represented) |
| Model 2 (Essential) | Series Circuit versus Parallel Circuit (Electricity travels in various types of circuits, either in series or in parallel) |
| Model 3 (Essential) | Solar Cells Connected In Series (An example of how solar cells are connected in series) |
| Model 4 (Essential) | Solar Cells Connected In Parallel (An example of how solar cells are connected in parallel) |
| Lab 1 (Essential) | Investigating factors that impact power of photovoltaic cells (Lab involving solar cells and lights to determine how power is impacted) |
Photovoltaic Cells: How can we maximize their efficiency?

WHY?
A single solar panel does not generally produce the desired power for electrical applications. Solar panels can be wired in series or in parallel to increase voltage or amperage, separately, or they can be wired BOTH in series and in parallel to increase both volts and amps. Solar cells are often electrically connected in series as a module, creating an additive voltage. The power output of a solar array is measured in watts or kilowatts. In order to calculate the typical energy needs of the application, a measurement in watt-hours, kilowatt-hours, or kilowatt-hours per day is often used. A common rule of thumb is that average power is equal to 20% of peak power. How solar cells are connected as well as their orientation or tilt and the particular climate all contribute to the efficiency of the solar array for electricity production.

Background: See “Solar Cells: A Comparative Study” for PV cell background.

MODEL 1: Electricity Symbols

Based on your knowledge of electricity, use the following words to correctly identify the pictures and symbols that represent parts of electricity: voltage source, conductor, load, switch. Place each word in the appropriate box above.
Based on Model 2, a series circuit allows electrons to follow ________ path(s), whereas in parallel circuits, the electric current can follow ________________ path(s).
MODEL 3: Solar Cells Connected in Series

MODEL 4: Solar Cells Connected in Parallel

Predict: Which set up is better?
Lab Protocol: Investigating Factors That Impact Power Of Photovoltaic Cells

Background:
Photovoltaic cells, like those used in solar powered calculators, convert sunlight directly into electricity. Photovoltaic cells are made of special materials called semiconductors such as silicon. When light strikes the cell, a certain portion of it is absorbed within the semiconductor material. The energy knocks electrons loose, allowing them to flow freely. By placing metal contacts on the top and bottom of the PV cell, we can draw the current off for external use. This current, together with the cell’s voltage defines the power that the solar cell can produce. In this lab you will investigate the factors that impact the amount of power a silicon solar cell can produce. This lab focuses on the impact of connecting silicon solar cells in parallel and in series.

Materials:
2.0 V silicon solar cells
lead wires with alligator clips
small motor
small (1 W) light bulb
light bulb base
60 W light bulb
light

TESTABLE QUESTION: ______________________________________________________

Procedure:
1. Take out one solar cell.
2. Using the solar cell with alligator clips connect the cell to the voltmeter
3. Record the voltage produced by the solar cell.
4. Turn on the 60 V light bulb and face the solar cell towards it.
5. Record the voltage produced by the solar cell.
6. Take the solar cell outside or point the solar cell towards the window. Record the voltage produced.

<table>
<thead>
<tr>
<th>Position and Light Conditions</th>
<th>Voltage Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>(________________________variable)</td>
<td>(________________________variable)</td>
</tr>
<tr>
<td>Flat on table, lights in the room only</td>
<td></td>
</tr>
<tr>
<td>Facing the 60 W bulb</td>
<td></td>
</tr>
<tr>
<td>Facing the window or outside in sunlight</td>
<td></td>
</tr>
</tbody>
</table>

7. Make a complete circuit using the wires, one solar cell and the motor.
8. Record observations
**OBSERVATION:** Explain the movement of the motor. How does it change if you move the solar cell or add additional light?

__________________________________________________________________
__________________________________________________________________

9. Switch the wires that are connected to the motor so that it is now opposite.

**OBSERVATION:** What happens to the movement of the motor?

__________________________________________________________________
__________________________________________________________________

10. Record observations.

**OBSERVATION:** Explain how bright the light is. How does it change if you move the solar cell or add additional light?

__________________________________________________________________
__________________________________________________________________

11. Take out another solar cell. Connect the solar cells in series with the motor attached as the load. Record observations.

**OBSERVATION:** Does the motor spin faster or slower with two solar cells in series? Explain why you are observing this.

__________________________________________________________________
__________________________________________________________________

12. Cover up one of the solar cells with your hand so that it does not obtain light. Record observations.

**OBSERVATION:**

__________________________________________________________________

13. Disconnect the motor and connect the solar cells to the voltmeter in series. Place the solar cells connected in series in the sun and then in the “shade.” Record observations.

