National Aeronautics and Space Administration

NASA Helio Club

Session 3

Parker Solar Probe Engineering Challenge

NASA Heliophysics Education Activation Team

Session 3: Parker Solar Probe Engineering Challenge

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Time

120 minutes for the full progression of activities
-or- three **25 minute** activities that stand alone

Learning Goal

To model the scientific processes that scientists and engineers use to conceptualize a mission to the Sun.

Full Session Overview

This session starts with a Know, Want-to-know, Learned (KWL) strategy for finding out what learners already know about the Sun. This session will engage learners in the engineering challenges of NASA's Parker Solar Probe Mission. Learners will complete two challenges to model how Parker will get to the Sun and how it will withstand the high temperatures of the solar environment. Students will compare how Parker Solar Probe takes images of the corona to other methods of viewing the corona. The session ends with learners creating an artistic representation of the Sun's corona.

- **Prior Knowledge:** What do you already know about the challenges of studying the Sun? KWL (15 minutes)
- **Engage:** Parker Solar Probe Mission Overview (15 minutes)
- **Explore: Activity 1:** Engineering Challenge 1: Speed (25 minutes)
- **Explain: Activity 2:** Engineering Challenge 2: Heat (25 minutes)
- **Extend: Activity 3:** Comparing Ways to Study the Sun (25 minutes)
- **Evaluate:** KWL (15 minutes)

Materials

NASA Helio Club Youth Guide (optional) includes all handouts for all six sessions.
Quantities are per learner.

Basics

- ☐ Writing tools (pens or pencils)
- ☐ Art supplies (markers or crayons)
- ☐ (1) pair of scissors
- ☐ (1) roll of tape

Prior Knowledge/Evaluate

- ☐ (1) Handout_KWL

Engage

- ☐ Handout_Structure of the Sun

Explore: Activity 1

- ☐ Handout_Engineering Challenge 1: Speed
- ☐ (1) dry erase marker
- ☐ (1) piece of transparent Plexiglas (8.5” x 11”)
- ☐ (2-3) strong round magnets of various sizes
- ☐ (2-3) steel ball bearings of various sizes
- ☐ (4) small, equally sized books or other objects to serve as corner supports for the Plexiglas baseboard (learner provides)
- ☐ (1) Index Card
- ☐ Tape
- ☐ Scissors
- ☐ Ruler

Explain: Activity 2

- ☐ Handout_Engineering Challenge 2: Heat
- ☐ Spoon
- ☐ Aluminum baking pan
- ☐ (4) larger clear plastic cups (~16 oz)
- ☐ (4) smaller “small (3 oz.) ” cups (~3 oz)
- ☐ (1) styrofoam cup (8-16 oz) (tear apart)
- ☐ (1) 10” x 10” piece of aluminum foil (tear apart)
- ☐ (~10) cotton balls (tear apart)

Extend: Activity 3

- ☐ Handout_Eclipse Chalk Art
- ☐ Handout_2023 & 2024 Solar Eclipse Map
- ☐ White, yellow, or orange chalk
- ☐ (1) piece of black construction paper
- ☐ (1) piece of cardstock
- ☐ Scissors

Digital Resources

- Educator Resource: Educator Background Information
- Educator Resource: Slides_Session 3
- Educator Resource: Engineering Challenge Pics and Videos folder
- Video: NASA Parker Solar Probe Mission Overview
- Video: Parker Solar Probe: Getting to the Sun
- Video: Parker Solar Probe: Orbital Path
- Video: Parker Solar Probe: Why won't it melt?
- Video: Parker Solar Probe's WISPR Instrument
- Webpage: NASA Parker Solar Probe Mission Homepage
- Webpage: NASA Eclipse Website
- Webpage:The 2023 & 2024 Solar Eclipses: Map and Data

Learning Objectives: At the end of the session, learners will be able to…

1. Describe the properties of the different layers of the Sun.
2. Identify the engineering challenges of missions going to the Sun.
3. Model solutions to mission challenges.
4. Compare different methods for viewing the Sun's corona.

