All About the Sun

Effects of the Sun on Our Planet

Supplemental science materials

for grades 9 - 12

Stanford SOLAR Center

These supplemental curriculum materials are sponsored by the Stanford SOLAR (Solar On-Line Activity Resources) Center. In conjunction with NASA and the Learning Technologies Channel.

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Teacher Overview

- Objectives
- Science Concepts
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Teacher Overview

Objectives

- Students will observe how technology (photovoltaic cells) can enhance the solar energy Earth receives.
- Students will develop an understanding of the importance of the Earth's Magnetosphere.
- Students will observe the effects of the sun's energy on the Magnetosphere.
- Students will develop an understanding of the various solar phenomena (flare, coronal mass ejections or CME, radiation) and their effect on the sun's output of radiant energy.
- Students will observe the effects of various solar phenomena (flare, coronal mass ejections or CME, radiation) on the Earth.
- Students will recognize the difference between true north and magnetic north.
- Students will develop an understanding of how solar cells convert solar energy to electricity.

Science Concepts

- Solar energy can be converted to other forms of energy such as electricity and food.
- A solar scientist studies the effects of the sun's energy on the Earth using various instruments.
- Solar phenomena such as solar flare, coronal mass ejection (CME), and radiation affect the Earth's magnetosphere by disrupting radio communication, shortwave operation, compass readings, space satellites, telecommunications satellites, prospecting equipment, navigation equipment, etc.
- The Earth's magnetosphere is integrally connected to solar activity and human technological usage.
- The Earth's magnetosphere is affected by magnetic storms from the sun.
- The sun gives off electromagnetic energy that affects the Earth's atmosphere.

Teacher Overview

Correlation to the National Science Standards

This segment of the Webcast *All About the Sun,* "Effects of the Sun on Our Planet", is brought to you by a correlation to the National Science Standards for grades 9 - 12 as delineated below.

Grades 9 - 12

Unifying Concepts and Processes

- Systems, order and organization
- Evidence, models and explanation
- Change, constancy and measurement

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Ask a question about objects, organisms, and events in the environment
- Plan and conduct a simple investigation
- Employ simple equipment and tools to gather data and extend the senses
- Use data to construct a reasonable explanation
- Communicate investigations and explanations
- Understandings about scientific inquiry

Physical Science

- Structure and properties of matter
- Motions and forces
- Interactions of energy and matter

Earth and Space Science

- Energy in the Earth system

Science and Technology

- Abilities of technological design
- Identify a simple problem
- Propose a solution
- Implementing proposed solutions
- Evaluate a product or design
- Communicate a problem, design and solution
- Understandings about science and technology

Correlation to the National Science Standards (continued)

Science in Personal and Social Perspectives

- Science and technology in local, national and global challenges

History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Teacher Overview

Segment Content/On-line Component Review

Teacher Overview

Materials List

Science Exploration

- **Now We're Cookin'!**
  Note: The materials listed need to be gathered in large enough amounts to be used by entire class as per each group's decision on their design for a solar cooker.
  - aluminum foil
  - small mirrors
  - clear and dark glass jars
  - shoe boxes
  - lightweight wire
  - toothpicks
  - cardboard
  - tape
  - plastic wrap
  - reflecting material

- **Parabolic Solar Collectors**
  - Directions: See section **Student Handouts,** Student Guidesheet: *Constructing a Parabolic Solar Collector*
  - Parabola maker (see directions above)
  - graph paper
  - tape
  - heavy cardboard
  - aluminum foil
  - white glue
  - small nut and bolt
  - wood strips 3 – 5 cm wide, 50 – 100 cm long

- **Wavelength and Solar Cells**
- Various types of solar cells (silicon, cadmium sulfide, selenium, etc.)
- Voltmeter or multimeter (0-1 volt range)
- Incandescent lamp
- Different types (colors) of filters: blue, green, yellow, red, infrared, yellow-green infrared blocking filter

- **What I can do with Solar Energy!**

Note: Materials will vary based upon students' designs.

Materials List (continued)

Science Exploration

- **Riding a Radio Wave**
  - Student Observation Chart
  - AM Radio

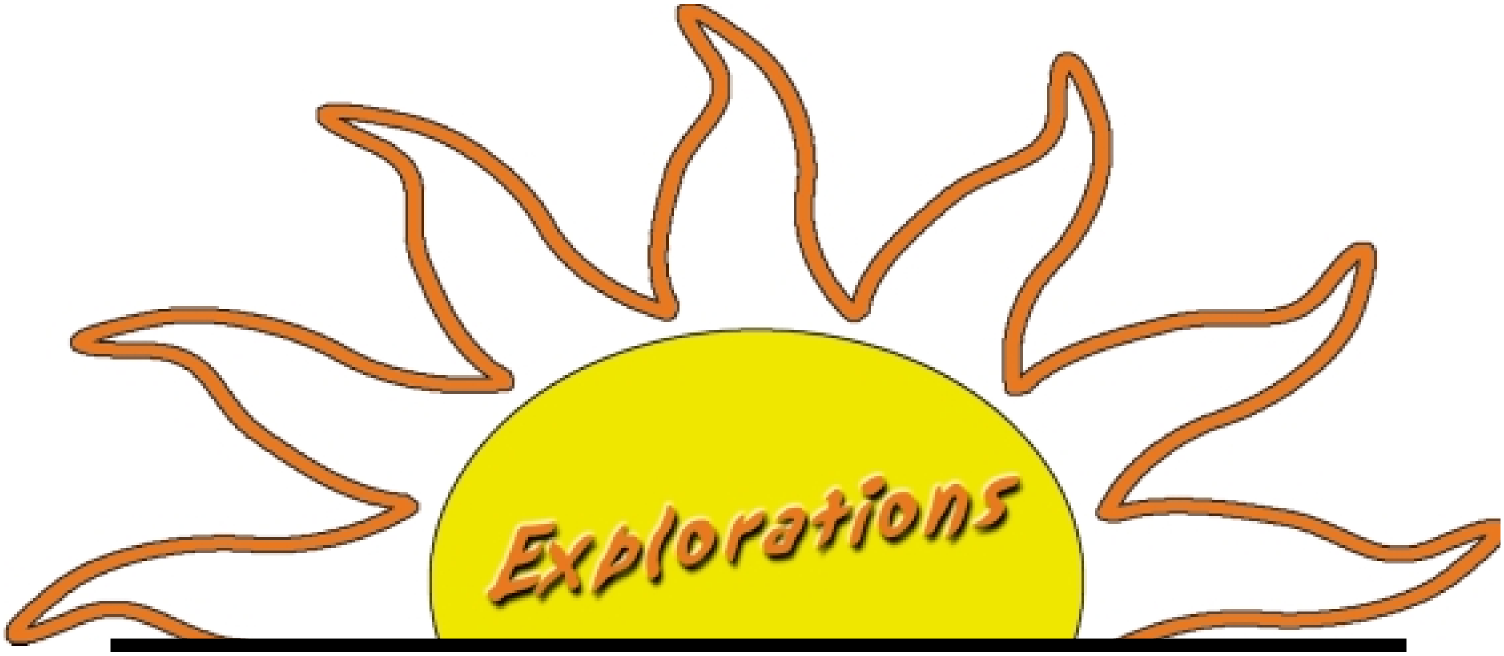
- **AM Radio Ionosphere Station**
  - AM radio with a tuner knob and a volume control know
  - Paper disk with a hole punched in its center to fit over the volume control
  - AM Radio Information Sheet (from the Web site given below.) http://image.gsfc.nasa.gov/poetry/workbook/p39.html

- **Magnetic Field**
  - 3 inch Styrofoam ball
  - 20 ft. of fine insulated copper wire
  - 1.5 volt dry cell
  - very fine iron filings
  - large sheet of paper

- **Soda Bottle Magnetometer**
  - One clean 2 liter plastic soda bottle
  - 2 pounds of sand
  - 2 feet of sewing thread
  - one small bar magnet
  - one 3 x 5 index card
  - a one inch piece of drinking straw
  - a mirrored dress sequin or small craft mirror
  - Superglue
  - 2 inch clear packing tape
  - a meter stick
  - an adjustable high intensity lamp with a clear bulb (not frosted)

- **Magnetism and the Sun**
  - Refer to the Web site given below for a series of magnetism explorations with a variety of materials.

    http://solar-center.stanford.edu.magnetism



Science Explorations

- Now We're Cookin'!
- Parabolic Solar Collectors
- Wavelength and Solar Cells
- What I Can Do with Solar Energy
- Riding a Radio Wave
- AM Radio Ionosphere Station
- Magnetic Field
- Soda Bottle Magnetometer
- Magnetism and the Sun
- Prospects are good

Career Explorations

- Solar Scientist

Science Explorations

- **Now We're Cookin'!**

  Purpose: Students will use the process of technological design to create a "solar-powered" method to cook a thin slice of hotdog meat. Students will also develop an understanding for how the technological design process works to solve problems and affect our lives in a positive way.

