

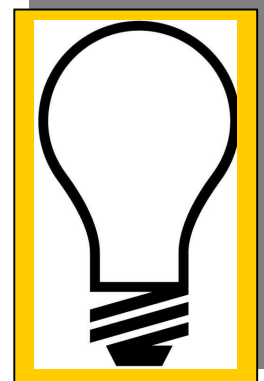
Dynamic Design: A Collection Process

Concentrate

TEACHER GUIDE

BACKGROUND INFORMATION

In this activity students will study the solar wind concentrator in the Genesis sample return capsule. They will then design a mirror model for the concentrator. The concentrator contains an entry grid that is positively charged to repel hydrogen ions. It also has a parabolic mirror grid to reflect the solar wind particles to the carbon vapor deposit gold-plated diamond target. Students will model the concentrator by using a plastic bowl lined with a reflective material (aluminum foil) for the mirror grid, polarized paper will represent the entry grid, a solar panel will represent the target, and a light bulb will provide “solar wind particles.” (Note: Light is not a perfect model for solar wind materials because solar wind is made up of different elements and ions. The purpose of this activity is to model the concentrator. As noted in the student text, photons are reflected out of the concentrator. After reading the text, students will describe how this model is limited.) Polarized paper is used to simulate the entry grid and can be manipulated such that only a certain amount of light gets into the concentrator.



NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

[Science as Inquiry](#)

Abilities necessary to do scientific Inquiry

[Physical Science](#)

Transfer of Energy

[Science and Technology](#)

Understanding about science and technology

Grades 9-12

[Science as Inquiry](#)

Abilities necessary to do scientific inquiry

[Physical Science](#)

Interactions of energy and matter

[Science and Technology](#)

Abilities of technological design

Understandings about science and technology

MATERIALS

For each group of three to four students:

- At least one small plastic butter container with lid
- Enough aluminum foil or other reflective material to line the bottom of the container
- Solar cell with light bulb
- Wire mesh with different sized holes or Polaroid film square (and IR filter)
- (Optional) Parabolic reflector demonstrator
- (Optional) Single rotator radiometer
- Light source (at least 100 watt)
- Student Text: [“The Concentrator”](#)
- (Optional) Student Activity: [“Hot Dog Cooker”](#)



PROCEDURE

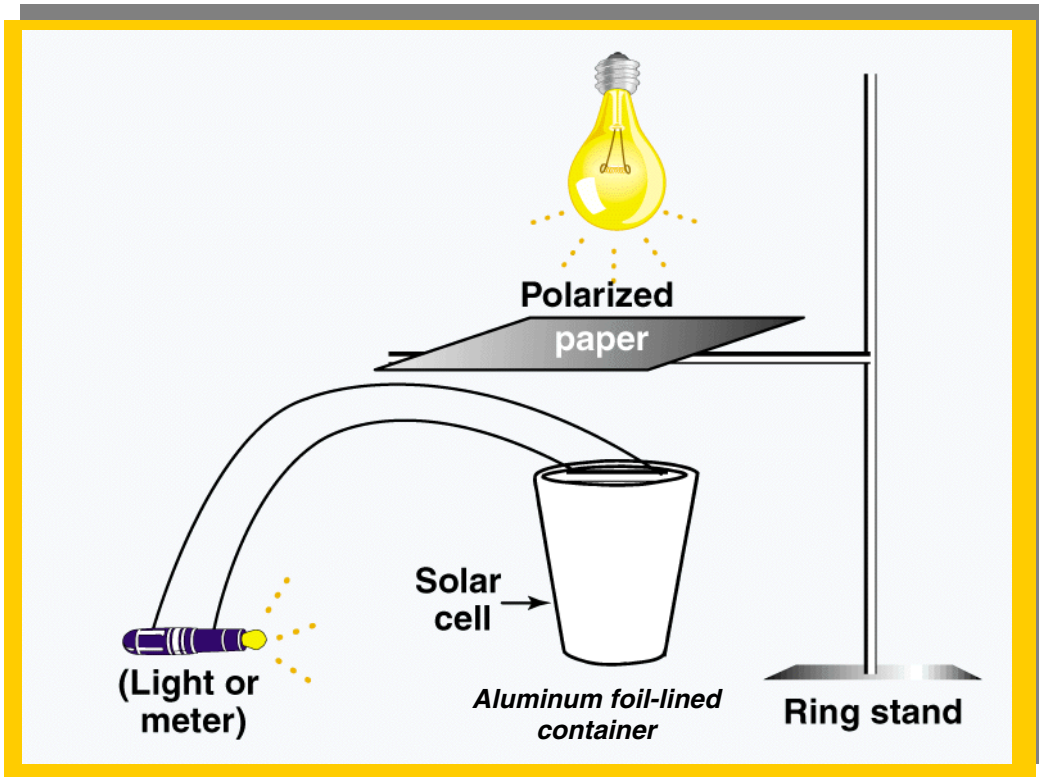
1. Ask students if they know the most common element found in the universe. Discuss potential answer. Explain that hydrogen is the most common element found in the universe, in the sun, and other stars.
2. Since solar wind is made up mostly of hydrogen, ask students, "What would be a method of separating the hydrogen from the other solar wind particles?" Allow students time in their small groups to discuss and present an answer to this question. Some students may choose filtering, or other "physical" means of separating the hydrogen from the other particles. Have the students read the student text, "The Concentrator."
3. Explain that the Genesis sample return capsule (SRC) will contain a concentrator that will repel the hydrogen ions (protons) and focus the remaining solar wind on a target. Explain that the concentrator will be using technology that has never been used before. This technology will enhance the ability of the Genesis scientists to learn about solar wind first-hand.
4. Tell students that they will design a concentrator that will model this process. Explain that the model will use a bowl-shaped container lined with aluminum foil to represent the mirror grid and polarized paper to model the entry grid. The solar cell will represent the CVD target material. Show the diagram of the concentrator and point out the different parts. (Optional) Also show how the parabolic reflector works by shining a light into the demonstrator.
5. Demonstrate the Polaroid® paper on the overhead projector for reviewing the process skills of observation and inference. Place two pieces of Polaroid® paper on the overhead projector side by side. Ask students to make two observations. Then place the Polaroid® paper one on top of the other such that the overlap is gray not black. Ask students to make two more observations. While the Polaroid® paper is overlapped, slowly rotate one of the papers until the overlapped section turns black. Ask students to make one more observation and an inference. Remind students that an inference is a logical explanation of an observation.
6. Make the supplies available for the students to complete the concentrator. Circulate around the room providing assistance for students who do not understand the procedure.