Key Vocabulary

- **Chromosphere –** lies just atop the photosphere; in the lower chromosphere, solar material moves as a typical gas or fluid; in the upper chromosphere and above, magnetic forces dominate the motion
- **Convective Zone –** the outermost layer of the solar interior, where hot material rises to the surface of the star, carrying, or convecting, heat with it. At the surface, the material cools by giving off sunlight, then sinks down, where it picks up more heat.
- **Corona –** the Sun's upper atmosphere; it is filled with plasma, whose movements are governed by the tangle of magnetic fields surrounding the Sun
- **Coronagraph –** a specialized instrument designed to block out the light of the main body of the Sun so that scientists can view the corona
- **Gravity Assist –** a flyby technique that can add or subtract momentum to increase or decrease the energy of a spacecraft's orbit
- **Path of Totality –** the area on Earth where observers experience a total solar eclipse
- **Photosphere –** often called the "surface" of the Sun, the photosphere is actually the first layer of the solar atmosphere. It is called the "surface" because the light we see comes from the photosphere. We can't see deeper layers.
- **Radiative Zone –** the layer just outside the Sun's core, where the light (energy) is passed from atom to atom
- **Solar Eclipse –** when the Sun's light is blocked out by the Moon, which occurs when the Moon is between the Sun and the Earth and lined up at just the right angle; there are different types of solar eclipses:
    - **Total Solar Eclipse –** a total solar eclipse happens when the Moon passes between the Sun and Earth, completely blocking (100%) the face of the Sun, revealing the Sun's corona. The sky will darken, as if it were dawn or dusk.
    - **Partial Solar Eclipse –** experienced when the Sun, Moon, and Earth are not exactly lined up and the Moon only partially blocks out light from the main body of the Sun
    - **Annular solar eclipse –** occurs when the Moon is farther away from Earth in its orbit, only blocking 90% of the Sun's disk.
    - **Hybrid solar eclipse –** this type of solar eclipse occurs when a total turns annular or the other way around
- **Solar Eclipse Glasses –** a solar viewing tool that protects your eyes from harmful light from the Sun
- **Sun's Core –** the central region of the Sun where nuclear reactions consume hydrogen to form helium

Review the [Educator Background Information](#) **for more information on major concepts.**

Next Generation Science Standards (NGSS) Connections

MS-ESS1-1. Space Systems: **Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.** In Activity 1 learners explore how NASA missions use the gravity of objects in the Solar System to alter the speed and vector of spacecraft.

MS-ETS1-4. Engineering Design: **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.** In Activity 1 and Activity 2 learners engineer two models to test the challenges of NASA missions.

MS-PS2-5. Forces and Interactions: **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** In Activity 1 learners use magnets to affect the speed and direction of steel balls in a model of a gravity assist.

MS-PS3-1. Energy: **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** In Activity 1 learners build a model to test the speed of different masses of steel balls.

MS-PS3-3. Energy: **Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.** In Activity 2, learners build a model to test the insulation properties of different materials.

Targeted STEM Skills

Asking questions

In this session learners ask questions using a KWL.

Making predictions

In Activity 1 and Activity 2 learners make predictions about the results of two engineering challenges.

Planning and carrying out investigations [MS-PS2-5]

In Activity 1 and Activity 2 learners carry out investigations into thermal insulation and motion.

Developing and using models [MS-ESS1-1] [MS-ETS1-4]

In Activity 1 learners model a gravity assist maneuver.

Recognizing patterns [MS-ESS1-1]

In Activity 1, learners recognize the patterns of motion in the Solar System.

Analyzing and interpreting data [MS-PS3-1]

In Activity 2, learners gather and interpret data in an experiment on insulating materials.

Constructing explanations and designing solutions [MS-PS3-3]

In Activity 1 and Activity 2, learners explore engineering solutions for missions going to the Sun.

Steps: Full Session

**Italics indicate recommended scripts to use with students.*

Use the accompanying slides to help keep learners engaged.

National Aeronautics and Space Administration

NASA Helio Club

Session 3
Challenges of Studying the Sun

NASA Heliophysics Education Activation Team

- **Prior Knowledge:** What do you already know about the challenges of studying the Sun? KWL (15 minutes)
- **Engage:** Parker Solar Probe Mission Overview (15 minutes)
- **Explore: Activity 1:** Engineering Challenge 1: Speed (25 minutes)
- **Explain**: **Activity 2:** Engineering Challenge 2: Heat (25 minutes)
- **Extend: Activity 3:** Comparing Ways to Study the Sun (25 minutes)
- **Evaluate:** KWL (15 minutes)

Prior Knowledge: What do you already know about the challenges of observing the Sun?

Overview
(15 Minutes)

A KWL chart is an effective way to assess learners' prior knowledge, identify misconceptions, and measure growth. Use the guiding questions provided in the chart below to focus learners on the content that is explored in this session.

As students share their ideas and predictions, don't give them the answers just yet; rather, encourage them to investigate their questions throughout the session.