  Activity description:
  Given a choice of materials listed below, students will design a "solar cooker" that will cook the quarter-inch thick, slice of hotdog in the quickest amount of time possible. Use the *Science Exploration Guidesheet: Now We're Cookin'!* from the **Answer Keys** section as students process through this exploration. This guidesheet will provide students with background information on solar energy and the technological design process from which they can derive and test their designs.

  Materials: aluminum foil, small hand-sized mirrors, large jars with lids, small shoebox-sized boxes, lightweight wire, toothpicks, pieces of cardboard various sizes, tape, plastic wrap, and any other which the students and teachers can safely consider for use.

- **Parabolic Solar Collectors**

  Purpose: To build a parabolic solar collector and demonstrate uses of the sun's energy for practical tasks.

  Activity description:
  Follow the procedures listed on the Student Guidesheet: *Constructing a Parabolic Solar Collector.* Upon completion of its construction, place it in the sun with a thermometer at its center, and every hour take a temperature reading. Next place either a slice of hot dog, apple or a small marshmallow on a skewer and cook it. Time the cooking process. Other suggestions might be to cook the same type of food at different times of the day, time the process and compare. Or develop a mechanism to angle the parabolic collector so that it follows the sun's path during the day giving maximum cooking temperature all day.

Science Explorations (continued)

- **Wavelength and Solar Cells**
  Purpose:
  To ascertain whether the voltage produced by a solar cell will vary with the wavelength of light incident upon it.

  Activity description:
  The basic procedure is to set up the solar cell, lamp and voltmeter with the lamp and cell in a fixed distance and position. Measure the voltage using the series of filters, then plot the voltage versus wavelengths. Have students determine the optimum wavelength for a particular solar cell. Or have students determine the spectral response for different types of solar cells.
  The spectral response of the solar cells varies with incident wavelength as well as due to the nature of the cell. Because it is beyond the scope of this activity, we know that the response of solar cells is zero beyond 12,000A. Because the absorption of the photons is too deep within the cell, below about 4000A the absorption is too near the surface and response is nearly zero. The optimum wavelength lies somewhere in between.

- **What I Can Do with Solar Energy**

  Purpose: Students will use the process of technological design to create a "solar-powered" method to perform a routine task or solve a problem. They will develop an understanding of how solar cells convert solar energy to electricity and how that energy can be used in the technological design process. Students will also develop an understanding for how the technological design process works to solve problems and affect our lives in a positive way.

  Activity description:
  For this activity the teacher will need to purchase enough solar cells and peripherals to engage each student group in their particular design pursuit. Or after a brief exhibition by the teacher or a guest speaker of what solar cells are, how they work and ways in which they can be used, students can simply follow the *Science Exploration Guidesheet: What I Can Do With Solar Energy* from the **Answer Keys** section and develop their solar design on paper only.

Science Explorations (continued)

- **Riding a Radio Wave**
  Purpose:
  Students will observe a difference in clarity and strength of radio signals received when comparing daylight and nighttime reception.

  Activity description:
  Place an AM radio in an appropriate area of the classroom where it will receive good reception. Divide the class into small groups and assign each group a bandwidth to survey (for example 500 – 600, 1400 – 15000) or as a class choose one section of the AM band to survey once an hour. Assign each group a time each hour (3 minutes maximum) during which they monitor their assigned band's reception. Adjust the volume to a reasonable listening level. Each hour of the day have the class or small groups survey the chosen bandwidth and note each radio station's call sign and call number. Have the students arbitrarily rate the station's reception for clarity and strength with an agreed upon rating system (such as weak, good, strong, or very weak, weak, audible strong, very strong). Also have the students note where within there area they receive steady or sporadic static (and have them describe the static). Use the graph provided in the **Student Handouts** section or have the students design their own graph with which to record their observations. (Note: If possible once an hour check the Web site given below for current solar and magnetosphere activity. This information can then be used to verify the type of reception being observed. Also, have the students locate each signal's source on a map and determine the distance from the area.

  http://www.set.noaa.gov/today.html

  http://solar-center.stanford.edu (for daily solar images)

  For homework have the students make 2 – 6 observations for their assigned AM band section during the night time hours and record their observations.

  During the next class session, have students in small groups discuss their findings, comparing nighttime reception to daytime reception. Ask them to hypothesize about any differences or anomalies they observed. Encourage them to include in their hypothesizing local weather data concerning electrical storms as well as solar activity data from the Web site given above.

Science Explorations (continued)

- **Riding a Radio Wave (continued)**
  Teacher Notes:
  Students should find that radio reception improves during the night time hours due to less direct solar energy entering the earth's atmosphere on the night side of the Earth. This solar energy would affect pulsations of loudness as well as steady static. Sporadic static can be accounted for through electrical storms in proximity to the radio signal's place of origin.

  This project could continue as a once a week activity for a longer period of time. When compared with solar activity information gathered on those same days, the students will be able to clearly perceive a correlation. Also, keeping track of electrical storms that occur within proximity, students will also be able to note a correlation to possible sporadic crackles and popping noises heard during their observations.

- **AM Radio Ionosphere Station**
  Purpose: Students will construct an Ionosphere Monitor by using an AM radio to track solar storms and other changes in ionosphere reflectivity.

  Activity Description:
  For this activity we refer you and your students to the Web site given below. Students can either design their own method of rating the loudness or follow the instructions available on the Web site. This activity is similar to *Riding a Radio Wave* (Science Exploration described above).

  http://image.gsfc.nasa.gov/poetry/workbook/page10.html

  http://image.gsfc.nasa.gov/poetry/workbook/p39.html

- **Magnetic Field**
  Purpose: Students will construct a device to illustrate how particles can be trapped in a magnetic field.

  Activity description:
  Step 1: Punch a small hole through the center of the Styrofoam ball (Do not make it over one-quarter inch in diameter.)

  Step 2: Feed the fine insulated wire through the hole forming continuous loops around the Styrofoam ball. (Vary the size of the loops making some half of the ball's diameter and some twice the ball's diameter.)

Step 3: Leave both ends of the wire free, extending about 6 inches from each pole. Remove the insulation at each end of the wire.

Step 4: Attach 1.5 volt dry cell to the ends of the wire.

Step 5: Place this assembly on a large sheet of paper and sprinkle fine iron filings through the loops.

Step 6: Record and discuss your observations.

Step 7: Place a compass near the loops. Move the compass from pole to pole.

Step 8: Record and discuss your observations.

- **Soda Bottle Magnetometer**
  Purpose: Students will create a magnetometer to monitor changes in the earth's magnetic field for signs of magnetic storms.

  Activity description:
  For this activity we refer you and your students to the Web site given below.

  http://image.gsfc.nasa.gov/poetry/workbook/page9.html

- **Magnetism and the Sun**
  Purpose: Through this activity students will learn the basic principles of magnetism and how they apply to the sun.

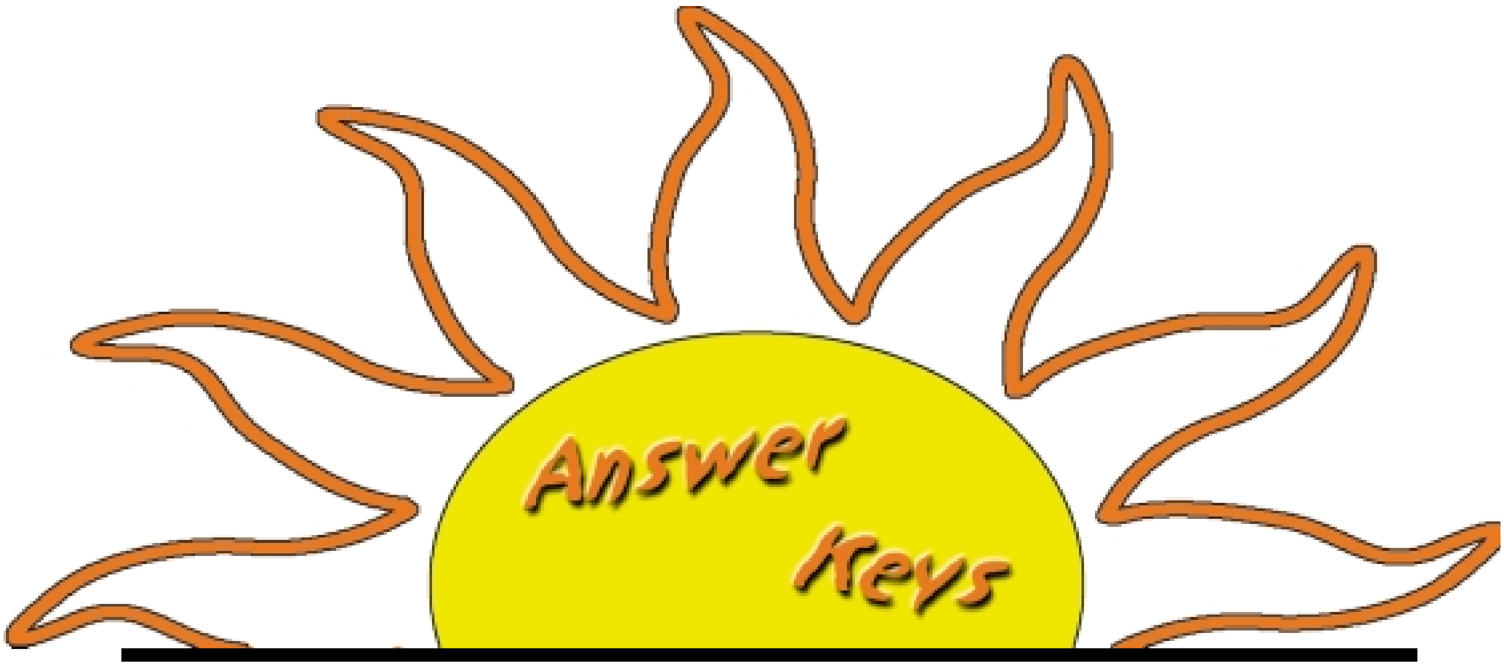
  Activity description:
  For this activity we refer you and your students to the Web site given below.