Alternate Strategy Tip

Constructing a solar cooker is a fun class activity. For a low-cost, step-by-step, illustrated set of instructions that include many common household materials, see the "[Hot Dog Cooker](#)" student activity.

Student Procedure:

1. Your group is going to design a model of a concentrator, using the supplies given.
2. Before you begin the model what decisions do you need to make?
 - How will you line the plastic container?
 - Which side of the aluminum foil will be facing up?
 - How smooth will the foil be?
 - Where will the solar cell be located?
 - How will the solar cell be suspended?
 - How will the Polaroid® paper be used? What other decisions need to be made?
3. Once your group is ready, start construction of the concentrator.
4. Use a light source to test how well your concentrator works. Then use the Polaroid® paper to manipulate the amount of light that enters the concentrator.
5. Try another type of reflective material or try the single rotator radiometer or try IR filters to model the concentrator.
6. Make a data table to record decisions and qualitative data observations from your model.
7. Once students have completed their models, have each group briefly demonstrate their model and explain the various components. Ask each group how having different technologies available affected their ability to collect light in a controlled manner.



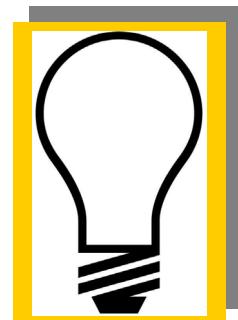
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Dynamic Design: A Collection Process

Concentrate

STUDENT ACTIVITY

In this activity your group will study the solar wind concentrator in the Genesis sample return capsule. You will then design a mirror model for the concentrator. The concentrator contains an entry grid that is positively charged to repel hydrogen ions and a mirror grid in the shape of a parabola to reflect the solar wind particles to the carbon vapor deposit gold-plated diamond target. You will model the concentrator by using a plastic bowl lined with a reflective material (aluminum foil) for the mirror grid, wire mesh, or polarized paper to represent the entry grid, a solar panel to represent the target, and a light bulb to model “solar wind particles.” (Note: Although light is not a perfect model for solar wind materials because solar wind is made up of different elements, the purpose of this activity is to model the concentrator.) Wire mesh or polarized paper is used to simulate the entry grid and can be manipulated so that only a certain amount of light gets into the concentrator.



PROCEDURE:

1. Your group is going to design a model of a concentrator, using the supplies given. First, read the Student Text, "[The Concentrator](#)."
2. Before you begin the model, what decisions do you need to make?
 - How will you line the plastic container?
 - Which side of the aluminum foil will be facing up?
 - How smooth will the foil be?
 - Where will the solar cell be located?
 - How will the solar cell be suspended?
 - How will the Polaroid® paper be used?
 - What other decisions need to be made?
3. Once your group has answered the above questions, gather the materials and start construction of the concentrator.
4. Use a light source to test how well your concentrator works. Then use the Polaroid® (or wire mesh) to manipulate the amount of light that enters the concentrator.
5. Try another type of reflective material for the mirror grid to model the concentrator.
6. Make a data table to record decisions and qualitative data observations of your model.
7. How is your model an accurate representation of the actual concentrator? How is it inaccurate?