If you don't use the Youth Guide, have learners use a notebook to record their observations, draw diagrams, and collect data.

Materials

- Handout_KWL

Instructions

A. **Direct learners to page 38** in the NASA Helio Club Youth Guide, or print the Handout_KWL

B. Have learners complete **K [Know Column]** and the **W [Wonder Column]** of the KWL chart. Instruct them to leave the L [Learn Column] blank until the end of the session. [Slide 4]

KWL

[K] – What do you already know?	[W] – What do you wonder about?	[L] – What did you learn?
What do you already know about the challenges of studying the Sun? - *Why is it challenging to study the Sun?*	*Record questions you have about the challenges of studying the Sun in this column.*	*Record what you learned about the challenges of studying the Sun in this column.*

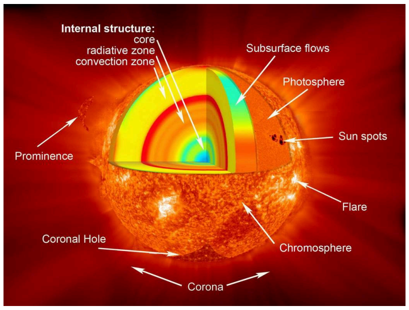
Engage: Parker Solar Probe Mission Overview

Overview
(15 Minutes)

In this introduction activity, students gather background information about NASA's Parker Solar Probe Mission and challenges of studying the Sun.

Emphasize that the Parker Solar Probe Mission is trying to answer one of the most perplexing mysteries of the Sun, which is the temperature of the corona, the Sun's outer atmosphere.

This activity explores some of the properties of the different layers of the Sun.



Anatomy of the Sun
Credit: NASA

Materials

- ☐ Handout_Structure of the Sun

Instructions

A. **Direct learners to turn to page 39** of the NASA Helio Club Youth Guide, or print the Handout_Structure of the Sun.

B. **Provide Context:** *The Sun has different layers. Each layer has different properties (characteristics). The* ***core*** *is where* ***nuclear fusion*** *is taking place and where the heat is generated. Each layer inside the Sun becomes cooler as you move away from the* ***core****, but then something interesting happens in the solar atmosphere. The middle layer of the solar atmosphere, the* ***chromosphere,*** *is actually hotter than the solar surface, the* ***photosphere****! And the outer layer of the solar atmosphere, the* ***corona****, is even hotter than the* ***chromosphere****!* [Slide 5]

This phenomenon is very surprising – for example, if you took a step back from a campfire and got hotter, you would be very confused. Scientists are not quite sure why this occurs, and it is one of the biggest mysteries about the Sun that they are trying to figure out.

In this session, we will explore a very special NASA Mission called the ***Parker Solar Probe****. This mission has flown closer to the Sun than any other mission before it and touches the outer edge of the* ***corona*** *(2025). Scientists are already learning a lot about the Sun from this mission and hope the data collected will help us understand why the Sun's* ***chromosphere*** *and* ***corona*** *are hotter than the* ***photosphere****.*

C. **Watch:** Show learners this short video, which gives an overview of the **Parker Solar Probe** mission: Video Parker Solar Probe Mission Overview [Slide 6].

Direct students to focus on the following questions, as they watch the video:

- *What question is the mission trying to answer?*
- *What are the major challenges this mission needs to overcome?*
- *What types of solutions have NASA engineers developed to overcome these challenges?*

Major Concepts

- ★ The Sun has different layers.
- ★ The energy of the Sun is produced by **nuclear fusion** in the **Sun's core**.
- ★ The energy produced in the core moves outward through each layer, the **radiative zone, convection zone, photosphere, chromosphere,** and **corona.**
- ★ Scientists are interested to know why the Sun's atmosphere, the **corona**, is hotter than the **chromosphere** and the **photosphere**.
- ★ Parker Solar Probe will fly closer to the Sun than any other mission ever has.
- ★ Parker carries a variety of instruments that are designed to measure the different properties of the **corona**.

Featured NASA Mission: NASA Parker Solar Probe Mission travels through the Sun's atmosphere, closer to the surface than any spacecraft before it, facing brutal heat and radiation conditions to provide humanity with the closest-ever observations of a star. Parker Solar Probe uses Venus' gravity during seven flybys over nearly seven years to gradually bring its orbit closer to the Sun. The spacecraft will fly through the Sun's atmosphere as close as 3.8 million miles to our star's surface, well within the orbit of Mercury and more than seven times closer than any spacecraft has come before.