  http://solar-center.stanford.edu.magnetism

Career Explorations

- **Web site review**
  Have the students read the brief biographies found on the Web site http://solar-center.stanford.edu to become more familiar with solar scientists and their work.

- **Webcast review**
  After the students view the Web cast on-line or participate in an on-line question and answer session, have them complete the Career Exploration Guidesheet: *Solar Scientist*



- Science Exploration Guidesheet: *Now We're Cookin'!*
- Science Exploration Guidesheet: *Parabolic Solar Collectors*
- Science Exploration Guidesheet: *Wavelength and Solar Cells*
- Science Exploration Guidesheet: *What I Can Do With Solar Energy*
- Science Exploration Guidesheet: *Riding a Radio Wave*
- Science Exploration Guidesheet: *AM Radio Ionosphere Station*
  Note: see given Web site for guidance
- Science Exploration Guidesheet: *Magnetic Field*
- Science Exploration: *Magnetism and the Sun*
  Note: see given Web site for guidance
- Science Exploration Guidesheet: *Soda Bottle Magnetometer*
  Note: see given Web site for guidance
- Science Exploration Guidesheet: *Prospects are good*

Science Exploration Guidesheet

Now We're Cookin'! - Key

Directions: Decide how you and your partner or group will explore ways in which the sun's energy can be used to do things like cook food by answering each question below.

1. **What science idea does your class want explore?**
   The sun's energy can be used to perform work for us. We can use it to do such things as cook.

2. **What question or questions do you want answered by this science exploration?**
   How can the sun's energy be used to cook food?

3. **Describe in general how your class will answer the question(s) or explore this idea.**
   The class will research information about the sun's energy and materials that can be used to construct a solar cooker. We will then design a solar cooker that uses the sun's energy to cook a slice of hot dog the fastest way possible.

4. **List step-by-step how you will answer the question(s).**
   - *Research information about the sun's energy (radiant energy)*
   - *Research information about solar cookers and materials that are used to harness the sun's radiant energy.*
   - *List the many types of household items that could be used to develop a solar cooker*
   - *Draw a diagram for a solar cooker*
   - *List the materials needed to make your solar cooker*
   - *Gather the needed materials*
   - *Make your solar cooker (prototype) and test it*
   - *Revise its design based upon test*
   - *Present your design to your fellow classmates*

Now We're Cookin'! - Key (continued)

5. **List the materials you or your group will need to follow those steps.**

   Types of materials the class could use:

aluminum foil	*small mirrors*	*clear and dark glass jars*
shoe boxes	*lightweight wire*	*toothpicks*
cardboard	*tape*	*plastic wrap*
reflecting material		

6. **What kind of observations will you make during this science exploration?**
   Test the cooker for generation of heat, thoroughness of cooking process, and total cooking time.

7. **What kind of measurements will you make during this science exploration?**
   Heat temperature, time the cooking process

8. **On a separate sheet of paper create a chart which you will use to record your observations.**
   Students should be encouraged as part of the technology design process to devise their own observation or prototype test data sheet.

9. **Record your observations and report your findings to the class.**
   Students results will vary dependent upon their technological design.

10. **At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.**

11. **What did you learn from this science exploration?**
    - *How are commercially-made solar cookers constructed?*
    - *In what other ways is solar energy harnessed for our use?*
    - *How do scientists and researchers envision that solar energy will be used in our future?*

12. **Does this lead you to any other questions? Write down one or two of your questions below.**

Parabolic Solar Collectors - Key

Directions: Decide how you and your partner or group will explore these science ideas by answering each question below.

1. **What science idea does your class want to explore?**
Different methods of collecting energy from the sun

2. **What question or questions do you want answered by this science exploration?**
   - *Is there a solar collector design that is better than others?*
   - *What is a parabolic solar collector?*
   - *Should the path of the sun and angles also be considered when collecting solar energy?*

3. **Describe in general how your class will answer the question(s) or how your class will explore this idea.**
Perform research on different styles of solar collection units or find design plans for a parabolic solar collector. Construct a parabolic solar collector. Upon completion of its construction, place it in the sun with a thermometer at its center, and every hour take a temperature reading. Next place either a slice of hot dog, apple or a small marshmallow on a skewer and cook it. Time the cooking process.

4. **List step-by-step how you will answer the question(s).**
   - *Upon completion of the parabolic solar collector construction, place it in the sun with a thermometer at its center*
   - *every hour take a temperature reading.*
   - *Next place either a slice of hot dog, apple or a small marshmallow on a skewer and cook it.*
   - *Time the cooking process.*

   Other suggestions might be to:
   - *cook the same type of food at different times of the day, time the process and compare.*
   - *Or develop a mechanism to angle the parabolic collector so that it follows the sun's path during the day giving maximum cooking temperature all day.*

Parabolic Solar Collectors - Key (continued)

5. List the materials you or your group will need to follow those steps.
   - *Directions: See section* ***Student Handouts,*** *Student Guidesheet: Constructing a Parabolic Solar Collector*
   - *Parabola maker (see directions above)*
   - *graph paper*
   - *tape*
   - *heavy cardboard*
   - *aluminum foil*
   - *white glue*
   - *small nut and bolt*
   - *wood strips 3 – 5 cm wide, 50 – 100 cm long*

6. What kind of observations will you make during this science exploration?
   - *How well cooked the food is*
   - *The path the sun follows during this time of the year*
   - *The angle of the collector to the sun's path*

7. What kind of measurements will you make during this science exploration?
   - *The angle of the collector to the sun's path*
   - *The temperature of the cooking area*

8. On a separate sheet of paper create a chart which you will use to record your observations.

9. Record your observations and report your findings to the class.

10. At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.

Parabolic Solar Collectors - Key (continued)

11. **What did you learn from this science exploration?**
    - *The parabolic design provides a greater and more concentrated heat source than other methods*
    - *Following the path of the sun maximizes the heat source*

12. **Does this lead you to any other questions? Write down one or two of your questions below.**
    - *How has this design been applied in the real world*
    - *Can a mathematical formula be devised that will compute and accurately predict the area needed to concentrate heat to reach a certain temperature?*
    - *Can this design be applied in space?*

Wavelength and Solar Cells - Key

Directions: Decide how you and your partner or group will explore these science ideas by answering each question below.

1. **What science idea does your class want to explore?**
   The power output of different types of solar cells when exposed to different types of light.

2. **What question or questions do you want answered by this science exploration?**
   - *Do certain types of solar cells produce more power with certain types of light?*
   - *Does the type of light being absorbed by solar cells affect their output?*

3. **Describe in general how your class will answer the question(s) or how your class will explore this idea.**
   Take different types of solar cells and using the same watt light source pass the light through various filters onto the solar cells and measure their output.