**OBSERVATIONS:**

__________________________________________________________________
14. Connect the two solar cells in parallel to the motor. Make observations.

**OBSERVATION:** Does the motor spin faster or slower with two solar cells? Explain why you are observing this.

__________________________________________________________________

__________________________________________________________________

15. Cover up one of the solar cells with your hand so that it does not obtain light. Record observations.

**OBSERVATION:**

__________________________________________________________________

16. Connect the solar cells in parallel to a voltmeter. Place the solar cells connected in series in the sun and then in the shade. Record observations.

**OBSERVATIONS:**

__________________________________________________________________

<table>
<thead>
<tr>
<th>Light Conditions</th>
<th>Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td></td>
</tr>
<tr>
<td>Shade</td>
<td></td>
</tr>
</tbody>
</table>
Lab Analysis

QUESTIONS:

1. What type of light produced the highest voltage? What was this voltage?
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

2. When you connected 2 solar panels in series, how did that affect the load?
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

3. What differences did you observe between the 2 solar cells connected in series and the 2 solar cells connected in parallel in terms of voltage and affect on the load?
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

4. Based on this experiment, if you were placing photovoltaic cells on the roof of the school, would you prefer that they be connected in series or in parallel? Explain.
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
5. Solar cells can also be called photovoltaic cells. Remember: photo=light and voltaic=electricity. Why is this a good name for this technology?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

6. What other words can you think of that contain the prefix “photo”?

_________________________________________________________________________________________________
_______________________________________________________________________________________________

CONCLUSION:
In your own words, write a conclusion to this lab. Be sure to:
• Answer the investigative or testable question
• Include supporting date
• Explain how the data support your conclusion
**Lab Protocol: Designing a Solar Car**

**Objective:** To design a car that utilizes the power of the sun to move on wheels a total of 10 feet on a flat surface.

**Background:** Solar powered cars have been around for decades, yet we still don’t see them on the roads. This is because it is difficult to build something that can be safe and powered by a car-sized solar cell, yet light enough to move from the power that cell generates. It is your duty to design a car that is able to move forward using the materials provided. First, you can use a ramp to power your car, but then, you will be given a solar cell which must be used to propel your final design.

**Materials Provided (Note: not all need to be used):**
- Drinking Straws (Not bendable)
- Bamboo Skewers (2 sizes if possible)
- Different Sizes of Drinking Cups
- 8½” x 11” piece of cardboard or chip board
- Various sizes of rubber bands
- Various sizes of spools or similar
- Scotch Tape
- Solar Cell and Motor (After successful Test)
- Ramp (Everyone can use one ramp)
- Scissors

Use the materials provided to design a car with a flat, cardboard body which can roll down the ramp.

Once you can roll down the ramp with ease, create a data table to record how your car moves every time you change your design a little. Don’t forget to utilize multiple trials.

Next, grab a solar cell, motor, and any other supplies you think you might need to build a working solar car. Create another data table for your solar car and record the distances with each design change.

Remember, the goal is to build a car that can roll for 10 feet on a flat surface, using the solar cell.

**Helpful Hints:**

A car usually has a base, two free-turning axels, and four wheels attached to the two axels. This isn’t the only way, but it is one way.

What should the motor be connected to in order to move the car? How can you connect these two things?

Obviously wheels are usually round. However, there are many ways to make round wheels with these supplies – some work far better than others.
**Extensions:**

Drag Race! Two (or more) cars race across the finish line. The champion gets a make-shift trophy.

Adding weight. To increase the challenge, a mass can be added to the car, making it much harder to move.

Customization. Markers can be used to stylize each car to make them unique.

**Going Further:**

Draw a model showing the flow of energy from the sun to the movement of the wheels.

Construct an argument based on evidence why your car was designed the way it was designed. Use the Claim, Evidence, Reasoning framework to structure your argument.