Explore: Engineering Challenge 1: Speed

Overview of Activity 1 (25 Minutes)

In this first engineering challenge, learners explore how Parker Solar Probe gets to the Sun. Learners will be modeling a gravity assist maneuver to demonstrate how Parker Solar Probe uses the gravity of Venus to gradually make its way to the Sun.

- ***The magnet represents a planet.***
- ***The ball bearing represents a spacecraft.***

This inquiry-based activity gives learners a chance to experiment with different-sized ball bearings, different sized magnets, and other variables like launch angle and the distance between magnet and launch ramp.

Emphasize to learners that magnetism is not involved in a gravity assist. We can't experiment with gravity without highly sophisticated equipment. So, we are just using the

Materials

☐ Handout Engineering Challenge 1: Speed
☐ (1) dry erase marker
☐ (1) piece of transparent Plexiglas (8.5" x 11")
☐ (2-3) strong round magnets of various sizes
☐ (2-3) steel ball bearings of various sizes
☐ (4) small, equally sized books or other objects to serve as corner supports for the Plexiglas baseboard (learner provides)
☐ (1) Index Card
☐ Tape
☐ Scissors
☐ Ruler

Instructions

A. **Provide Context:** *It takes lots of energy to launch a spacecraft into the Solar System, especially to places really far away, like Saturn or even Pluto. Remember that we learned about the* ***Voyager Missions****, which are now traveling beyond the edges of the heliosphere. It took Voyager 35 years to reach the edge of the* ***heliosphere****.*

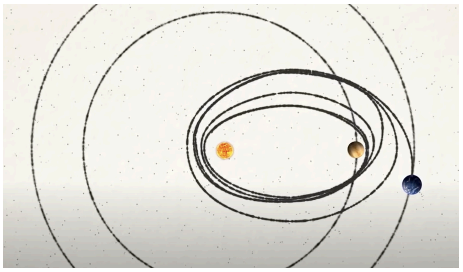
Rocket fuel is expensive, and spacecraft can't carry a lot of it, especially considering that some destinations take years to reach. So, scientists and engineers need alternative solutions in order to get these spacecraft where they want them to go.

One solution is using ***gravity assists*** *from planets and moons to gain speed and momentum to achieve extraordinary distances. A* ***gravity assist****, or a slingshot, is when a spacecraft takes some of this energy from an* non-contact force of magnetism to **model** the non-contact force of gravity.

Learners will gather data on how different-sized magnets and different-sized ball bearings affect the deflection of the ball from the launch trajectory.

Encourage learners to ask questions and experiment with the variables they have questions about.

Ask learners to share how they chose to collect data, and maybe have them share their plexiglass board if they used the dry erase marker to draw vectors during their experiment. See the Engineering Challenge Pics and Videos folder for more visuals, also included in the accompanying slides.



Animation of orbital path of PSP from Earth to Sun with 7 gravity assists from Venus *Credit: NASA GSFC*

orbiting planet or moon and transfers it to the spacecraft as a way to speed its journey to its planned destination.

In the case of the ***Parker Solar Probe****, we actually need to slow it down to reach the Sun, which also can be achieved by a* ***gravity assist****. Slowing down a spacecraft takes a lot of energy, too! So, why do we need to slow down a spacecraft flying to the Sun?*

First, we need to remember how fast the Earth is moving in orbit. The Earth travels at 30 km/s, or about 67,000 mph around the Sun. This speed is required to keep the Earth safely in orbit around the Sun, rather than falling into the Sun. To reach the Sun, ***Parker Solar Probe*** *needs to go slower than Earth, so that it can begin to spiral closer and closer toward the Sun.*

As Parker is locally slowed down by the Venus gravity assists, its orbit becomes elongated. As it falls closer and closer to the Sun, it picks up speed, and at its closest point to the Sun it becomes the fastest human-made object.

