Sun Tracking System for a Solar Panel

Grade Level: 6	**Total Time Required:** 3 periods (90 minute each), approximate

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Lesson Objectives:

Students will be able to:

1. Demonstrate that the seasons in both hemispheres are the result of the inclination of the earth on its axis, which causes changes in sunlight intensity and length of day.
2. Identify the difference between direct and indirect rays of light.
3. Apply their understanding of indirect and direct rays to design a device that can be used to track the sun through the day and various times of the year.
4. Use various materials and typical engineering design components (examples provided).
5. Measure the angles associated with the inclination of the sun and position of the sun throughout the day.

Indiana Standards:

6.ESS.2 Design models to describe how Earth's rotation, revolution, tilt, and interaction with the sun and moon cause seasons, tides, changes in daylight hours, eclipses, and phases of the moon.

6-8.E.1 Identify the criteria and constraints of a design to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Next Generation Science Standards:

Discipline Core Ideas

MS-ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patters of lunar phases, eclipses of the sun and moon, and seasons.

MS-ESS1.A Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

MS.ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Crosscutting Dimensions

4. *Systems and system models.*

Science/Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
7. Engaging in argument from evidence

Mathematics Connections:

The design activity requires the students to perform the following mathematical calculations:

- The measurement of the horizontal angle of the solar panel on their completed design to show the design functions for the sun crossing the sky from East to West.
- The measurement of the vertical angle to show the design functions for the change of sun angles from the summer to the winter.
- Measurement of elapsed time.

Concepts and Vocabulary

Term	***Defined by a scientist or engineer***	***Defined by a student***
Axis	An imaginary line around which an object rotates. In a rotating sphere, such as the Earth and other plants, the two ends of the axis are called poles.	An imaginary line that goes through the center of the earth.
Solar	Relating to the sun	Sun
Solar Panel	(Engineering/Electrical Engineering) A panel exposed to radiation from the sun, used to heat water or, when mounted with solar cells, to produce electricity directly.	Something used to collect the sun's energy.
Direct Rays	A direct ray is when the Sun's light hits the specified part of Earth that you are observing at an exact angle of 90 degrees. This means that the Sun's rays are perpendicular to the Earth; (Site: http://wiki.answers.com/Q/What_is_the_definition_of_direct_rays)	The sun is directly overhead and there is no shadow.
Indirect Rays	Indirect rays are when the Sun's light hits the specified part of Earth at an angle other than the perpendicular angle of 90 degrees.	The sun's rays are coming at me from the side and there is a shadow.

Equipment, Materials, and Tools

Materials		
Marbles	Flexible straws	Clay
Plastic cups	Duct tape	Brass paper fasteners
Vinyl corner bead pieces	Round plastic plates	Small Solar Panel**

Tools		
Scissors	Rulers	Flashlight
Electrical clips and leads	Multi-meter*	

*Equus 3300 hands-free Digital Multi-meter (~$13.00 at Walmart)

**Small solar panels are available on the following websites:
http://store.sundancesolar.com/3v-70ma-solar-cell-10-pack-with-wires/ (approximately $29.95)
http://www.futurlec.com/Solar_Cell.shtml

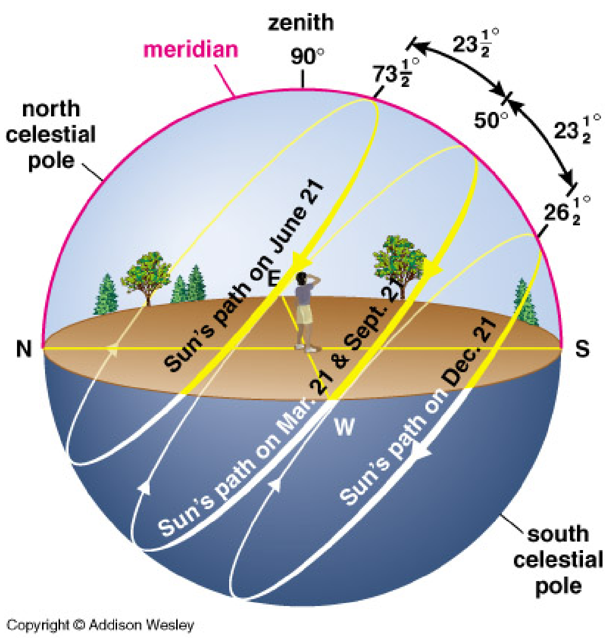
In addition to purchasing them on-line, you may also purchase inexpensive solar lights at a hardware store and remove the solar panel. Note: Some are easier to remove than others. You may want to try a couple of different varieties to see which solar panels come out the easiest.