If you had access to more materials, what would you want and why?
<table>
<thead>
<tr>
<th>Topic Template</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Modeling Global Conditions To Enhance Photovoltaic Efficiency</td>
</tr>
<tr>
<td>Associated Curriculum</td>
<td>Solar Energy</td>
</tr>
<tr>
<td>Associated Content</td>
<td>Solar Energy; Electricity; Light Energy; Sunlight =&gt; Energy; Global Awareness</td>
</tr>
<tr>
<td>Materials Required</td>
<td>• Computer with internet</td>
</tr>
<tr>
<td></td>
<td>• Solar panel</td>
</tr>
<tr>
<td></td>
<td>• Vernier current probe</td>
</tr>
<tr>
<td></td>
<td>• Vernier LabQuest</td>
</tr>
<tr>
<td></td>
<td>• Load (Light Bulb, Motor, etc.)</td>
</tr>
<tr>
<td></td>
<td>• Optional: Vernier circuit board</td>
</tr>
<tr>
<td>5E Learning Cycle</td>
<td>• Research how long the longest night is in Deadhorse, Alaska.</td>
</tr>
<tr>
<td></td>
<td>• What factors influence solar energy collection?</td>
</tr>
<tr>
<td></td>
<td>• Why do solar panels work better in some areas than other areas?</td>
</tr>
<tr>
<td></td>
<td>• Why would a solar panel on the North Pole be a bad idea in the winter?</td>
</tr>
<tr>
<td></td>
<td>• Where would you construct a solar power plant to gather the most energy?</td>
</tr>
<tr>
<td>Related NGSS Standards</td>
<td><strong>MSPS2-3.</strong> Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. <strong>MSPS4-2.</strong> Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td>
</tr>
<tr>
<td>Background/Why</td>
<td>The amount of energy that hits the earth’s surface is not constant and is not consistent. It changes with the latitude and longitude and with cloud coverage and the sun’s angle at different parts of the day.</td>
</tr>
<tr>
<td>Model 1 (Essential)</td>
<td>PV Applet (Solar energy changes depending on the angle of the sun and the angle of the solar collector)</td>
</tr>
<tr>
<td>Exercise 1 (Essential)</td>
<td>Manipulating the Applet (Solar energy is vastly different in different locations around the globe)</td>
</tr>
<tr>
<td>Exercise 2 (Essential)</td>
<td>Investigating Factors that Influence Energy Production (Solar energy production is influenced by location and by the angle of the solar panel)</td>
</tr>
<tr>
<td>Model 2 (Essential)</td>
<td>Modeling (Models are a useful tool for explaining scientific content, but they do have limitations which need to be recognized)</td>
</tr>
<tr>
<td>Exercise 3 (Essential)</td>
<td>Using mini solar panels to investigate how sun’s placement in the sky impacts solar energy (The effect of angles on solar energy can be explored on an individual basis)</td>
</tr>
<tr>
<td>Exercise 4 (Essential)</td>
<td>Varying other factors to change power output (Many factors influence how much solar energy is received by a collector)</td>
</tr>
<tr>
<td>Lab (Essential)</td>
<td>Investigating Factors that Influence Solar Panel Power Output (Scientific instruments can be used to get exact measurements of the different factors that influence solar energy collection)</td>
</tr>
</tbody>
</table>
**Elaborate: Modeling Global Conditions To Enhance PV Efficiency**

**Why?**
The sun has produced energy for billions of years. Solar energy is the solar radiation that reaches the Earth. This energy can be converted into other forms of energy, such as heat and electricity. Photovoltaic devices change sunlight directly into electricity. These PV cells can be used to charge calculator and watch batteries, power single homes or generate electricity to a power plant that covers many acres. Although photovoltaic systems use energy from the sun, the amount of sunlight that arrives at the Earth's surface is not constant. It depends on location, time of day, time of year, and weather conditions. You will find out what factors affect the amount of electricity a photovoltaic produces and then complete a challenge using miniature solar cells to enhance the efficiency of electricity production by altering a specific factor.

**Background:**

Some solar cells are designed to operate with concentrated sunlight. These cells are built into *concentrating collectors* that use a lens to focus the sunlight onto the cells. This approach has both advantages and disadvantages compared with flat-plate PV arrays. The main idea is to use very little of the expensive semiconducting PV material while collecting as much sunlight as possible. But because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country. Some concentrating collectors are designed to be mounted on simple tracking devices, but most require sophisticated tracking devices, which further limit their use to electric utilities, industries, and large buildings.

The performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and much of it is reflected or absorbed by the material that make up the cell. Because of this, a typical commercial solar cell has an efficiency of 15%—about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed, and that means higher cost. Improving solar cell efficiencies while holding down the cost per cell is an important goal of the PV industry, NREL researchers, and other U.S. Department of Energy (DOE) laboratories, and they have made significant progress. The first solar cells, built in the 1950s, had efficiencies of less than 4%.
**MODEL 1: PV Applet**
This is a screenshot of the PV Applet. The applet is a model of the power output of a photovoltaic panel. Go to this address to access it:

1. What does the yellow circle represent?
2. What does the white line represent?
3. What does the grey rectangle on the pedestal represent?
4. Based on Model 1 and your knowledge of photovoltaics, what factors do you think affect the amount of electricity a solar panel produces? Compare this to photosynthesis in a leaf of a plant.