Parker Solar Probe *will use seven* ***gravity assists*** *from Venus to travel within 3.83 million miles (6.16 million kilometers) of the Sun. We can still call this a* ***gravity assist*** *because gravity is helping to achieve the speed that we need the spacecraft to go, only in this case, we want Parker to actually go slower.*

B. **Watch:** This short video explains how Venus helps Parker to get to the Sun: Getting to the Sun Video [Slide 7].

Direct students to focus on the following questions, as they watch the video:

- *Why is it so hard to fly to the Sun?*
- *What solutions will NASA use to get the Parker Solar Probe to the Sun?*

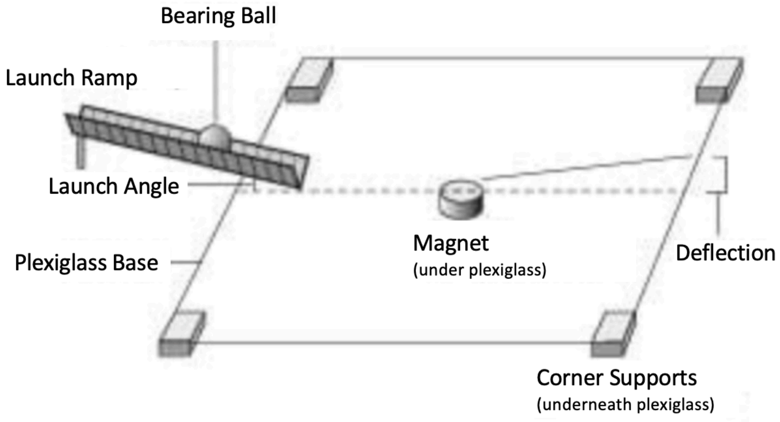
[Optional: *This three-minute video shows the complete orbital path of Parker Solar Probe:* [Video_Parker Solar Probe Orbital Path.]]

You have the option of grouping learners; recommend no more than 2 learners per setup.

C. Experiment: Direct learners to page 40-41 of the NASA Helio Club Youth Guide**,** or print the Handout_Engineering Challenge 1: Speed for directions on how to set up the experiment (see directions below). [Slides 8-9]

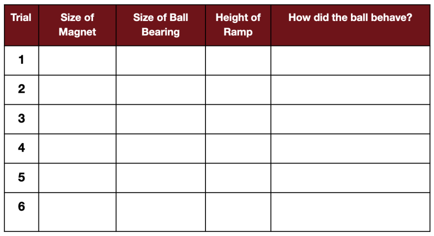
You are going to build a model showing how the ***slingshot effect*** *works. Using magnets and ball bearings to simulate a planetary flyby, you will investigate what factors influence the deflection angle of a* ***slingshot maneuver****. Remember that this model is intended to show just the basic principles of a* ***gravity assist*** *by using magnetism to approximate the effect.*

- ***The magnet represents a planet.***
- ***The ball bearing represents a spacecraft.***



Credit: TeachEngineering.com

Show learners additional pictures and videos on [Slides 11-14] to give them a better idea of how to set up the experiment.



Trial	Size of Magnet	Size of Ball Bearing	Height of Ramp	How did the ball behave?
1				
2				
3				
4				
5				
6				

Data Table

Make a prediction: *How will the magnet affect the speed and direction of the ball?* [Slide 10]

Have learners share their predictions.

D. **Gather Data.** Encourage learners to use a data table to record results. [Slide 15]

E. **Communicate Results:** After learners have had time to experiment, ask learners to share their results. [Slide 16]

   a. *How did the launch angle (vector) affect the deflection of the ball (spacecraft)?*
   b. *How did the size of the magnet (planet) affect the deflection of the ball (spacecraft)?*
   c. *How did the size of the ball (spacecraft) affect the deflection of the ball (spacecraft)?*

Procedure

Part A. Experimental Set-up

(1) Find some equally sized books or other objects to create the corner supports for the plexiglass base.
(2) Using the dry erase marker, draw a line down the middle of the underside of the plexiglass and tape the magnet to the middle of the plexiglass, under the line.
(3) Assemble a launch ramp by folding an index card in half. The angle of the launch ramp represents the energy with which the spacecraft is launched.

Part B. Experiment

(4) Make a prediction: What will happen to the ball when it approaches the magnet?
(5) Use the ramp to launch the ball (spacecraft) toward the magnet (planet). This may take a few times to practice and to determine the proper launch angle of the ramp.
(6) Trace the path the ball took on the plexiglass, using a dry erase marker. Record your observations; note the size of the magnet you used, the size of the ball, and how high your ramp was.
   (a) Experiment with different-sized balls (spacecraft) and different-sized magnets (planets), marking the path of the ball for each trial.
   (b) Experiment with different angles of the launch ramp.

Part C. Conclusions

(7) Use claim, evidence, and reasoning to summarize your results.
    (a) How did the size of the magnet (planet) affect the speed and deflection of the ball (spacecraft)?
    (b) How did the size of the ball (spacecraft) affect the speed and deflection of the ball (spacecraft)?
    (c) How did the launch angle affect the speed and deflection of the ball (spacecraft)?