**Dynamic Design:
A Collection Process**

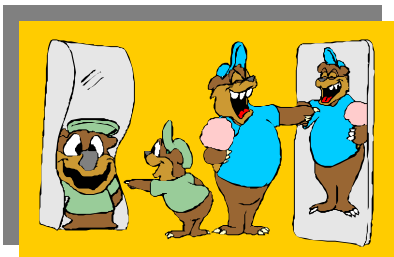
The Concentrator

STUDENT TEXT

The concentrator in the Genesis spacecraft will collect solar wind particles. This device will collect specific elements of solar wind. The concentrator is an electrostatic mirror that is designed to focus solar wind particles on a special chemical vapor deposit (CVD) diamond and silicon carbide surface. This will enable collection of a more dense concentration of oxygen and its isotopes.

MIRRORS

When light hits an object, three things can happen depending on the type of surface that it hits. Light can be transmitted through an object, absorbed into the object, or reflected away from the object. Mirrors are made of glass coated with silver that reflects light, allowing you to see your reflection. There are many shapes of mirrors. Think of a time when you were in a fun house and saw your image in a curved mirror. How did it make you look? Only gentle curves are needed to produce many different effects. The three most common mirror shapes are plane, concave and convex.

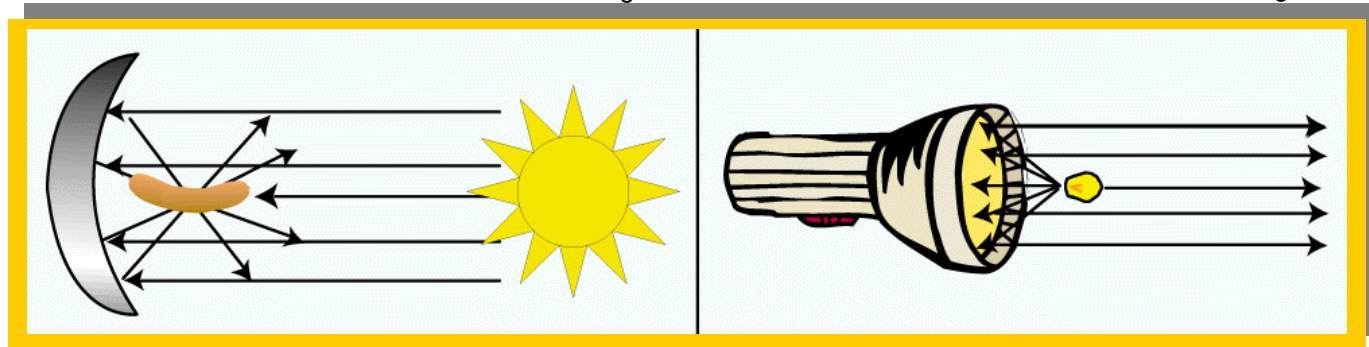


Plane mirrors have a flat surface and are the kind you might see in a bathroom. Convex mirrors have edges that are bent away from you and are used to make images appear larger. They are often found in stores and as rearview mirrors on cars or trucks. Concave mirrors have edges that are bent toward you and make images appear smaller. Concave mirrors are used to focus light to a point and are used in solar ovens (Figure 1) and flashlights (Figure 2). Solar radiation hitting the ground does not have a high enough density for cooking. But if radiation is concentrated into a small volume, then cooking temperatures can be reached quite easily. There are many techniques for constructing solar cookers.

To make your own solar cooker, see the Student Activity "[Hot Dog Cooker](#)." Solar cookers and flashlights both use concave mirrors but in opposite ways. A solar oven directs the light from the sun to the focal point to cook food. In a flashlight, the light at the focal point is reflected outward by the concave mirror behind the light bulb resulting in parallel light rays.

Figure 1

Figure 2



Solar cooker with hot dog at focal point

Flashlight with light bulb at focal point

To see an animated explanation of the physics of concave mirrors go to:

<http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/optics/ifcma.html>

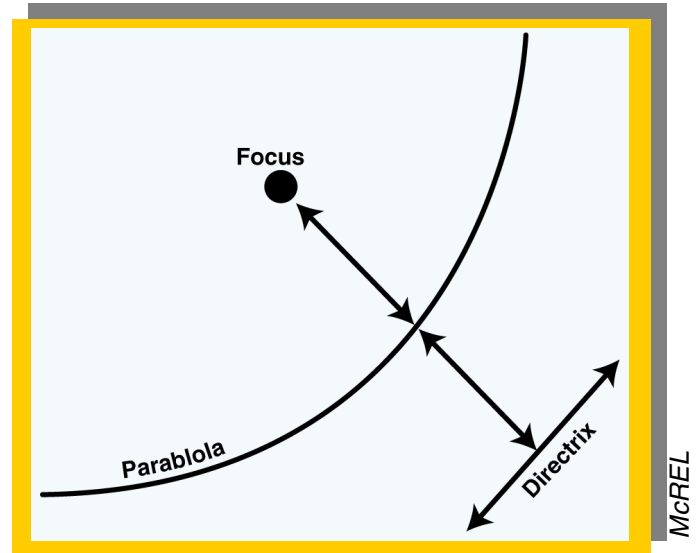


PARABOLAS

Concave mirrors are also known as parabolic mirrors. In a plane, any curve consisting of a set of points equidistant from a line and a point not on the line is a parabola. On the diagram at right the line is called the directrix, and the large dot is called the focus. The standard equation of a parabola is $y = x^2$. A paraboloid is a three dimensional parabola. A simple example of a paraboloid is the concave side of a spoon.

Parabolic mirrors are used in many instruments; some include reflector telescopes, spectrometers, and lasers as well as flashlights and solar ovens. One common use is in satellite dishes. The purpose of a satellite dish is to collect a signal from a satellite and focus it onto a receiver. From physics it is known that the angle of incidence is equal to the angle of reflection. The paraboloid is a good shape for a satellite dish because its surface reflects the incoming signal to the receiver from every point on the dish surface. Every signal from the satellite that strikes the dish and is reflected to the focus travels the same distance regardless of where it strikes the dish. This assures that all signals reach the focus "in phase" and do not interfere with each other.

Figure 3



THE CONCENTRATOR

Figure 4



The job of the concentrator on the Genesis sample return capsule is to repel hydrogen protons and to enhance the density of heavy ions, particularly oxygen that will be collected. The concentrator (see Figure 6) is made up of three basic components: the entry grid, the mirror grid, and the target material. The entry grid is made up of three layers. The entry grid repels protons and straightens the trajectories of heavier ions. How would you design a grid that would repel protons and allow other solar wind ions to enter? Why would the Genesis scientists want to repel protons? (HINT: Most solar wind is made up of...) The entry grid is made up of three entry grids that are convex and attached by an "embroidery hoop" around the circumference. Once through the entry grid, the ions are straightened before being reflected by a parabolic mirror.

The second component, the mirror grid, is made up of 30 pie-shaped sections that have a backing plate underneath them. The mirror grid has an electrode surface under each mirror that reflects the ions toward the target. The electrode surface consists of a series of micro-steps that reflect photons out of the concentrator so that the sun's light does not hit the target.

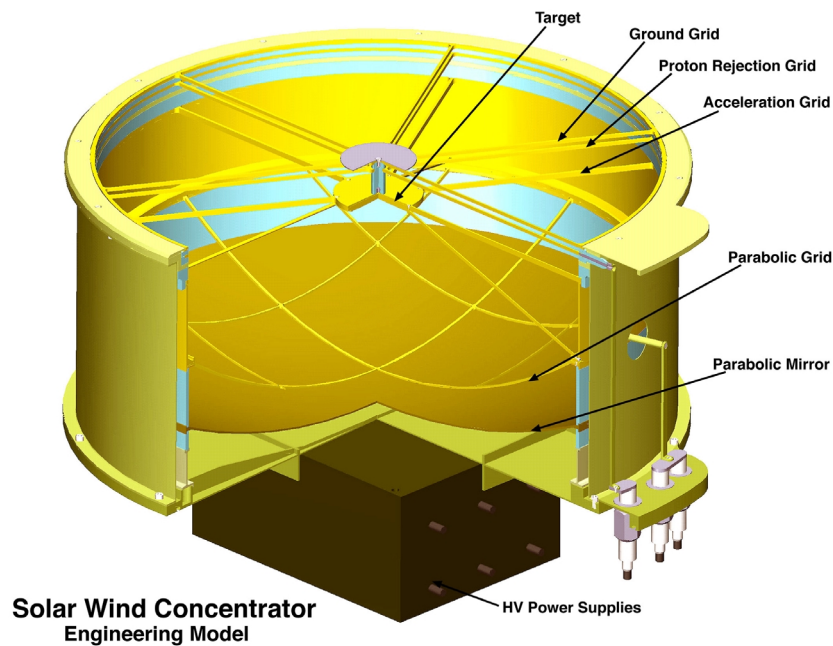
The third component, the target, is made of CVD diamond film that was specially designed for the Genesis mission. Concentrator models were tested at the University of Bern, California Institute of Technology, and Los Alamos National Laboratory. One test used 50 million trajectories to map ions to ensure the proper focal length for the target. The concentrator will provide for a more specific type of solar wind to be brought back to Earth for analysis. Discuss with your group how this new technology and design will enable scientists to study the solar wind in ways that have never been done before.