**Exercise 1: Manipulating the Applet**
5. Click the LOCATION button. Choose a city and record it in the space below.

6. Indicate the latitude and hemisphere of the city you have chosen.

7. What is the average annual solar energy from a 1kW array?

8. Once you have chosen a city, click the SIMULATION TYPE AND DATE button to choose your simulation time frame. Record it here:
9. To start the simulation, click PLAY under the panel. Record three changes you notice as the simulation runs in the space below.

10. Click on the GRAPHED RES. button. You will see a graph of energy produced by our panel during the simulation. What conclusions can you draw about the energy produced by your panel in this simulation?

11. Click on the PHOTOVOLTAIC ARRAY DESIGN button to see how you can change the characteristics of your panel. Write down some characteristics of your array that you can manipulate.
Exercise 2. Investigating Factors that Influence Energy Production
Choose one of the following inquiries to complete on your own or with a partner. Your choices are:
• #1: Northern and Southern HEMISPHERES
• #2: Latitude and Solar Energy
• #3: Panel Angle and Solar Energy

1. Once you have decided on a topic, state it as a testable question. (i.e. What is the effect of ____ on ____?)

2. Write a hypothesis.

3. Test your hypothesis using the PV Applet. Collect data in the space below using an appropriate data table.

4. Analyze results and draw a conclusion.
MODEL 2: MODELING
Whenever scientists use models to help them study a question, it is important that they take a step back and consider the strengths and weaknesses of the model. For example, a globe is a model of the Earth. However, despite the models strengths it also has limitations.

<table>
<thead>
<tr>
<th>Model: Globe</th>
<th>What it represents: Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths</strong></td>
<td><strong>Limitations</strong></td>
</tr>
<tr>
<td>• Helps us see how the earth is round.</td>
<td>• Smaller than actual size.</td>
</tr>
<tr>
<td>• Helps us see how much of the earth is covered in water, how much is covered in land.</td>
<td>• Does not show weather patterns.</td>
</tr>
<tr>
<td>• Gives us a sense of where different countries are.</td>
<td>• Does not show actual mountains, rivers, and oceans.</td>
</tr>
<tr>
<td></td>
<td>• Does not teach us about what is inside the earth.</td>
</tr>
</tbody>
</table>

1. Have you ever built a model airplane? What does it represent?

2. Fill out the chart below, like in Model 2, to demonstrate the strengths and limitations of this model.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 3. Using mini solar panels to investigate how sun’s placement in the sky impacts solar energy

Materials for Each Group:
1 miniature solar panel
1 digital multimeter
1 pair of alligator clip wires
1 incandescent bulb

1. What are the limitations of this model?

2. Draw a sketch of diagram that indicates the panel placement. Show the direction it faces and the degree of the tilt, if appropriate. (If the panel faces straight up it has a tilt of 0 degrees)
3. Record the data at different times of the “day” to determine power production.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Voltage (V)</th>
<th>Current (μA)</th>
<th>Power (μW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00 am</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00 am</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 pm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00 pm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:00 pm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. When did you get the most power?

5. What other things can you vary?

**Exercise 4. Varying other factors to change power output**

Using the materials provided, work with your group to manipulate another variable. Record your results below.

1. Draw or sketch a diagram to indicate your experimental set-up. Indicate what variable is being manipulated.

2. Collect data and record in a table below.

3. Write a conclusion to summarize your findings.
STEM Connection: Investigating Factors that Influence Solar Panel Power Output

Materials:
Solar panel
Vernier current probe
Vernier LabQuest
Load
Optional: Vernier circuit board

Procedure:
1. Choose a location for the apparatus
2. Construct the circuit according to the diagram below
3. The load could be anything that creates resistance (e.g., holiday lights in series, motors, or ohm resistors on the Vernier circuit board hooked in series)
4. Organize the circuit such that the Vernier LabQuest and load are inside a cardboard box and the solar panel is sitting flat above them (see photo).
5. Run the experiment for 15 hours from roughly sunrise to sunset.
6. Be sure to set it so that current readings are taken every 15 seconds.
7. Correlate the data with the sky conditions
8. Repeat experiment on different days
9. Repeat experiment, varying the angle of the solar panel
10. Repeat experiment to investigate other factors (e.g., type of solar panel, number of panels, connection of panels – series or parallel, suntracker panels, colored filters, cooling the panel by misting it, etc.)
Performance Task

What’s Your Angle?