Science Content - Basics

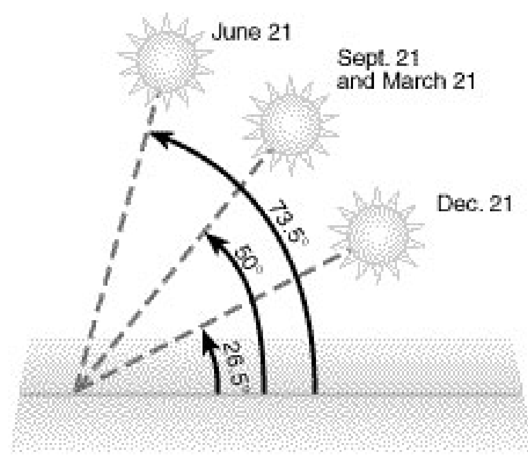
Why do you need to design a solar panel that can move?

- Sunlight intensity and length of day changes because the earth is tilted on its axis. During the summer in the Northern Hemisphere the north axis is tilted towards the sun and the sun's rays hits that part of Earth more directly. The Northern Hemisphere is tilted away from the sun during winter and therefore the sun's rays hit that part of earth less directly.

- In order for the solar panel to be as efficient as possible, the panel needs to be pointed towards the sun during the day and also be angled correctly for the seasons. The solar panel will still function if it is not exactly pointed at the sun, however, the efficiency decreases.



Sun angle at various times of the year.
Image retrieved 05 May 2011 from
http://curious.astro.cornell.edu/images/pathofsun_40deg.jpg



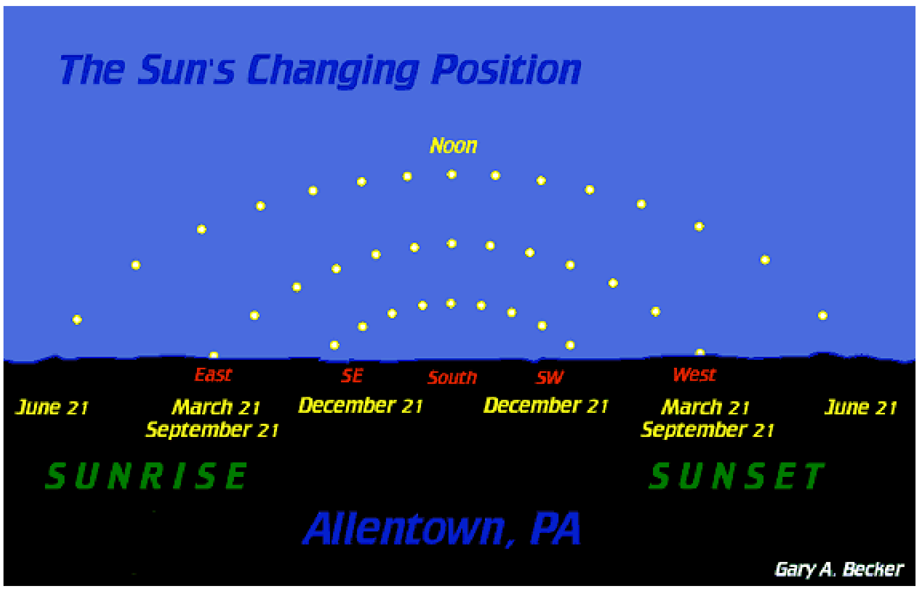
Sun angle at various times of the year.
Image retrieved 05 May 2011 from
http://parametricmodel.com/upload/image/full_4d4040fdc802a.jpg