Activity 1 Major Concepts

★ It takes lots of energy to launch a spacecraft into the Solar System.

★ Scientists need to be creative about how they get enough energy to launch the spacecraft to its destination. One solution is using **gravity assists** from planets and moons to gain speed and momentum to achieve extraordinary distances.

★ A **gravity assist**, or a slingshot, is when a spacecraft takes some of this energy from an orbiting planet or moon and transfers it to the spacecraft as a way to speed its journey to its planned destination.

★ To reach the Sun, Parker Solar Probe needs to go slower than Earth, so that it can begin to spiral closer and closer toward the Sun.

★ Parker Solar Probe will use seven gravity assists from Venus to travel within 3.83 million miles (6.16 million kilometers) of the Sun. We can still call this a **gravity assist** because gravity is helping to achieve the speed that we need the spacecraft to go, only in this case, we want it to actually go slower.

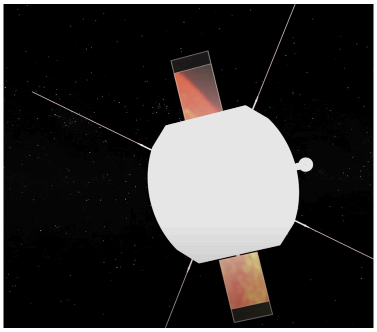
This activity was adapted from “Slingshot to the Outer Planets” activity from teachengineering.org.

Explore: Engineering Challenge 2: Heat

Overview of Activity 2 (25 Minutes)

In this second engineering challenge, students model how NASA engineers test different materials for missions.

With Parker Solar Probe traveling within 3.83 million miles of the Sun, it needs a sophisticated heat shield to protect its instruments. In this activity, learners will explore the insulation properties of different materials and learn some of the basic properties of thermal energy transfer.



Animation of PSP's heat shield
Credit: NASA GSFC

Materials

- ☐ Handout_Engineering Challenge 2: Heat
- ☐ Spoon
- ☐ Aluminum baking pan
- ☐ (4) larger clear plastic cups (~16 oz)
- ☐ (4) smaller small (3 oz.) cups (~3 oz)
- ☐ (1) styrofoam cup (8-16 oz) (tear apart)
- ☐ (1) 10" x 10" piece of aluminum foil (tear apart)
- ☐ (~10) cotton balls (tear apart)

Instructions

A. **Provide Context:** *Now that you have a better understanding of how Parker is going to get to the Sun, let's explore how the spacecraft and all of its instruments won't melt.*

B. **Watch:** *This short video to learn about the engineering behind keeping Parker Solar Probe cool: Why won't it melt?* [Slide 17]

Direct students to focus on the following questions, as they watch the video:

- *What are the properties of Parker's heat shield?*
- *How does the density of the corona affect heat transfer?*

C. **Experiment: Direct learners to page 42** of the NASA Helio Club Youth Guide, or use the Handout_Engineering Challenge 2: Heat for directions on how to set up the experiment (see procedure below). [Slide 18-19]

If learners are having a hard time seeing the ice, have them gently swirl the water in the cup while looking for ice formation. Styrofoam and cotton may not have any ice, yet.

After learners put the cups in the freezer, move onto the next activity. Set a timer and pause the next activity for learners to go to the freezer and make observations.

Styrofoam

Air

Cotton

Aluminum Foil

While we don't have carbon to experiment with, like NASA does, we can still test the insulation properties of other materials, using the same scientific processes as NASA scientists do. We will test the insulation properties of air, Styrofoam, aluminum foil, and cotton.

Guide learners through the procedure for experimental setup.

Make a prediction: Have learners share their predictions. [Board 4]

While learners are waiting for their cups to freeze, get them started on the next activity.

D. Communicate Results: After learners have had time to experiment, ask learners to share their observations. [Slide 20]

- *Which cup froze first?*
- *Which cup thawed the quickest when you added hot water to the tray?*
- *Which materials are the best insulators and why?*

Use the Educator Note below to guide the discussion of results.

Procedure

Part A. Experimental Set-up: Insulating the Cups

(1) Put each insulation material (foil, Styrofoam, cotton, air) at the bottom of the plastic cups (each material goes in a separate cup). Just fill to about an inch. You will need to tear up the aluminum foil, Styrofoam cups, and cotton balls into small pieces.
(2) Place the small small (3 oz.) cup inside the plastic cup and fill all the spaces around the little cup with the insulating material. Again, the cup filled with air is already done!