Directions: Use the following information to answer questions 1 through 7.

Sunlight strikes Earth at different angles due to the shape of Earth, as shown below.

Sunlight Striking Earth

Two students, Amy and Chris, wanted to know if the shape of Earth affects surface temperatures on Earth. They investigated this phenomenon with a model of the Earth-Sun system as described in the Earth-Sun Model.

Question: What is the effect of the angle at which light strikes a wooden block on the surface temperature of that block?

Hypothesis (prediction): As the angle that the light strikes the block increases to 90°, the block’s surface temperature will increase because the light will strike the block more directly.

Materials:
wooden block
thermometer
black paper
lamp
protractor
meterstick
stand and clamp
timer
Write a reasonable hypothesis for the experiment that Amy and Chris conducted.

Identify the independent variable for this investigation: __________________________
Identify the dependent variable for this investigation: ____________________________

Table 1 indicates that temperatures listed are averages of three trials. Explain why conducting three trials instead of one will help Amy and Chris reach a more reliable conclusion.

Complete the table below by calculating the temperature change for each angle after 5 minutes.

**Table 2:**

<table>
<thead>
<tr>
<th>Angle Light Strikes Block (degrees)</th>
<th>Change in the Block’s Surface Temperature (Degrees Celsius)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Use the data from Table 2 to construct a line graph on the grid below.

***Be sure to provide:***
- An appropriate title
- A label for each axis with appropriate units
- An appropriate number scale and category labels
- Correctly plotted data
Predict the surface temperature of the wooden block if the block was set at a 45 degree angle for five minutes. In your prediction be sure to:

- Predict the approximate surface temperature of the wooden block.
- Include data from the table to support your prediction

Identify two factors that should be held constant for this investigation.

Why is it important to hold some conditions constant during an investigation?

How could Amy and Chris change their Earth-Sun model to more accurately show how Earth is heated by the Sun? Be sure to

- Identify one change that could be made to the model
- Explain how this change would more accurately show how Earth is heated by the Sun.
Describe two energy transfers that happened in Chris and Amy’s investigation.

The diagram below shows how sunlight strikes Earth at different angles. Explain why sunlight creates a pattern of decreasing temperature as someone moves from the equator toward areas of higher latitudes.
Sunlight strikes Earth at different angles due to the shape of the Earth (as seen in the diagram above). At which location would shadows be longest at noon on a clear summer day? Explain.

Amy and Chris want to repeat their investigation with different color paper over each thermometer. Describe how different colors of paper would affect the surface temperature of the block.

In order to see if the color of paper makes a difference in how much energy is absorbed by the light, Amy and Chris set up the experiment with three thermometers set the same distance from a lamp. Each thermometer was wrapped in a different color of paper.

Identify two factors that will need to be measured during the experiment. Next to each one, identify the tool they will need to use.

<table>
<thead>
<tr>
<th>Factor to be measured</th>
<th>Tool needed for measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
</tbody>
</table>
Extension: Investigations with Solar Trackers and Solar Battery Chargers

Using the materials in the kit – the **Solar Tracker** and the **Solar Battery Charger** – design an experiment. In your experimental design be sure to consider the testable question, come up with a hypothesis, identify variables, and create a detailed procedure. A guideline for planning follows:

Name: ___________________________

Group Members: ___________________________

Experiment: ___________________________

**Experiment Testable Question:**

________________________________________________________________________

________________________________________________________________________

**Experiment Purpose:**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Experiment Overview:**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Experiment Connection to Renewable Energy Research:**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Hypothesis (What and Why):

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Materials Needed (What and Why):

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Group Member Responsibilities (each person):

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Experiment Set-Up Design and Diagram (color):
Experiment Step-by-Step Procedure (bullet points):

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
Experiment Data (Tables and Graphs):

Observations During Experiment (bullet points):

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

32
Experimental Errors (yes or no?):
If yes, explain. If no, what could your group have done better?
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Experiment Conclusion:
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

New Questions?:
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
Solar Energy Kit #6A: Efficiency of Solar Cells
[Setup: Solar Cells in Parallel]

Solar Energy Kit #6B: Solar Extension Activities

Materials to build Suntracker apparatus

Manual

Solar Battery Charger

Solar Car Kit

Suntracker