4. **List step-by-step how you will answer the question(s).**
   - *Set up solar cell with light source at an arbitrarily measured distance.*
   - *Set up filter holder*
   - *Attach wiring to voltmeter*
   - *Measure the voltage of the solar cell without a filter*
   - *Place each filter between the light source and the solar cell and measure the solar cell's output.*
   - *Record each measurement*
   - *Plot the voltage versus wavelength on a graph or chart*

5. **List the materials you or your group will need to follow those steps.**
   - *Various types of solar cells (silicon, cadmium sulfide, selenium, etc.)*
   - *Voltmeter or multimeter (0-1 volt range)*
   - *Incandescent lamp*
   - *Different types (colors) of filters: blue, green, yellow, red, infrared, yellow-green infrared blocking filter*

Wavelength and Solar Cells - Key

6. **What kind of observations will you make during this science exploration?**
   - *Color of filter (Determine its wavelength through research.)*
   - *Monitor meter*

7. **What kind of measurements will you make during this science exploration?**
   - *Voltage as measured on the meter*

8. **On a separate sheet of paper create a chart which you will use to record your observations.**
   This chart should compare voltage versus wavelength.

9. **Record your observations and report your findings to the class.**

10. **At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.**

11. **What did you learn from this science exploration?**

    The spectral response of the solar cells varies with incident wavelength as well as due to the nature of the cell. Because it is beyond the scope of this activity, we know that the response of solar cells is zero beyond 12,000A. Because the absorption of the photons is too deep within the cell, below about 4000A the absorption is too near the surface and response is nearly zero. The optimum wavelength lies somewhere in between.

12. **Does this lead you to any other questions? Write down one or two of your questions below.**
    - *Would space station solar cells need to be shielded with filters?*
    - *Are certain types of solar cells or solar arrays better suited for different climates, geographic locations, latitudes or space?*

Science Exploration Guidesheet

What I Can Do With Solar Energy - Key

Directions: Decide how you and your partner or group will explore other ways solar energy can be used by answering each question below.

1. **What science idea does your class want explore?**
   Learn how solar cells work and how this technology can be used.

2. **What question or questions do you want answered by this science exploration?**
   - *How do solar cells change solar energy into electricity?*
   - *How can solar cells be used to do work?*

3. **Describe in general how your class will answer the question(s) or explore this idea.**
   The class will research solar cells, observe how solar cells operate and can be used in machines. The class will then design a machine that uses solar cells to do work or power some machine.

4. **List step-by-step how you will answer the question(s).**
   - *Research information about the sun's energy (radiant energy)*
   - *Research information about solar cells*
   - *List the many types of machines that solar cells could power*
   - *Draw a diagram for a solar powered machine*
   - *List the materials needed to make your solar powered machine*
   - *Gather the needed materials*
   - *Make your solar powered machine (prototype) and test it*
   - *Revise its design based upon test*
   - *Present design to fellow students*

5. **List the materials you or your group will need to follow those steps.**
   Materials will vary based upon students' designs.

6. **What kind of observations will you make during this science exploration?**
   Students will observe how well their prototype operates checking connections, angle of cells to sun's energy, etc.

7. **What kind of measurements will you make during this science exploration?**
   Students will need to determine this based upon their product design.

What I Can Do With Solar Energy - Key (continued)

8. On a separate sheet of paper create a chart which you will use to record your observations.
Students' results will vary dependent upon their technological design.

9. Record your observations and report your findings to the class.

10. At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.

11. What did you learn from this science exploration?

Students should be able to articulate some of the following points:
- *the design process for developing technological tools*
- *the process of evaluating a new technological design (prototype)*
  ways in which the sun's energy can be harnessed

12. Does this lead you to any other questions? Write down one or two of your questions below.

- *How are commercially-made solar machines constructed?*
- *In what other ways are solar powered machines used?*
- *How do scientists and researchers envision that solar powered machines will be used in our future?*

Science Exploration Guidesheet

Riding a Radio Wave - Key

Directions: Decide how you and your partner or group will explore these science ideas by answering each question below.

1. **What science idea does your class want to explore?**
   The effects of solar energy within our atmosphere.

2. **What question or questions do you want answered by this science exploration?**
   Does solar energy affect the radio signals we use?
   Can we detect fluctuations in solar energy by monitoring a radio?

3. **Describe in general how your class will answer the question(s) or how your class will explore this idea.**
   Monitor a certain part of the AM radio band during the day and night time hours, then compare the reception.

4. **List step-by-step how you will answer the question(s).**
   - *Develop a rating system for rating the clarity and strength of a radio signal*
   - *Decide which part of the AM band will be monitored*
   - *Each hour of the day and night monitor the band and note the station's call sign and name*
   - *Locate each signal's source on a map and determine the distance from the area*
   - *Record the observations*
   - *Check a Web site that gives daily updates on solar energy activity and record the observations given there*
   - *Develop a graph or chart to organize the information collected*
   - *Discuss and present the findings*

5. **List the materials you or your group will need to follow those steps.**
   - *AM radio*
   - *Observation chart*
   - *Rating system*
   - *Access to the Internet*

6. **What kind of observations will you make during this science exploration?**
   - *Strength and clarity of radio signals*
   - *Solar energy fluctuations from scientists*

Riding a Radio Wave - Key (continued)

7. **What kind of measurements will you make during this science exploration?**
   - *Using our own rating scale we will rate the clarity and strength of radio signals*

8. **On a separate sheet of paper create a chart which you will use to record your observations.**
   See ***Student Handouts*** *section for an example.*

9. **Record your observations and report your findings to the class.**
   - *Signals are clearer and stronger during daylight hours*
   - *Electrical storms cause sporadic static in reception*
   - *During the evening hours we receive increased number of radio signals from a farther distance*
   - *We get more steady static during daylight hours*
   - *Manmade electrical disturbances might also be observed*

10. **At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.**

1. **What did you learn from this science exploration?**
   - *That solar energy does have an effect on the reception of radio signals*
   - *Fluctuations in solar energy can be observed by monitoring radio waves*

2. **Does this lead you to any other questions? Write down one or two of your questions below.**

   - *Does increased sunspot activity cause interference in radio waves?*
   - *Do other types of solar activity interfere with radio reception? If so, what kinds of solar activity does so? (CMEs, etc.)*
   - *How do solar scientists monitor fluctuations in solar energy?*

Magnetic Field - Key

Directions: Decide how you and your partner or group will explore these science ideas by answering each question below.

1. **What science idea does your class want to explore?**
The magnetosphere, how at the Earth's magnetic lines of force act and what the Earth's magnetic lines of force look like.

2. **What question or questions do you want answered by this science exploration?**
Can we construct a device that demonstrates how particles can be trapped in a magnetic field?

3. **Describe in general how your class will answer the question(s) or how your class will explore this idea.**
After performing some research on the magnetosphere we will construct a working model using magnets.
http://solar-center.stanford.edu/magnetism/beefields.html

4. **List step-by-step how you will answer the question(s).**
Step 1: Punch a small hole through the center of the Styrofoam ball (Do not make it over one-quarter inch in diameter.)

Step 2: Feed the fine insulated wire through the hole forming continuous loops around the Styrofoam ball. (Vary the size of the loops making some half of the ball's diameter and some twice the ball's diameter.)

Step 3: Leave both ends of the wire free, extending about 6 inches from each pole. Remove the insulation at each end of the wire.

Step 4: Attach 1.5 volt dry cell to the ends of the wire.

Step 5: Place this assembly on a large sheet of paper and sprinkle fine iron filings through the loops.

Step 6: Record and discuss your observations.

Step 7: Place a compass near the loops. Move the compass from pole to pole.

Step 8: Record and discuss your observations.

Magnetic Field - Key (continued)

5. List the materials you or your group will need to follow those steps.
   - *3 inch Styrofoam ball*
   - *20 ft. of fine insulated copper wire*
   - *1.5 volt dry cell*
   - *very fine iron filings*
   - *large sheet of paper*

6. What kind of observations will you make during this science exploration?
   We will observe how the iron filings react to the magnets and the reading on the compass

7. What kind of measurements will you make during this science exploration?
   We will take various compass readings.

Magnetic Field - Key (continued)

8. On a separate sheet of paper create a chart which you will use to record your observations.
   Drawing will look something like what is found on this Web site

   http://solar-center.stanford.edu/magnetism/beefields.html

9. Record your observations and report your findings to the class.

10. At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.

11. What did you learn from this science exploration?

    The poles of the Earth actually act like a giant magnet.

12. Does this lead you to any other questions? Write down one or two of your questions below.

    - *What factors influence the Earth's magnetism?*
    - *Does the magnetic polls ever reverse?*

Grades 9 - 12

- Science Exploration Guidesheet
  (Generic Guidesheet for use with all explorations)
- Student Guidesheet: *Constructing a Parabolic Solar Collector*
- Riding a Radio Wave: *Observation Graph*
- Career Exploration Guidesheet: *Solar Scientist*

Science Exploration Guidesheet

Science Exploration: ___________________________________

Directions: Decide how you and your partner or group will explore these science ideas by answering each question below.