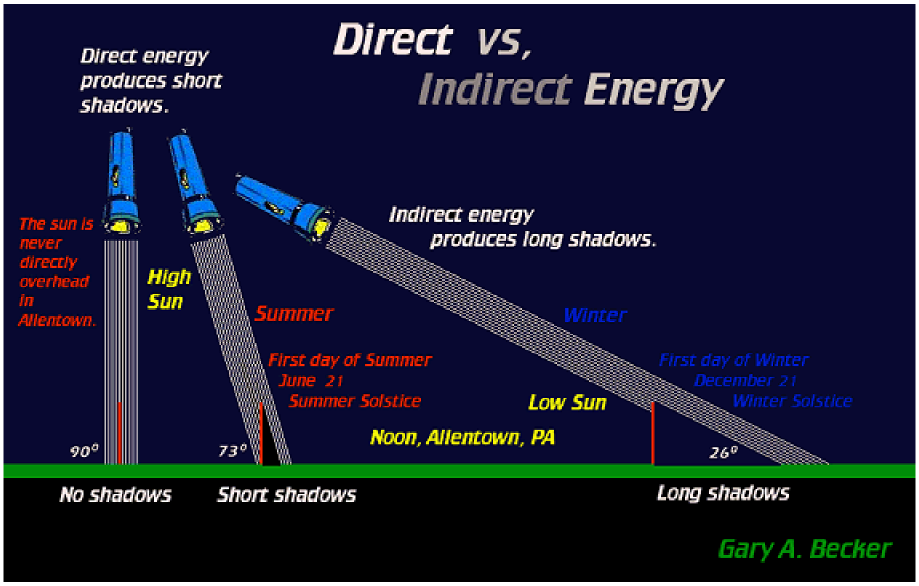
Direct and Indirect Sunlight

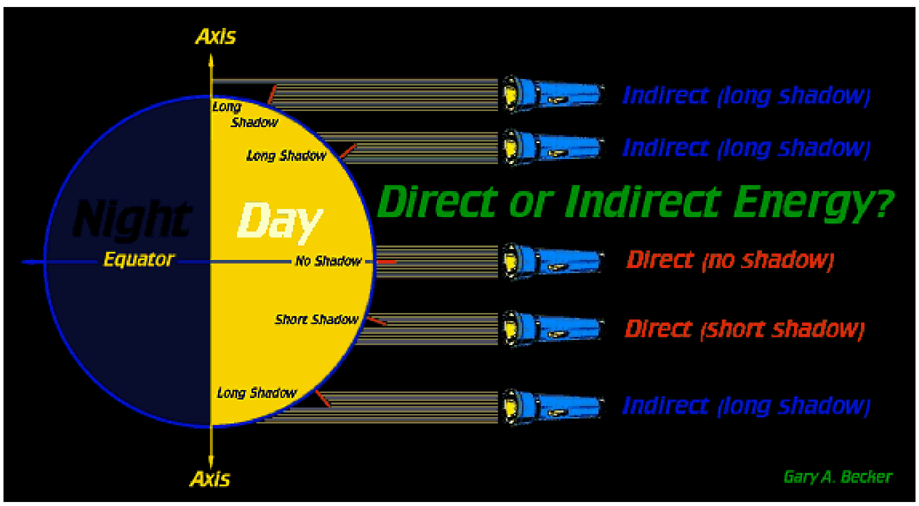
The website "The Reasons for the Seasons" by Gary Becker provides an excellent review on why we have seasons and the concepts of direct and indirect light. The link to the website is: http://www.astronomy.org/programs/seasons/index.html#reasons