Figure 5





Figure 6: Labeled Diagram of the Concentrator



Los Alamos National Laboratory

After reading about the Genesis concentrator, make the model as described in the laboratory procedure. When you finish, think about what aspects of the model that you made are accurate representations of the actual concentrator? How is it inaccurate?

RELATED WEB SITES

<http://accept.la.asu.edu/PiN/opticskit/expt/expt9.shtml>

Optics Discovery Kit Experiment #9: MIRRORS

<http://forum.swarthmore.edu/dr.math/problems/miyasaki6.3.97.html>

Parabolic Mirrors and Telescopes

<http://mathcentral.uregina.ca/RR/database/RR.09.95/weston1.html>

Why are satellite dishes parabolic?

<http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l3a.html>

Physics Classroom Reflection Lesson

<http://solarcooking.org/plans.htm#parabolic-style>

Procedures for making your own solar cooker

<http://www.jyu.fi/~hvirtane/con1.html>

Procedures for making your own solar cooker

**Dynamic Design:
A Collection Process**

**Parabolic Problem
Algebra Enrichment**

TEACHER GUIDE

BACKGROUND

For students to be successful with this enrichment activity, they should have had previous experience with the following algebraic concepts: square roots, exponents, graphing on a Cartesian grid, the distance formula, and multiplying binomials.

A cross-section of the mirror grid in the Genesis solar wind concentrator is a parabola. A parabola is a curve consisting of all points equidistant from a line called the directrix and a point called the focus. One way to determine the equation of a parabola is to use the distance formula. In this mathematics enrichment activity, students determine the equation for a parabola and graph the parabola using measures similar to that of the Genesis concentrator. Students work backwards compared with the Genesis designers. In the mission, the designers worked to find the location of the focus from the parabolic shape of the concentrator. The focus on the Genesis concentrator is about 20 cm from the vertex of the parabola. In this problem the focus is given and the students will graph the resulting parabola.

NATIONAL MATH STANDARDS ADDRESSED

Grades 9-12

Mathematics Standard: Mathematics as Problem Solving

Apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics. Apply the process of mathematical modeling to real-world problem situations.

Mathematics Standard: Functions

Model real-world phenomena with a variety of functions. Represent and analyze relationships using tables, verbal rules, equations, and graphs. Recognize that a variety of problem situations can be modeled by the same type of function.

(View a full text of the [National Math Education Standards.](#))

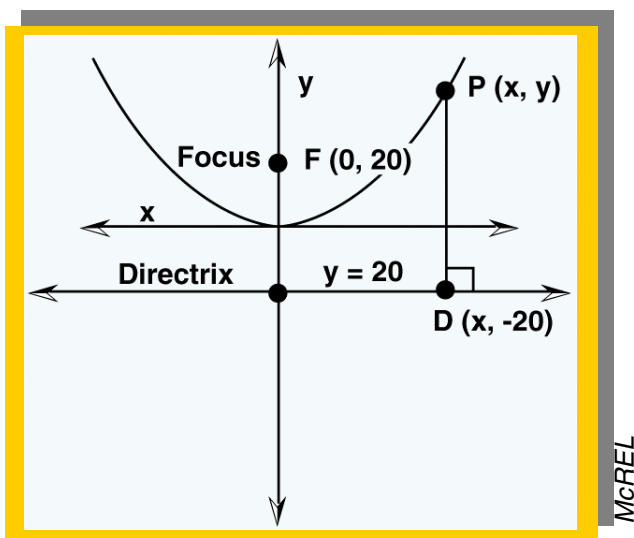
MATERIALS

- Graph paper
- Paper, pencil
- Pipe cleaners and clay
- Calculator (optional)

PROCEDURE

1. Set the scenario by reading the background information with students. Allow students to determine the distance between two points by using the distance formula or by other means. Let students explore to find out how to solve the problem. Below is one way to solve the first part.
2. The distance between two points can be determined by using the distance formula. If P_1 is (x_1, y_1) and P_2 is (x_2, y_2) then the distance between them is :