1. What science idea does your class want to explore?

2. What question or questions do you want answered by this science exploration?

3. Describe in general how your class will answer the question(s) or how your class will explore this idea.

4. List step-by-step how you will answer the question(s).

5. List the materials you or your group will need to follow those steps.

6. What kind of observations will you make during this science exploration?

7. What kind of measurements will you make during this science exploration?

Science Exploration Guidesheet

Science Exploration: ___________________________________

8. On a separate sheet of paper create a chart which you will use to record your observations.

9. Record your observations and report your findings to the class.

10. At the end of the science exploration create a special report to give to the class. Follow the form your teacher gives you.

11. What did you learn from this science exploration?

12. Does this lead you to any other questions? Write down one or two of your questions below.

Constructing a Parabolic Solar Collector

Introduction:
One method for collecting energy from the Sun is through the use of concentrating collectors. Solar energy impingent on a large area is directed toward a small area where a given task is to be performed. Depending upon the size of the collector and the area the solar energy is concentrated on, temperatures of up to several thousands of degrees can be reached.

Materials:
- Parabola Maker (See Procedures, Part A)
- Graph paper
- Tape
- Cardboard
- Aluminum Foil
- White glue
- Small nut and bolt
- Wood strips 3 to 5 cm wide, 50 to 100 cm long
- Nails

Procedure:

Part A: Parabola Maker

1. Joint two thin strips of wood together with a small nut and bolt at one end.
2. Draw a straight line down the middle of the top strip.
3. Drill 1/8" holes through both strips at 1 cm intervals starting 10 cm from the nut and bolt.
4. Number the holes on each strip.

Part B: Drawing the Parabola

1. Tape several pieces of graph paper together and place on top of a sheet of cardboard.
2. Draw a straight line (base line) along one side of the graph paper and a perpendicular line to that line through the middle of the paper.
3. Place a dot on the perpendicular line 20 cm from the base-line. This dot will be the focus of the parabola.

Science Exploration Guidesheet

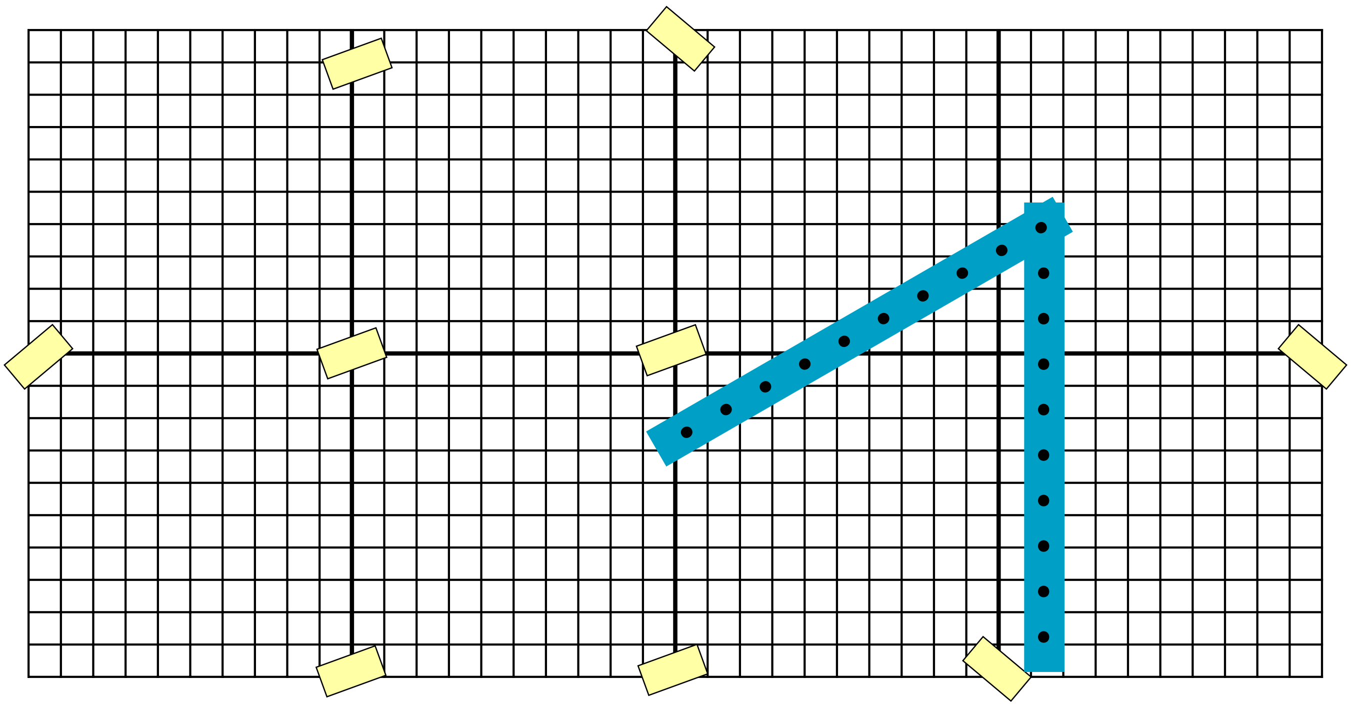
Constructing a Parabolic Solar Collector (continued)

Procedure:

Part B: Drawing the Parabola (continued)

4. Push a pin through the 40 cm mark of one strip of wood into the focus.

5. Slide the other strip of wood so that the 40 cm mark touches the baseline and so that the edge of this strip is parallel to the perpendicular line.



6. Apply pressure to the nut and bolt. The dent in paper will be one point of the parabola. Darken this point.

7. Repeat procedure 3 through 6 for all the other holes in the wood strips. Do this on one side of the perpendicular line only.

8. Connect all the dots with a smooth line. (A french curve used in drafting is very useful here).

9. Trace the curve onto the other side of the perpendicular line. The parabola is now complete.

10. Draw other parabolas by changing the distance of the focus from the baseline.

Constructing a Parabolic Solar Collector (continued)

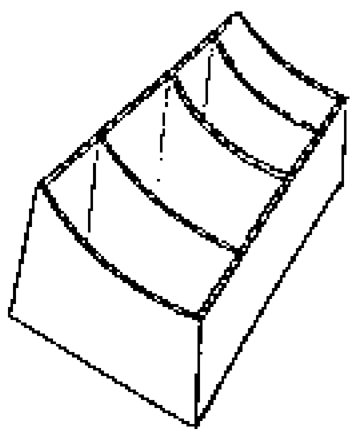
Procedure:

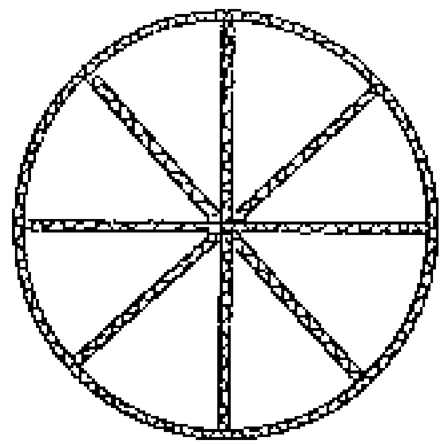
Part C: Making the collector

1. Select a parabolic curve that is relatively flat and 50 to 70 cm in diameter.

2. Transfer the parabola to cardboard with the ribs of the cardboard running perpendicular to the curve.

3. Cut out several pieces of cardboard with the same curve. The collector may be either trough-shaped or round.





4. Intersect the necessary pieces of cardboard and support the edges with more cardboard. Glue.

5. Bond aluminum foil on additional cardboard with glue.

6. Cut and fold the foil-covered cardboard to fit into the parabola. Round collectors need pie shaped pieces joined together.

7. Push nails through the foil-covered cardboard into the ribs of the cardboard frame. Bond with glue.

CAUTION: Do not place hands or clothes at the focal point. Serious injury may result.

Science Exploration Guidesheet

Riding a Radio Wave: Observation Graph

Directions: For each observation time note each station that is received while scanning your assigned section of the AM band (call sign and dial number). Then rate each station's reception in terms of clarity and strength by placing an appropriate mark on the graph below. Note any observations as indicated.