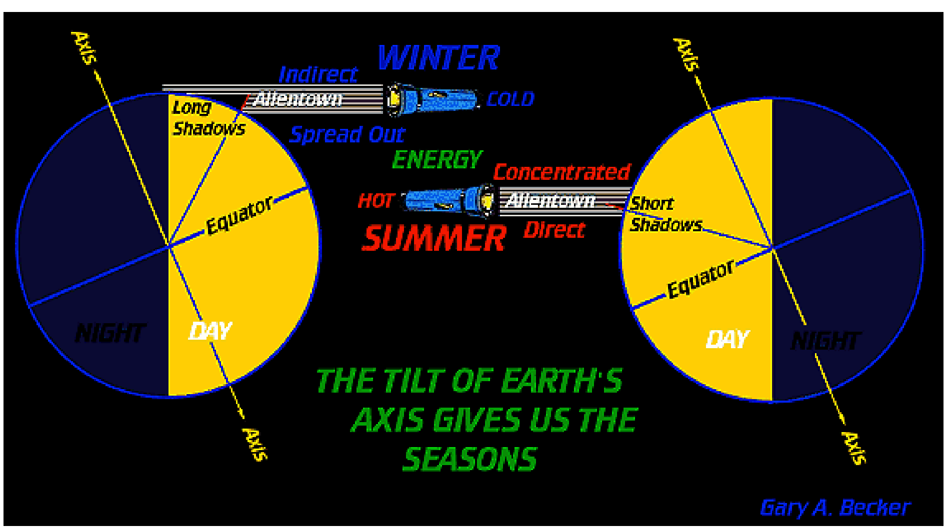
Excerpts from the website are provided below:

"Imagine the flashlights to be the sun. The energy coming from each flashlight is the same, but the way the light is striking the ground is different. The two flashlights on the left are allowing their energy to strike the ground DIRECTLY in a concentrated manner. The flashlight on the right is tilted so that when its energy strikes the ground, the energy is spread over a much larger area. The energy from the tilted flashlight is striking the ground INDIRECTLY, and its energy is less concentrated."




Direct vs, Indirect Energy
Direct energy produces short shadows.
Indirect energy produces long shadows.
The sun is never directly overhead in Allentown.
High Sun
Summer
Winter
First day of Summer June 21 Summer Solstice
First day of Winter December 21 Winter Solstice
Low Sun
Noon, Allentown, PA
90°
73°
26°
No shadows
Short shadows
Long shadows
Gary A. Becker


Axis
Long Shadow
Long Shadow
Night
Day
Equator
No Shadow
Short Shadow
Long Shadow
Axis
Indirect (long shadow)
Indirect (long shadow)
Direct or Indirect Energy?
Direct (no shadow)
Direct (short shadow)
Indirect (long shadow)
Gary A. Becker


Axis
WINTER
Indirect
Allentown
COLD
Long Shadows
Spread Out
ENERGY
Concentrated
HOT
Allentown
Short Shadows
SUMMER
Direct
Equator
Equator
NIGHT
DAY
DAY
NIGHT
Axis
Axis
Axis
THE TILT OF EARTH'S AXIS GIVES US THE SEASONS
Gary A. Becker

Synopsis of Engineering Design Activity

Synopsis of the Design Activity:

Problem:	Indiana Solar Power Company is trying to find a way to obtain as much energy as they can from the sun.
Goal:	Design a solar panel system that is able to track the sun so that the panel can collect as much solar energy as possible.
Who is the client:	Indiana Solar Power Company
End-User:	Anyone who uses electricity
What is the design:	Design a solar panel system that can be easily moved to track the sun.
Criteria:	• The solar panel should be able to move horizontally to track the sun through the day. • The solar panel should also be able to be moved vertically to capture the different angle of the sun during summer and winter. (See Figure 3) • The solar panel does NOT have to move on its own (motors are not provided), however, students can assume that a product would use a motor or other system to move the solar panel.
Constraints:	• May only use the materials provided. • Time.

Lesson Plan #1
Guiding Question – How does a solar panel move? What are the common principles?

Time: Two 90 minute class sessions

Procedure:

1. Introduce design task and information on the client (Design Activity, Student Resources) by distributing the desk task to students.

   Ask: *What is the problem?*
   Who is the client?
   Who is the end user?
   What are examples of constraints?

2. Before students begin their plans, discuss important science principles that need to be understood in order to perform the design task. These are listed under the "Science Content" section.