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$



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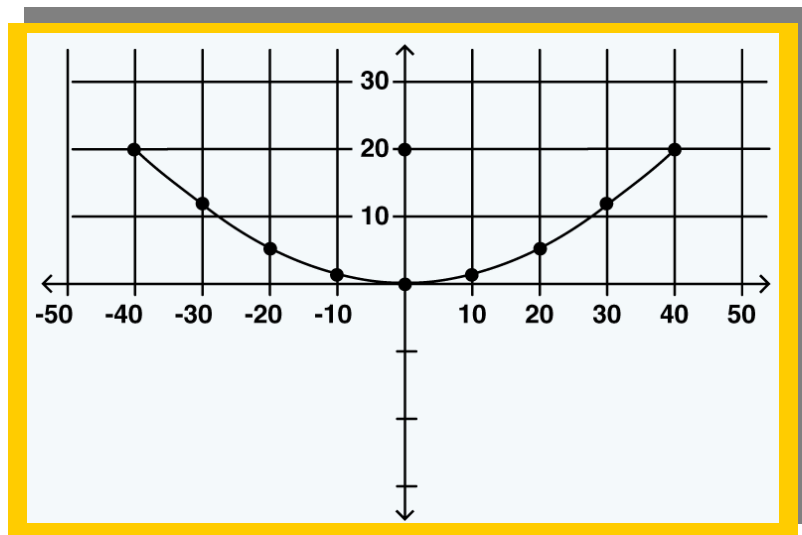
3. The target on the concentrator is about 20 centimeters from the vertex of the parabola. This can be stated as $F(0,20)$, the directrix is $y = -20$, $P(x,y)$ is any point on the parabola, and $D(x,-20)$ is the point where the perpendicular line through point P to the directrix intersects the directrix. (See figure 1) Find the equation of the parabola.

Figure 1

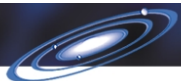
Line A	$\overline{PF} = \overline{PD}$
Line B	$\sqrt{(x-0)^2 + (y-20)^2} = \sqrt{(x-x)^2 + (y-(-20))^2}$
Line C	$(x-0)^2 + (y-20)^2 = (x-x)^2 + (y-(-20))^2$
Line D	$x^2 + (y-20)^2 = (y+20)^2$
Line E	$x^2 + (y-20)(y-20) = (y+20)(y+20)$
Line F	$x^2 + y^2 - 40y + 400 = y^2 + 40y + 400$
Line G	$x^2 = 80y$
Line H	$y = x^2 / 80$

4. Using this information, graph the parabola: $y = x^2 / 80$. Encourage students to fill in the T-chart with values for several points (x,y) on the parabola that can be found.

x	y



5. Using pipe cleaners, make a model of the parabolic curve. Make the model three-dimensional by using three pipe cleaners bent to the shape of the parabola. (Join them at the vertex).
6. Use clay to make a three dimensional model of the paraboloid.



EXTENSION

With an understanding of calculus, students may:

1. Find the area under the curve.
2. Find the surface area of part of the paraboloid.
3. Find the volume of part of the paraboloid.

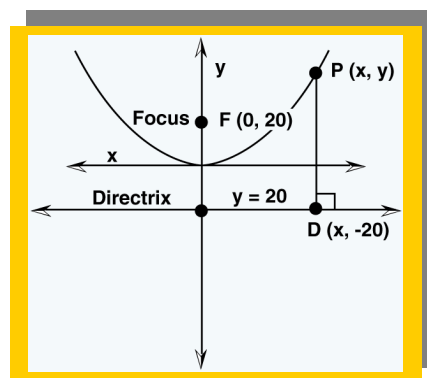
**Dynamic Design:
A Collection Process**

**Parabolic Problem
Algebra Enrichment**

STUDENT ACTIVITY

BACKGROUND

A cross-section of the mirror grid in the Genesis solar wind concentrator is a parabola. A parabola is a curve consisting of all points equidistant from a line called the directrix and a point called the focus. One way to determine the equation of a parabola is to use the distance formula. In this mathematics enrichment activity, students determine the equation for a parabola and graph the parabola using measurement similar to that of the Genesis concentrator.



MATERIALS

- Graph paper
- Paper, pencil
- Pipe cleaners and/or clay
- Calculator (optional)

PROCEDURE

1. The distance between two points can be determined by using the distance formula. If P_1 is (x_1, y_1) and P_2 is (x_2, y_2) then the distance between them is :

$$\text{Distance between } P_1 \text{ and } P_2 = d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

2. Suppose the focus of the concentrator is located at $F(0, 20)$, the directrix is $y = -20$, $P(x, y)$ is any point on the parabola, and $D(x, -20)$ is where the perpendicular line joining the directrix and point P intersect the directrix. Find the equation of the parabola.
3. Using the equation fill in a T chart.
4. Using this information graph the parabola.
5. Using pipe cleaners make a model of the parabolic curve. Make the model three-dimensional by using three pipe cleaners bent to the shape of the parabola. (Join them at the vertex.)
6. Use clay to make a three-dimensional model of the paraboloid.

x	y

EXTENSION

With an understanding of calculus you may:

1. Find the area under the curve.
2. Find the surface area of part of the paraboloid.
3. Find the volume of part of the paraboloid.