5

4

3

2

1

BAND #: ______________
Call signs: ______________
Location: ______________
Distance: ______________

Date:	Time:
Observations	
Weather Conditions:	
Solar Conditions:	
Other Observations:	

Career Exploration Guidesheet

Solar Scientist

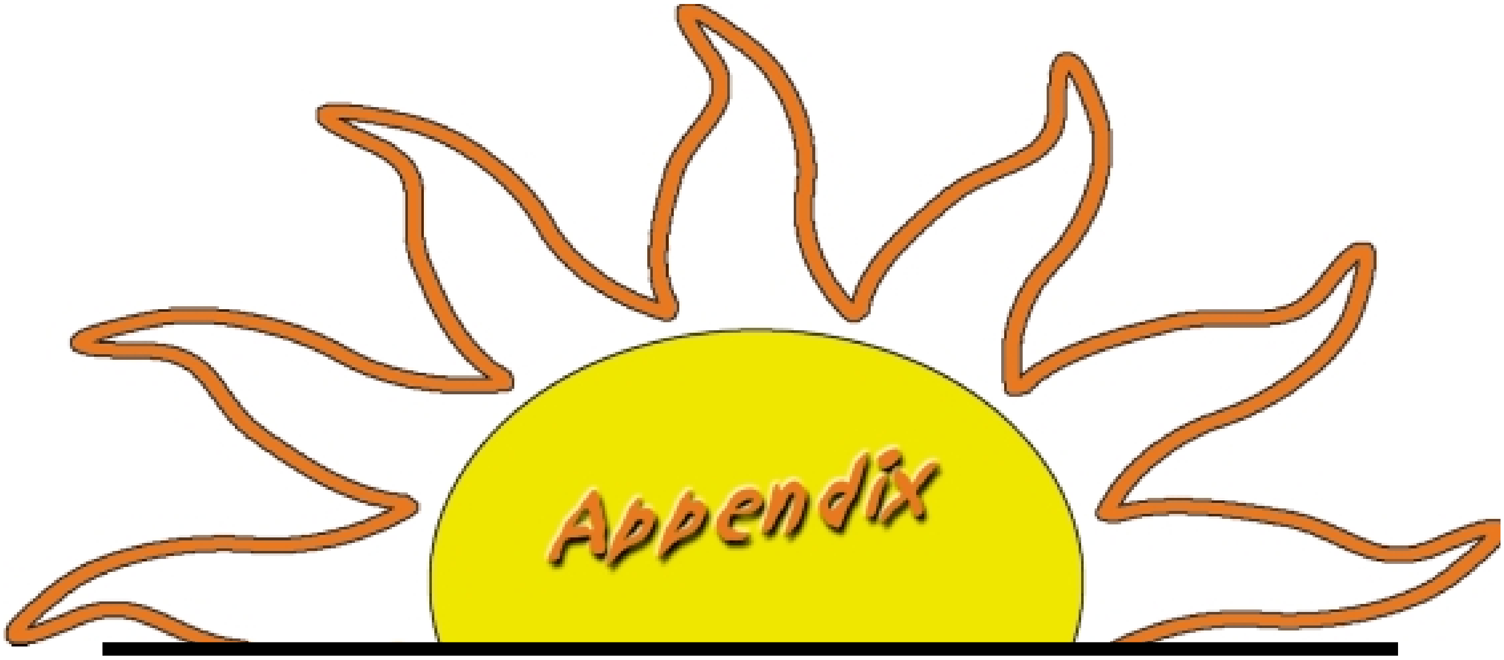
Directions: After listening to the broadcast or visiting the Web site to learn about the work of a solar scientist, answer the questions below.

1. **Tell about one thing you are good at that a solar scientist needs to know how to do.**

2. **Tell one thing about what a solar scientist does that you think is interesting. Explain why that is interesting to you.**

3. **If you were a solar scientist what would you want to learn more about?**

4. **If you could ask the solar scientist one question about his/her job, what would you want to know?**



- Solar Glossary
- Web Work
- NASA Educational Topics

Solar Glossary

coronal mass ejection (CME) — bubble-shaped disturbances that rise above active sunspot regions and send expanding plasma clouds that move rapidly through space

magnetic field lines — the phenomenon of magnetism where electrically charged particles tend to become attached to field lines and spiral around them while sliding along them. These lines of force come together where the field lines are magnetically strong and spread out where the magnetic force is weaker.

magnetic north — the direction toward which the compass needle points indicating north

magnetosphere — Located 60 miles above the Earth's surface where the earth's magnetic lines of force flow

radiation — electromagnetic waves that are emitted by the sun

solar — having to do with the sun

solar energy — energy converted from the sun

solar flares — tremendous eruptions from sunspots that quickly release magnetic energy into space

sunspots — huge regions in the sun's atmosphere of magnetic fields that slow the flow of heat from the sun's interior

Web Work

The following Web sites can be used for additional student activities and for student research.

http://solar-center.stanford.edu/magnetism

Magnetism and sun activity

http://solar-center.stanford.edu/magnetism/beefields.html

Contains an applet simulating the earth's magnetic field

http://www.star.le.ac.uk/edu/planets/sun.html

A concise overview about the sun: composition, solar eclipse, solar wind.

http://image.gsfc.nasa.gov/poetry

Lots of good information and plenty of links along with interesting student activities.

http://www.rt66.com/r.bahm

Basic introduction to solar energy on this commercial site. It briefly explains the state of solar energy today, future applications and challenges of design. Includes a United States map depicting the annual daily total horizontal solar radiation.

http://www.pvpower.com

Large, interesting resource site about photovoltaics: history, technology, applications and other information.

http://solarcooking.org

Great site with lots of good resource information on solar cooking. Check out the FAQ subsection, interesting history of solar cooking, the Plans section and the Multimedia section.

Web Work (continued)

The following Web sites can be used for additional student activities and for student research.

http://helios.gsfc.nasa.gov

Cosmic and Heliospheric Learning Center NASA/GSFC. Covers the basics of Astrophysics at a challenging level (composition/elements, energetic particles, acceleration, magnetic fields, cosmic rays and an informative write-up about the heliosphere.

http://wekngdc.noaa.gov/stp/

This Web site gives sunspot counts as part of its daily solar activity observations.

http://www.set.noaa.gov/today.html

This Web site gives the space weather forecast that includes solar activity.

Appendix

NASA Educational Topics

The following pages provide you and your students with NASA Educational Topics. These can be printed and freely distributed to your students for classroom use.

- **Pioneer 11 Provides New Data about the Sun's Magnetic Field**
- **Concentrated Sunlight: A Way to Increase the Power of Microwaves?**
- **A Simple Device to Measure Solar Radiation**

Please Note: *The following pages will not appear properly in PDF format, but will print clearly.*

NASA Educational Topics

An Educational Publication
of the
National Aeronautics and
Space Administration

Grade: 9-12

Subject: Astronomy, physics

Topic: Sun's magnetic field

Pioneer 11 Provides New Data about the Sun's Magnetic Field

The first evidence of the Sun's magnetic field was discovered in 1908 by the astronomer, G. E. Hale. However, its exact shape and nature have remained unknown because of a lack of data. The Pioneer 11 spacecraft, the first to travel high above the plane of the ecliptic, has provided measurements which support a new solar magnetic field model.

The new model was proposed by Dr. Edward Smith of NASA's Jet Propulsion Laboratory, Pasadena, California. His magnetometer experiments aboard Pioneer 11 confirmed some earlier theories and indicate that the Sun's magnetic field is roughly spherical in shape and extends throughout the solar system.

Dr. Smith's model (see Figure 1) has a relatively simple north pole-south pole structure. The magnetic field is split into northern and southern hemispheres by a warped current sheet located at the magnetic equator.

The Pioneer findings indicate that the Sun's magnetic field may be similar to those of Earth and Jupiter. Both have current sheets similar to the Sun. This discovery is important for a better understanding of the Sun. It may help us learn about the solar magnetic storms which alter the solar wind and may affect our weather. It may also help us better understand the operation of the Sun, our only source of heat and light.

Some Details

Scientists have puzzled over how the Sun behaves and the nature of its magnetic field. This has caused a great deal of speculation.

The Sun's magnetic field is believed to extend several billion miles above the Sun's north and south poles. It is known to exist beyond the orbit of Saturn and may reach as far as Pluto, nearly 4 billion kilometers (2.5 billion miles) away. This field, generated by electrical currents in the Sun, is stretched far outward in every direction by the solar wind of charged particles which flows constantly outward from the Sun. The Sun's field reverses direction every eleven years, near the period of maximum sunspot development. During this reversal process, measurements have suggested that the field is weak and disordered.

Since the Sun's equatorial regions rotate faster than the polar regions, the surface fields near the equator apparently wind around the Sun's middle like taffy. The equatorial magnetic fields often run east-west.

The random small-scale magnetic fields in the mid-region of the Sun have closed magnetic field lines which extend slightly out into the corona but not beyond. According to Dr. Smith these fields are all mixed up due to the Sun's violent convection currents and uneven rotation.