Part B. Experiment: Which cup will freeze first?

(3) Fill each small (3 oz.) cup with 3 spoonfuls of water.
(4) Put the cups in the freezer for 15 minutes.
(5) Make a prediction. Which cup will freeze first?
(6) After 15 minutes in the freezer, take the cups out and record your observations. Which cups are starting to freeze? Do some cups have more ice than others?

15 Minutes: The cup insulated with aluminum will begin to freeze first. The other three materials may not be as obvious for which one freezes next. Learners will likely observe that the cup filled with air will start to show a few ice crystals next. Have learners gently swirl the cup to look for ice crystals.

(7) Put the cups back in the freezer. After another 15 minutes in the freezer, take the cups out and record your observations.

30 Minutes: The cup insulated with aluminum and the cup insulated with air should be completely frozen. It may be hard to tell if the Styrofoam or cotton is more frozen than the other. Have learners gently swirl the cup to look for any remaining liquid water.

Part C. Experiment: Which cup will melt first?

(8) Remove the cups from the freezer and place them in an aluminum tray.
(9) Pour hot water into the tray.
(10) Make a prediction. Which cup will melt first?
(11) Record your observations.

Add Hot Water: This is where things may surprise learners. The cup insulated with air melts first, followed by the Styrofoam/cotton, and the aluminum melts last.

Educator Notes: **Aluminum foil** is an interesting material because it can be both a good and bad insulator. It is a good insulator because it reflects thermal radiation. For example, when you put it over a hot plate of food, the food stays hot because the aluminum foil is reflecting the heat from the food back to the food, keeping it warm. In the case of the cups of room temperature water in the freezer, the water doesn’t have enough thermal energy for the aluminum to reflect back at it.

Because aluminum is a metal, it also makes it a good conductor of heat. Thermal energy flows from a warmer object to a colder object. For example, if you hold an ice cube in your hand, the ice cube isn’t making your hand cold, it is just that the heat from your hand (warmer object) is flowing to the ice cube (colder object). As the aluminum foil loses all of its heat to the freezer, it is its conductive properties that cause the small amount of heat from the warmer water in the cup to flow to the colder air in the freezer, making that cup lose its heat faster and freeze first.

Air is a fairly good insulator, especially paired with **Styrofoam** or **cotton**. Because the molecules in a gas are farther apart than in a liquid or solid, the thermal energy takes longer to travel from molecule to molecule. Both Styrofoam and cotton balls are filled with lots of air, which is why they are good insulators.

Activity 2 Major Concepts

- The Sun is hot! The **corona** can reach up to 2-3 million degrees F.
- Parker Solar Probe uses a lightweight material called carbon-carbon (superheated composite) and carbon foam to construct a heat shield to protect the spacecraft instruments.
- Parker Solar Probe is equipped with autonomy software, which means the spacecraft can make its own adjustments to the position of the heat shield to protect the instruments from the heat.
- Parker Solar Probe is equipped with a cooling system, which circulates water around the solar cells to keep them cool.
- While the **corona** is hot (temperature), the **corona** is not dense; the **plasma** molecules are very far apart. This makes the heat (energy) transfer from the **corona** to the spacecraft much more manageable (the spacecraft is simply touching fewer molecules).
- Thermal energy flows from a warmer object to a colder object.
- Insulation depends on how dense the material is. Air is a good insulator because the molecules in a gas are farther apart than in a liquid or solid, which means the heat takes longer to travel from molecule to molecule. Both Styrofoam and cotton balls are filled with lots of air, which is why they are good insulators.

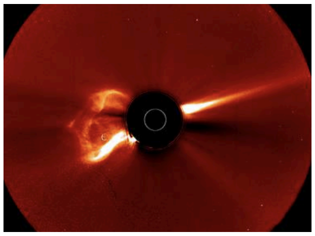
This activity was adapted from the “What is the best insulator: Air, Styrofoam, Foil or Cotton” activity from teachengineering.org.

Explain: Comparing Ways to Study the Sun

Overview of Activity 3 (25 Minutes)

In this activity, students compare several methods for observing the Sun's corona, including Parker Solar Probe, coronagraphs, and total solar eclipses.

Students end this session with creating art that shows the Sun's corona.