   Ask: *How do we get the four seasons?*
   If I put a diagram on the board, how or where should I put the sun? Where should I put the Earth?
   Now let's look at our diagram, what time of year is it?
   Where would the sun be if it was fall in Indiana?
   Where would the sun be if it was winter in Indiana?
   Where would the sun be if it was spring in Indiana?
   Where would the sun be if it was summer in Indiana?

   Explain to students that there are three central ideas related to the seasons: 1) the tilt of the Earth; 2) the direction of the sun's rays (indirect vs. direct); and 3) the path the Earth takes around the sun.

3. Before proceeding, ensure students understand the reason we have seasons and how the sun crosses the sky during the day.

   Ask: *Using a model of the Earth, how would we position the Earth relative to the sun when it is winter in Australia?*
   Using a model of the Earth, how would we position the Earth relative to the sun when it is summer in Alaska?

4. Introduce components that they can use to build the solar tracking device. (This is a very open ended project and there are many ways to fabricate a working model).

5. Introduce concepts on how the solar panel can move using typical mechanical design components, such as ball bearings and four bar linkages. (See the Mechanical Design Components Section).

6. Instruct students to sketch his/her possible designs for a solar tracking system in their design books.

   Ask: *What are the important features of your design?*
   How will you use some of the materials in your design?
   What are some challenges or problems you think your team may face?
   How could address these problems now?

7. Instruct each team to decide on one plan after they share their designs. The design could be a specific design of one student or a combination of designs.

8. Students will then construct one prototype per team. Allow for 90 minutes for construction.

9. A list of items and potential monetary value is provided. Students may be asked to determine how much their design costs and they can "buy" additional items, if needed.

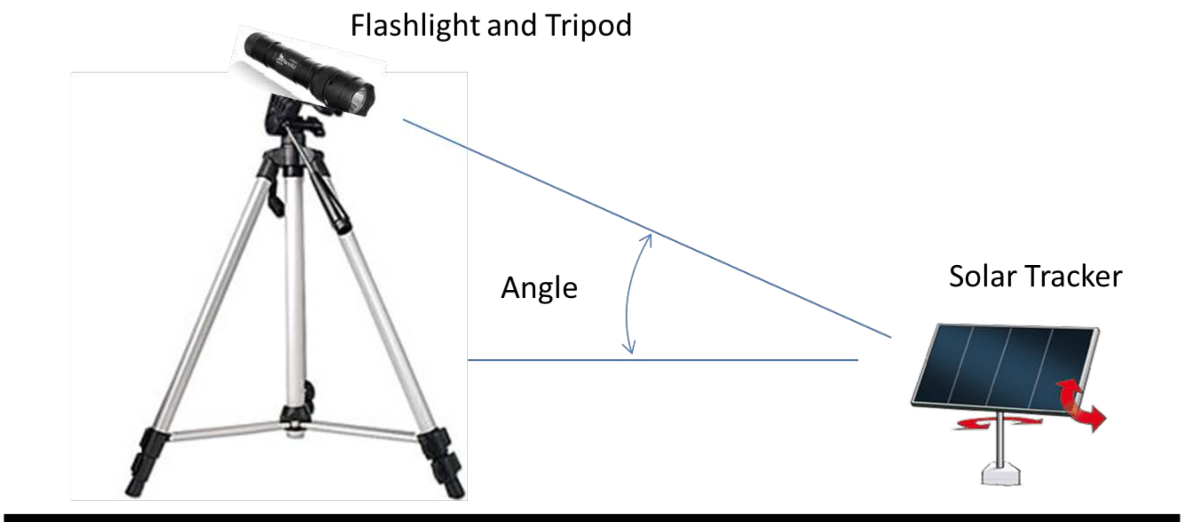
Lesson Plan #2
Guiding Question – How can you measure the angle of your solar panel device? How well does your device track the sun crossing the sky?

Time: one 90 minute class session

Procedure:

After the prototype is built the student can measure angles of the solar panel to show the design functions as required by the client.