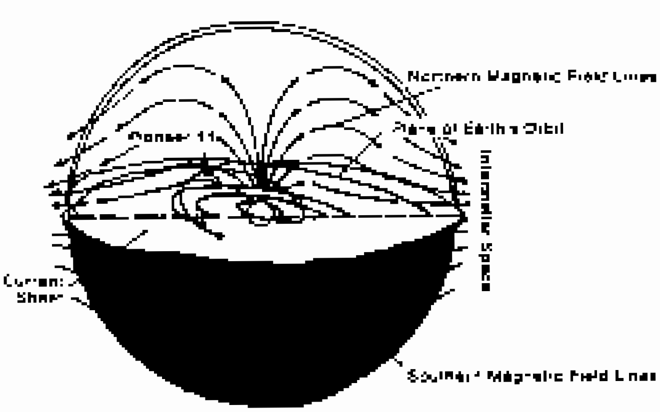


Figure 1. Magnetic field of the Sun viewed above the plane of the ecliptic.

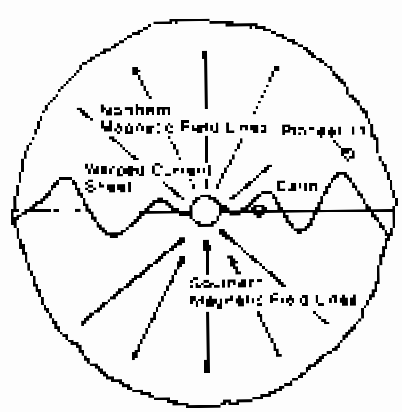


Figure 2. Magnetic field of the Sun relative to the warped current sheet.

The north polar region, on the other hand, has a well-ordered field in just one direction, and the south, in the opposite direction.

This large-scale magnetic configuration greatly eases the outflow of solar wind and depletes the solar corona of charged particles. This effect leads to formation of coronal holes which nearly always occur in polar regions and often extend down toward the solar equator. The outflow of solar wind carries the solar magnetic field out until the solar wind ends up mixing with interstellar gas—perhaps somewhere near the orbit of Pluto. The outgoing north polar field may link up with the incoming south polar field to complete the loop. However this is merely theory, perhaps the north and south field components never do link up, but rather join with the intersellar magnetic field at the boundary.

Applying the Model

If we apply Dr. Smith's new model to the part of the solar cycle now affecting Earth, we see that the magnetic field comes primarily out of the northern hemisphere of the Sun and is carried outward by the solar wind. In most of the southern hemisphere, the field direction is reversed, the field comes back in toward the Sun. Near the magnetic equator, the northern and southern fields are separated by a warped sheet of electrical current. These currents tend to circle the Sun in the inner portion of the solar system. However, in the outer part of the solar system, they gradually turn and finally flow outward.

As the Sun rotates, the warped equatorial current sheet appears to move up and down relative to the Earth's orbital plane. Because all of the spacecraft prior to Pioneer 11 traveled in the Earth's orbital plane, the current sheet passed through them each time it was warped below the spacecraft, and repassed them as it was warped upward again. Thus, these spacecraft were in a magnetic field direction away from the Sun when they were above the current sheet and in the magnetic field direction toward the Sun when below it. (See Figure 2.)

This simply means that these earlier spacecraft saw reversals in the magnetic field each time the current sheet encountered them. This led to a variety of interpretations.

According to the warped current sheet model, the current sheet in space has a range in latitude when near the sunspot maximum (as it was in 1976) of about 15 degrees on each side of the Sun's equator. When Pioneer 11 was 16 degrees away from the solar equator, it was above the current sheet. Thus, the magnetic field reversals stopped.

Besides Dr. Smith's work, theoretical work on this subject has been done by Nobel Laureate Dr. Hannes Alfven, University of California, San Diego and Dr. Michael Schultz, Aerospace Corp., El Segundo, California. Drs. Leif S. Valgaard and John M. Wilson, Stanford University, have developed the model further.

Activities

1. Prepare a model of a simple planetary magnetic field by imbedding a bar magnet in a styrofoam ball. Use a small compass needle to test the field and identify its direction.
2. Prepare a map or chart of the magnetic field you determined in Activity 1.
3. Make scale drawings of the Sun and planets which have known magnetic fields. Show the size of the planet and the size of its magnetosphere to scale.
4. Prepare a chart of NASA's spacecraft which carried magnetometer experiments. Include the trajectory or orbit of each to show where their measurements were made.
5. Prepare a comparison chart of sunspot numbers and major meteorological disturbances (hurricanes, tornados, drought, etc.). Is there a simple correlation? Why? Why not?

Student Questions

1. Which planets and planetary bodies in the solar system have magnetic fields? Why do some have a magnetic field and others do not? Have all planets been tested?
2. What is meant by the term magnetosphere? magnetopause? solar wind?
3. How does a magnetometer operate? How does it differ from a compass?
4. Describe some ways magnetism research is applied in nuclear fusion research or mass transit research.

Notes, References, and Bibliography

1. *Evolution of the Solar System*, NASA SP-345, 1976, 559 pp. $11.00 (GPO Stock No. 033-000-06613-6).
2. *Pioneer Odyssey: Encounter with a Giant*, NASA SP-349, 1974, 171 pp. $5.50 (GPO Stock No. 3300-00584).
3. Referenced NASA publications that are unavailable from your library may be obtained by them on interlibrary loan from a library which is a repository for U.S. government publications.
4. GPO publications may be ordered from the U.S. Government Printing Office, Washington, DC 20402.

NASA Educational Topics

An Educational Publication
of the
National Aeronautics and
Space Administration

Grade: 10-12

Subject: Physics, electronics

Topic: Microwave generation, energy conversion

Concentrated Sunlight: A Way to Increase the Power of Microwaves?

NASA has been studying energy transmission methods which use microwaves. While many problems remain, microwave transmission appears to have some potential for helping us use solar energy.

Some research groups have proposed using a series of energy conversions for this purpose. First, solar cells in geosynchronous orbit would convert sunlight to electrical energy. Next, the electricity would be converted to microwave radiation and transmitted to receiving stations on Earth. The last conversion would be from microwaves to electricity suitable for use. Major obstacles remain between this idea and reality: silicon solar cells are expensive, placing objects in orbit is costly, energy is lost during conversion processes, and there is concern for the safety of the microwave transmission process.

Richard M. Dickinson of the Jet Propulsion Laboratory has proposed a new concept, an electromechanical device which may be able to convert sunlight into microwave energy by a direct process.[1] Its theoretical efficiency is 90%. If successful, this concept may lead to lighter, more efficient, and more direct systems than those using present-day technology—and magnetrons.[2]

The Figure shows Mr. Dickinson's idea. It consists of a reflector which focuses sunlight on a movable piston which, in turn, oscillates in a microwave-resonant cavity. The concentrated sunlight forces the piston to oscillate in such a way that it alternately compresses and expands the cavity.[3]

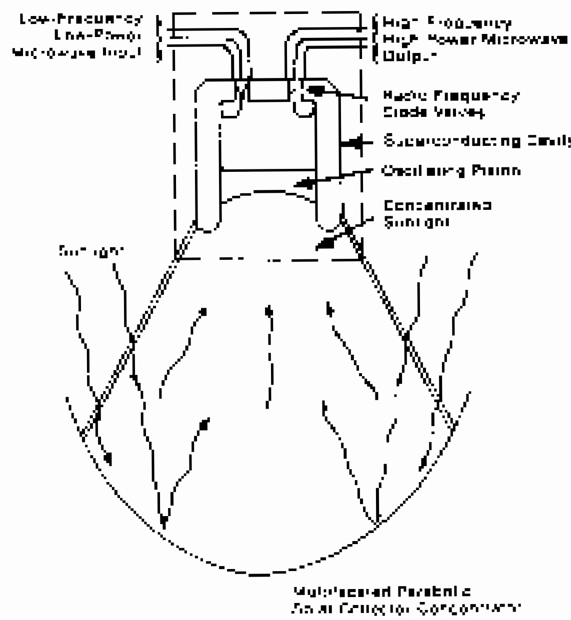


Figure. Concentrated sunlight could make a piston oscillate in a microwave cavity. This use of the pressure of the light increases the microwave energy in a superconducting cavity.

The principles of a reciprocating solar-powered piston are known. The piston compresses the electromagnetic field in the cavity. In so doing the piston increases the energy of the electromagnetic waves passing through the cavity; they leave it with higher frequency and greater power than when they entered.

Until recently, electromagnetic radiation could not be contained long enough for it to interact with a mechanical system. In fact, if this device were made of ordinary metals, it would not work. Microwave energy (at frequencies of several billion hertz) would dissipate into the cavity walls before the piston (operating at only a few hundred hertz) could move more than a tiny distance. However, superconducting materials are now available. When cooled to liquid helium temperatures, these materials can contain the microwaves long enough for electromechanical interaction to take place.

The theoretical basis of the device is the Boltzmann-Ehrenfest theorem from the field of quantum mechanics: under certain conditions of adiabatic deformation the number of photons contained in a lossless resonator remains constant. Since the energy in a cavity is the product of the number of photons and the instantaneous characteristic frequency, decreasing the volume of the cavity, which increases the characteristic frequency, will increase the energy in it. For example, if the cavity is compressed to one-tenth its original volume, its frequency and energy content will increase tenfold. If the compression is repeated at a high rate, a small amount of power at a low microwave frequency becomes a large amount of power at a high microwave frequency.