**Dynamic Design:
A Collection Process**

Hot Dog Cooker

STUDENT ACTIVITY

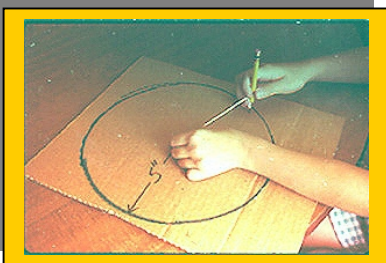
There are many techniques for constructing solar cookers. A reflective hot dog cooker can be built from materials that are often found in the home, including cardboard, aluminum foil, masking tape, wire, and poster board. In this cooking method, sunlight hits the reflective surface and focuses on the hot dog held in the center. Basic materials, instructions, and illustrations for building a solar hog dog cooker are listed below.

MATERIALS

1. Two pieces of heavy cardboard (like the side of a cardboard carton). The first piece must be at least ten inches square and the second smaller piece must be at least four inches by five inches.
2. A piece of light posterboard eight inches wide and sixteen inches long.
3. Twelve-inch wide aluminum foil. (You will use about 32 inches of the material.)
4. Some masking tape. (You may experiment with other types of tape.)
5. Nine inch long sticks about 1/16 inch in diameter. You may also use lengths of heavy wire. (At your local grocery store in the international food section you may find small bamboo sticks used to make shish kebobs and imported from Japan. These are inexpensive and will do the job.)
6. Four one inch long spreading brass brads.

INSTRUCTIONS

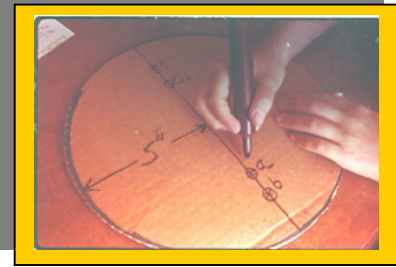
To make this special solar energy cooker, do each step. As you finish each step, put a check mark in the space ahead of the instruction. Make sure you also look at the photograph that goes with the step or steps. Have fun and here we go.



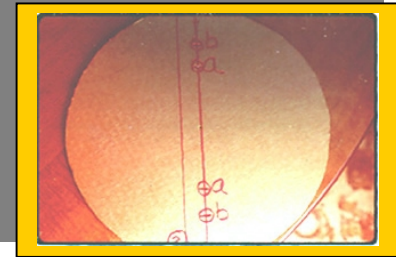
1. Using a large compass or a string and pencil, lay out a ten inch diameter circle on the larger piece of heavy cardboard. Cut out this circle using a large scissors or a sharp knife.



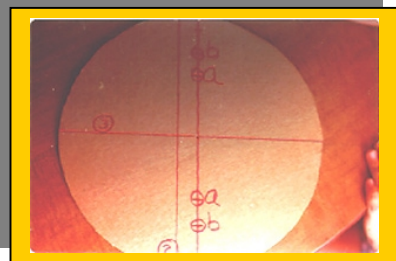
2. Draw a straight line (line "1") through the center pinhole in the cardboard, (a line along the diameter of the circle).



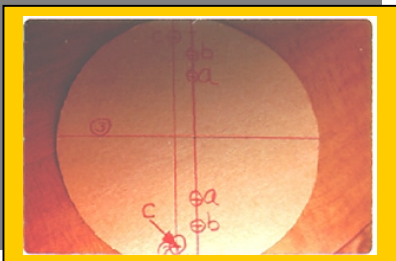
3. Mark off points at 2-1/2 inches (hole "a") and 3-1/4 inches (holes "b") on either side of the centerpoint along the straight line you just have drawn.



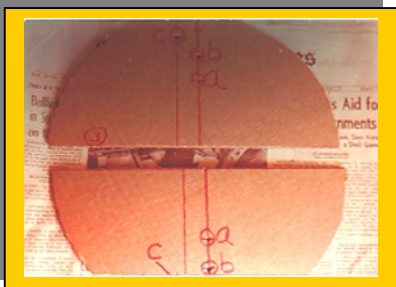
4. Draw a straight line (line #2) 3/4 inch on one side of the straight line through the center.



5. Draw a line that goes at right angles to the lines you have drawn and through the center hole (line #3).



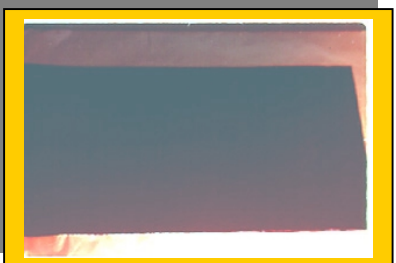
6. Mark off holes that are 4-1/4 inch (holes "c") on line #2 from line #3.



7. Using an ice pick or other sharp instrument, punch out the holes "a," "b," and "c".

8. Using a sharp knife or razor blade, cut along line #3 so that the cardboard circle is cut in half.

9. Put the cardboard semicircles to one side now and get your piece of posterboard. (It should already be eight inches wide and sixteen inches long.)