1. First measure the vertical angle of the solar panel to show the design functions for the change of sun angles from the summer to the winter. For Lafayette, Indiana, the winter solstice angle is 26.5 degrees and the summer solstice angle is 73.5 degrees. *Note: the angle of ray is provided and the solar panel is perpendicular to the ray.*



2. If an electrical multi-meter has been purchased, a flashlight can be set-up at the angle for the sun. The students can see the change in voltage if the solar panel is not directly in line with the beam of the flashlight.

3. Measure the horizontal angle required that the device needs to move to capture the sun rays as the sun moves from East to West (horizontal plane).

4. The students can again use the multi-meter to see the change in voltage output.

5. Other angles can be determined for other dates from: http://solardat.uoregon.edu/SunChartProgram.html

Assessment

The following are possible sources of formative and summative assessment:

- Design notebooks (individual) – Note how students identify and clearly label their drawings; Identify the types of science vocabulary students use in their notebooks (tally the number of times each concept is used); Note how students record data from testing their prototypes and how well they explain their results (patterns in the data)

- Presentation of design to class by the team. Provide positive design attributes, how design criteria where met, and possible redesigns.

- Participation (group) – Note level of engagement; questions students asked; how well they worked in a group; how well each team met the goals of the task

- Other (individual and/or group) – Create a short pre and posttest that highlights key science vocabulary terms; Present a new situation or new problem on the same theme

- See Lesson Extensions

Lesson Extensions and Resources

Activity Extensions:
http://science-class.net/astronomy/cycles/seasons/seasons.html
Site provides a clear explanation of terms, concepts, and ideas related to students' conceptions of the four seasons. This site also provides ideas for extension activities on topics related to Earth's rotation, four seasons, and planetary motion.

Web Resources:
http://www.nationalgeographic.org/activity/the-reason-for-the-seasons/
National Geographic Education – provides an excellent short video of the reasons for the seasons. Also provides additional learning activities and handouts for teachers.

http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.html
University of Nebraska at Lincoln provides a season simulator that shows the earth/sun relationship at any time and latitude throughout the year.

Design Activity
Student Resource

SLED
Science Learning through Engineering Design

Indiana Solar Power Company needs your help. They are interested in finding a way to obtain as much energy as they can from the sun. One way is to use solar panels. In order to maximize the amount of solar energy collected by the solar panels, the panels must be positioned such that they face the sun at all times of the day and during all seasons. The Indiana Solar Power Company believes your team can help.

The company is asking you to develop a solar panel system that can be easily moved to track the sun, so that the panel can collect as much solar energy as possible. To complete this task you need to use what you know about the sun's location in the sky during different times of the day and during different seasons. You may also want to use what you have learned about how machines move.

Design Constraints

1. The solar panel should be able to move horizontally to track the sun through the day.
2. The solar panel should also be able to be moved vertically to capture the different angle of the sun during summer and winter.
3. The solar panel does NOT have to move on its own (motors are not provided), however, students can assume that a product would use a motor or other system to move the solar panel.

Possible cost for items to link with a classroom economy

Marbles	$2 Each
Plastic Cups	$10 Each
Vinyl Corner Bead Pieces	$5 Each
Bendy Straws	$15 Each
Duct Tape	Free
Round Plastic Plates	$10 Each
Golf Balls	$4
Clay	$20 (As much as needed)
Brass Paper Brads	$1 Each
Small Solar Panel	$100

Mechanical Design Components

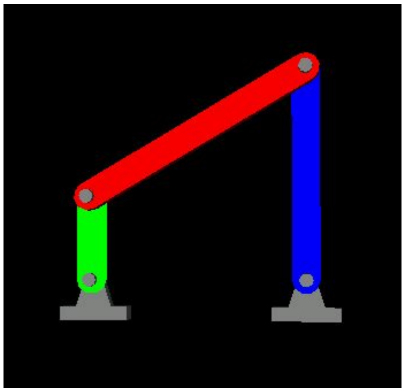
Ball Bearing Information

- Things tend to roll better than they slide.
- Rolling friction has less resistance than sliding friction.
- The balls or rollers “bear” the load in a ball bearing (shown below).
- Balls can be put between to surfaces to decrease sliding friction. Examples of how they can be built for this project are shown in the following pages.