Instead of using sunlight, the piston could be moved by a rotating crank. Mechanical energy could then be converted directly into electrical energy, or microwaves, into kinetic energy. Perhaps, even a self-excited device could be designed to which no external microwave energy would need to be added.

However, certain technical problems must still be solved before any devices can be built. The moving piston must be cooled to cryogenic temperatures. Stronger superconducting alloys must be developed.

These are not insurmountable problems. Rather, they are typical of the type of problem which has been the subject of past research efforts, and which will be faced by future research scientists and engineers. Many important devices would not be present today if researchers had simply said, "We don't have the right materials." Research and development is the process of continuing to test, probe, try, investigate, and persevere in spite of seeming failure and constant difficulty.

If you solve any of the remaining technical problems and wish to use or manufacture Mr. Dickinson's device commercially, please contact the Patent Counsel, NASA Resident Legal Office, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91103 (refer to NPO-14068).

In order to encourage competition and achieve the widest use of NASA inventions, NASA will usually grant nonexclusive licenses for commercial use. These licenses are usually royalty free, but must be used before a negotiated target date.

Student Questions

1. What are the fundamental differences between microwaves, radar, and radio waves? How is each generated? Which represents the greatest energy? the least?
2. What is meant by a superconductor? What conditions are necessary? What kinds of materials can function as superconductors?
3. What is the temperature of liquid helium? How is it produced? contained?
4. What is meant by the following terms: adiabatic, isothermal, Boltzmann-Ehrenfest theorem, radio frequency diode, cryogenics?

Notes, References, and Bibliography

1. NASA Tech Briefs, Vol. 2, No. 3, Fall 1977, p. 324.
2. A magnetron is an electron tube used as an oscillator in microwave transmitters.
3. The fact that sunlight can exert a force is discussed in the PSSC Physics film entitled "The Pressure of Light."
4. For discussions of microwave generation, consult a reference work on electronics.
5. For discussions of superconductivity, consult recent college-level physics text books.
6. Referenced NASA publications that are unavailable from your library may be obtained by them on interlibrary loan from a library which is a repository for U.S. government publications.

NASA Educational Topics

An Educational Publication of the National Aeronautics and Space Administration

Grade: 6-12

Subject: General science, physics, environmental science, industrial arts

Topic: Energy measurement

A Simple Device to Measure Solar Radiation

Could you measure the intensity of radiation from the Sun? You probably recall that heat can be transferred by conduction, convection, and radiation; however, isolating radiation from its two companions for separate measurement can be difficult. Complex instruments are often used for this purpose, but William R. Humphries of NASA's Marshall Space Flight Center has invented a simple and dependable device.[1]

This device, shown in the Figure, is inexpensive and can measure the intensity of either solar radiation or the radiation from other energy sources such as furnaces or ovens. It consists of a conventional thermometer that is nearly isolated from the effects of convective and conductive heat transfer to or from its surroundings. Therefore, its temperature (liquid level) is determined mainly by the amount of radiation it absorbs or emits (radiative heat transfer). The instrument's reading depends on the surrounding (ambient) temperature in a way which is predictable and which can be corrected by proper calibration.

Construction

The thermometer is encased in an evacuated transparent glass or plastic jacket to isolate it from its surroundings. The thermometer reservoir must be spherical in order to expose an unchanging surface area to the Sun as it moves across the sky. Thus, the calibration curve for a given ambient temperature can be used at any time of day on any day of the year.

Any liquid can be used which neither freezes nor boils at the combined radiant energy intensities and ambient temperatures to which the device is exposed. For the normal range of conditions encountered in the United States, mercury is a good choice.

The capillary stem must be long enough to accommodate the anticipated expansion of the liquid. For example, mercury in a capillary 0.13 mm (0.005 in.) in diameter and a 3.28 cm^3 (0.20 in^3) reservoir will rise 15 cm (6 in) as the radiation intensity increases from zero to 249 cal/sec m^2 (348 kilojoules/sec m^2 or 330 Btu/hr ft^2), the maximum solar intensity expected in the United States.

The instrument mounting is coated with a flat (low reflectivity) paint so that it does not reflect radiation into the reservoir. During use the reservoir is exposed to the Sun's rays, but it may be necessary to shield the capillary.

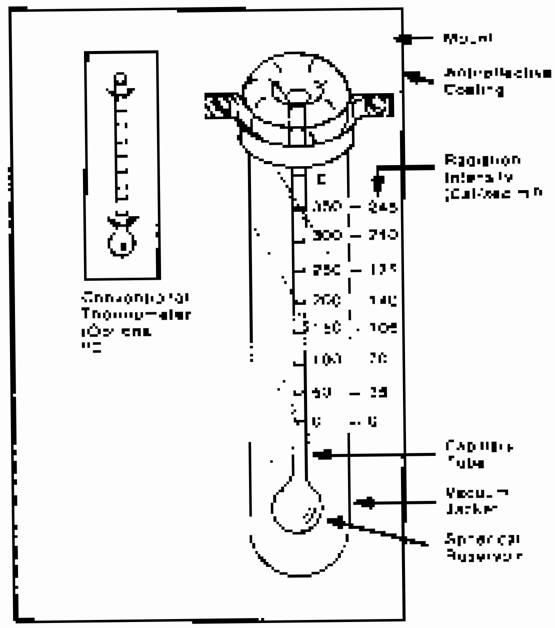


Figure. Inexpensive radiation thermometer which consists of a capillary tube and reservoir in a vacuum jacket made by techniques similar to those used for manufacturing electric light bulbs. Radiation intensity values shown are only approximate.

Operation

When the length of the liquid column in the capillary remains unchanged, the device is said to exhibit "steady-state" operation. During steady state, the amount of thermal (heat) energy entering the device is equal to the amount leaving it. The entering amount depends on the solar radiation intensity and such properties as the transmittance of the glass walls of the reservoir. The amount which leaves is determined by the temperature difference between the reservoir and the outside air, and the radiative properties of the reservoir.

This balance of radiant energies allows the solar intensity to determine the reservoir temperature which, in turn, determines the volume of the liquid which expands into the capillary.

For typical solar intensities, the reservoir temperature is considerably higher than the outside air and the effect of the ambient temperature is relatively small. For precise measurements, however, a calibration curve should be used which gives the error caused by ambient temperature effects. For this purpose, a conventional thermometer should be mounted nearby and shaded from direct sunlight.

If, for convenience, the device is to be read from a remote location, an electrical output can be derived from the varying resistance, capacitance, or pressure of the mercury column.

NASA holds the patent for this invention; however, it may be used for educational purposes. For inquiries concerning commercial use, write to the NASA Patent Counsel.[2]

Activities

1. Construct a device to measure solar radiation. Obtain a glass tube which is longer than the thermometer. Seal one end and mount the thermometer in the center of the tube. The tube may be evacuated and sealed.[3]

   A 0-360 C thermometer should be long enough for all measurements. If a mercury thermometer with a spherical bulb is not available one with the standard cylindrical bulb can be used. In the case of a cylindrical reservoir either measure the solar radiation while maintaining a constant solar angle, or calibrate the device for a range of solar angles.
2. Calibrate the device.
3. Use the device at a specific location on your school roof, or in front of your school, home, etc. How does the solar radiation intensity vary during the day? during the year? with thin clouds? over different surfaces?

Student Questions

1. Describe some instruments which are used to measure radiant energy or solar radiation. What are their similarities and differences? What are the units of measurement?
2. Why is it important to be able to measure solar radiation accurately? When were the first such measurements made? by whom? where?
3. How might the amount of solar radiant energy affect the design of a new home or building?

Notes, References, and Bibliography

1. NASA Tech Briefs, Vol. 2, No. 4, Winter 1977, pp. 483-4.
2. NASA inventions are available for either exclusive or non-exclusive commercial licensing.

   Non-exclusive licenses for commercial use are encouraged by NASA to promote competition and to achieve the widest use of inventions. Such licenses must be used by a negotiated target date, but are usually free of royalty.

   Exclusive licenses may be granted to encourage early commercial development of NASA inventions, especially when considerable private capital investment is required. Such grants are generally for a period of five to ten years and usually require royalties based on sales or use.

   For information concerning this solar radiation device, write the Patent Counsel, Mail Code CC01, NASA Marshall Space Flight Center, AL 35812 (refer to MFS-23751).
3. Consult a standard reference work on glass working techniques.
4. Referenced NASA publications that are unavailable from your library may be obtained by them on interlibrary loan from a library which is a repository for U.S. government publications.