10. Take a piece of aluminum foil that is about 18 inches long (and, of course, twelve inches wide).

11. Lay the shiny side of the foil down on the table and put the piece of posterboard on top of it - center the board so there is roughly an equal amount of foil sticking out on all sides.



12. Fold the aluminum foil over the posterboard so that the side of the board facing down on the table will be foil covered. Put a few pieces of masking tape at the corners and along the sides to hold the foil securely in place. Put the foil covered posterboard to one side for a moment.



13. Take the two half circles of heavy cardboard. These will be the sides of the hot dog cooker. Hold them up for a moment so that you can see how the holes line up.
14. Mark the sides of the half circles that are on the outsides away from where the hot dog will be, with an "O" (for the "outside," of course!).
15. Mark the other sides with an "I" (you guessed it - for "inside!").



16. Get two more pieces of aluminum foils that are about seven inches long (of course, again, twelve inches wide). Lay one of the piece~ down on the table, shiny side down, as you did with the larger piece of foil.
17. Put one of the half circles with the "I" (inside) side down onto the foil (the "O" side will be up). Again, center the piece of cardboard on the foil.



18. Fold the foil over the cardboard and tape the foil to hold it.
19. Make sure you find the "a," "b," and "c" holes and poke the through the foil.
20. Do the same thing with the other half circle of cardboard so that it is also foil covered on the inside surface.

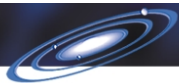
Now, we will assemble the back and sides of the cooker.



21. Lay the aluminum-covered posterboard down on the table with the aluminum-covered side up.
22. Take one of the aluminum-covered half circles. Hold it so that the aluminum-covered side faces in towards the aluminum cover on the posterboard, and also so that the outside edge of the half circle (where it was cut along line 3) lines up with the edge of the posterboard.



23. Put a piece of tape from the posterboard to the cardboard so that the cardboard half circle stands up on the aluminum-covered posterboard.
24. Now roll the aluminum-covered half circle along the edge of the aluminum-covered posterboard, putting a piece of tape every two or so inches as you go. Make sure there is a snug fit between the aluminum half circle side and the foil covered back posterboard.



25. Continue until the half circle (with the aluminum foil on the inside) is attached to the aluminum foil-covered posterboard. (This will make one end of a trough.)



26. Now attach the other foil-covered cardboard half circle, with the aluminum-covered side facing in, to complete the trough. Use a similar technique as you did with the other piece of cardboard using tape every two or so inches.



27. Put the trough to one side.

We are almost done now !



28. Take the small piece of heavy cardboard (four inches by five inches) and draw a line (line 4) down the center along the five-inch length.



29. Draw a straight line one inch on each side of line 4 (lines #5).

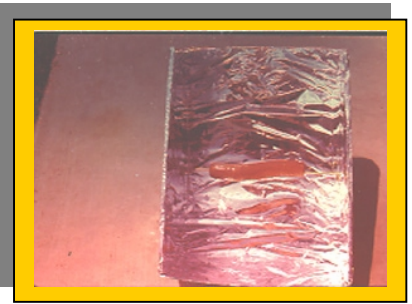


30. Mark off points one-half inch and 1-5/8 inches along line 5 from one end of the cardboard (holes "d").



- _____ 31. Punch out holes "d" using an ice pick or sharp instrument.
- _____ 32. Using a sharp knife or razor blade, cut along line 4 so that you have two pieces of cardboard, each two by five inches.
- _____ 33. Put two brass brads from the inside of the trough through holes "b" and "c," and through holes "d" on the two-inch by five-inch piece of cardboard. Spread the brad so that the rectangular piece of cardboard is securely attached to one side of the cooker.
- _____ 34. Do the same thing on the other side of the cooker with the remaining piece of two-inch by five-inch cardboard.

These pieces of cardboard act as legs to prevent the hot dog cooker from just rolling around on the table, and now you are ready to start cooking!



- _____ 35. Slide the stick from the outside in through one of the "a" holes.
- _____ 36. Hold the hot dog so that as you slide the stick further in through the "a" hole, you also put the stick through the length of the hot dog.
- _____ 37. Continue until the stick is completely through the hot dog. Then, put the stick about one-fourth inch through the other "a" hole so that the stick and hot dog are supported at both ends. Center the hot dog on the stick.



- _____ 38. In summer, stand the cooker so that the opening looks more upward and, if winter, turn the cooker over so that the opening faces more downward.



- _____ 39. Aim the hot dog cooker toward the sun. It will take about 45 minutes to one hour, and then ... HAPPY HOT DOG EATING! Note: You can shorten your cooking time by stretching a piece of clinging plastic wrap over the whole front of the cooker after the hot dog is on the stick. This will keep the hot dog from cooling down as the wind blows over it.

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