Image of a ball bearing retrieved December 10, 2012 from
http://www.nskeurope.com/cps/nsk/eu_en/p/images/content/1030_DGBB_rgb_rdax_95.jpg

Four-Bar Linkage

A typical engineering design component to move something is a four-bar linkage. A four-bar linkage consists of four pieces of material connected in a loop by pin joints. In the image below, three links are shown. The fourth would be connected between the ground pins (grey bases) and is not shown because it would not move.



Example showing a four bar linkage retrieved December 10, 2012 from
http://www.robotics.utexas.edu/simulations/images/FourBar.jpg

Note: The bars do not have to be the same length. The students may change the lengths of the various bars to get different effects.

Animations of types of four-bar linkages can be found at:
https://www.youtube.com/watch?v=Vh8r_Cpfb8Q shows movements of four bar linkages (1:59)

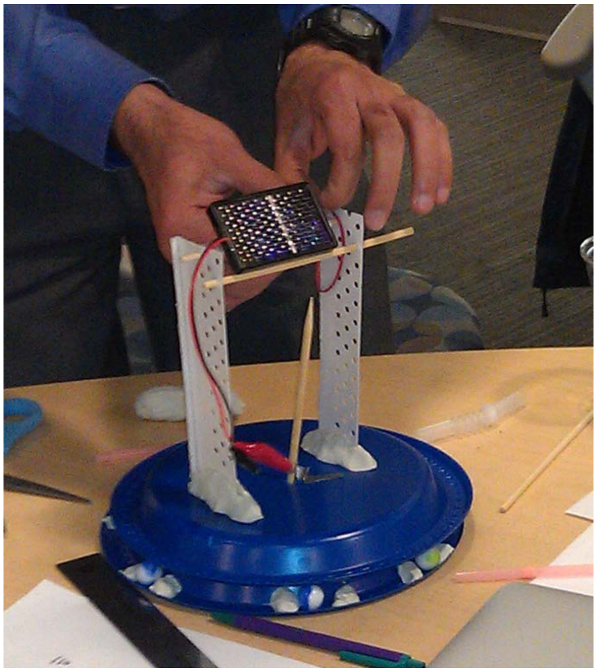
https://www.youtube.com/watch?v=AyII9xaAQ7M shows how four bar linkages can be used (1:36)
https://www.youtube.com/watch?v=wWvB3lNYXB0 animation of four bar linkage movement (1:26)
https://www.youtube.com/watch?v=k6UPBo9eems models of four bar linkages (2:16)

http://dynref.engr.illinois.edu/aml.html Website has interactive simulations allowing you to see the effects of changing the length of members as an animation. Also, several real world examples of four bar linkages are shown.

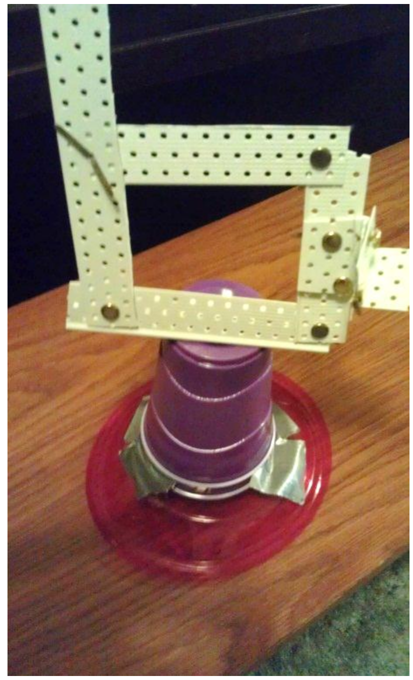
Possible Designs:

Example of a solar tracker utilizing ball bearings (marbles between clear plastic cups) and a four-bar linkage.

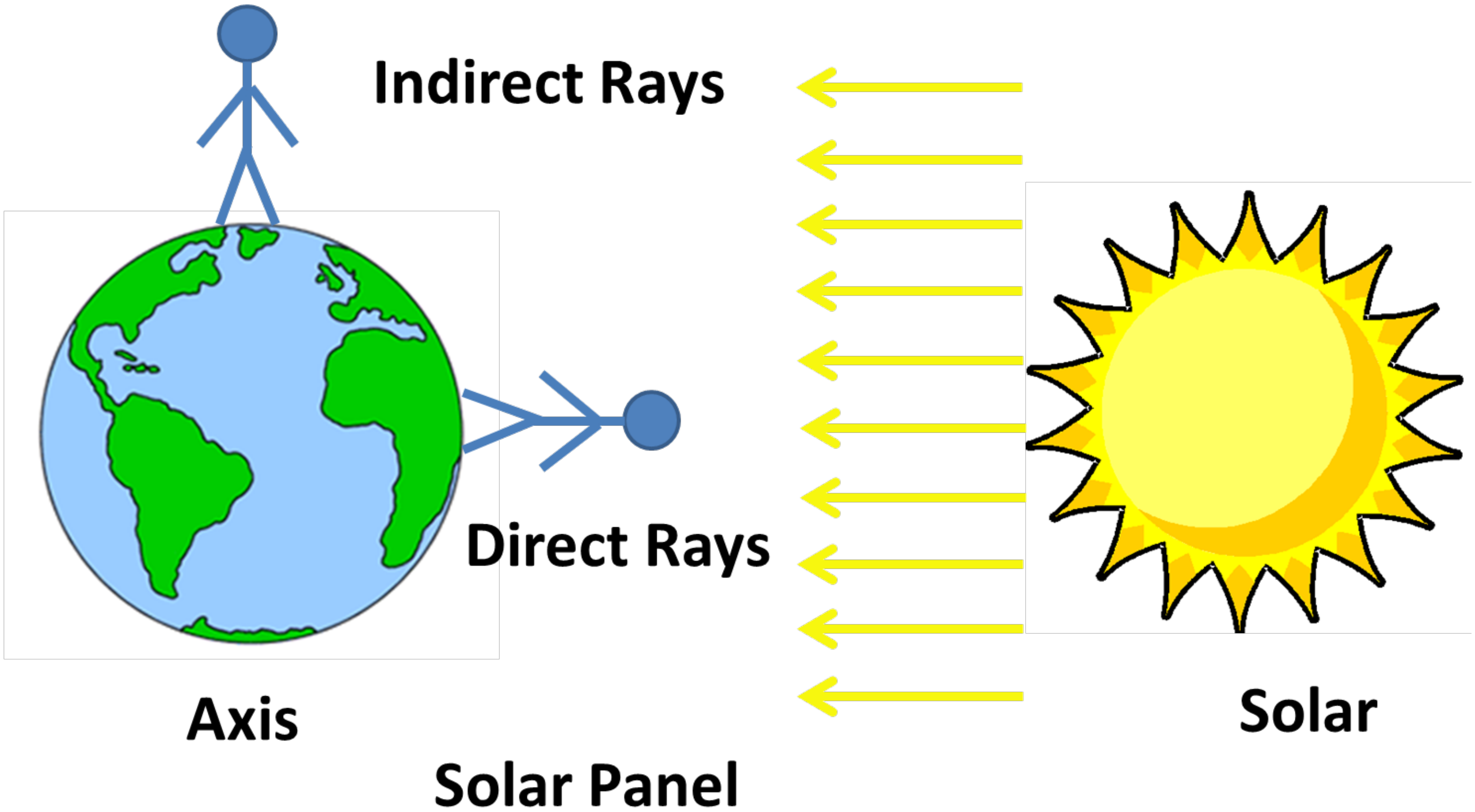
Example of a solar tracker utilizing a piece of foam with a solar panel attached to the top and a straw inserted into the bottom which slides over a wooden post inserted into a foam base.



Example of a solar tracker utilizing ball bearings (marbles between two plates) and a rotating shaft to provide vertical alignment.

Example of a solar tracker utilizing ball bearings (marbles between plastic cups) and a four-bar linkage. The solar panel is attached to the long vertical member.



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http://inchargefitnesscenter.com/wp-content/uploads/2011/07/yellow-sun.gif