Coronagraph
Credit: NASA/ SVS/ GSFC

Parker Solar Probe WISPR Image of the Corona 1/31/21
Credit: NASA/JHU APL

Materials

- ☐ Handout_Eclipse Chalk Art
- ☐ Handout_2023 & 2024 Solar Eclipse Map
- ☐ White, yellow, or orange chalk
- ☐ (1) piece of black construction paper
- ☐ (1) piece of cardstock
- ☐ scissors

A. **Provide Context:** *Parker Solar Probe aims to solve one of the greatest mysteries of the Sun. Scientists call this mystery the "coronal heating problem," which is the surprising fact that the Sun's* ***corona*** *is hotter than the* ***photosphere****. Parker will fly right into the* ***corona*** *and will take measurements of the* ***solar wind*** *using several instruments aboard the spacecraft.*

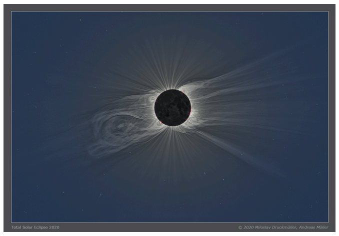
Studying the Sun is challenging for many reasons, including the speed it takes to get to the Sun and the intense heat of the Sun, which we explored during this session. The brightness of the Sun also makes it challenging to directly view the ***corona****.*

We learned in the last session about the STEREO Mission, which uses something called a ***coronagraph*** *to view the Sun's corona. The Wide-Field Imager (WISPR) instrument is the only imaging instrument aboard Parker Solar Probe. It uses the heat shield of the spacecraft to block the light of the Sun, similar to how a* ***coronagraph*** *works.*

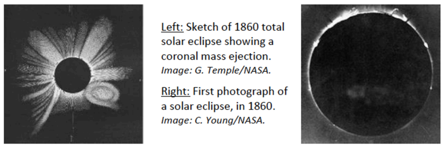
B. **Watch:** This video summarizes how WISPR takes images of the Sun. [Slide 21]

C. **Analyze: Direct learners to pages 43-44** of the NASA Helio Club Youth Guide, or print the Handout_Eclipse Chalk Art.

Before modern missions like Parker Solar Probe and



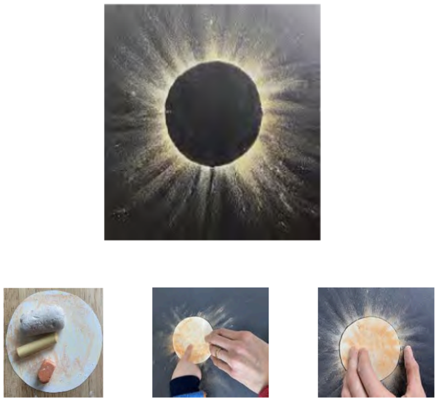
Total Solar Eclipse
Credit: Miloslav Druckmuller, Andreas Moller



Left: Sketch of 1860 total solar eclipse showing a coronal mass ejection. *Image: G. Temple/NASA.*

Right: First photograph of a solar eclipse, in 1860. *Image: C. Young/NASA.*

Early total solar eclipse drawings and the first photograph of a total solar eclipse
Credit: NASA



Total Solar Eclipse Chalk Art
Credit: UAF

STEREO, scientists could only view the ***corona*** *during a* ***total solar eclipse****. A* ***total solar eclipse*** *occurs when the Earth falls into the Moon's shadow, completely blocking out the Sun. The Moon acts just like the occulting disk of a* ***coronagraph****, and Parker's heat shield, allowing scientists to view the* ***corona****, which is otherwise impossible to see without blocking out the brightness of the Sun.*

Even before telescopes and astrophotography, scientists drew what they saw during a ***total solar eclipse.*** [Slide 22]

D. **Create:** *We can create our own image of a* ***solar eclipse*** *using chalk and black construction paper.* [Slide 23]]

C. **Reflect: Direct learners to page 22** of the NASA Helio Club Youth Guide, or print the Handout 2023 & 2024 Solar Eclipse Map. [Slide 24]

Are you ready to experience two solar eclipses in the next year? Make a plan!

On October 14, 2023, an ***annular solar eclipse*** *will cross North, Central, and South America creating a path of annularity, shown in the dark path with the yellow circles.*

An ***annular solar eclipse*** *occurs when the Moon passes between the Sun and Earth, while at its farthest point from Earth. Because the Moon is farther away from Earth, it does not completely block the Sun (only 90% of the solar disk). This will create a "ring of fire" effect in the sky for those standing in the* ***path of annularity. Solar eclipse glasses must be worn during the entire duration of the eclipse, or use a pinhole projector.*** (See Session 2)

On April 8, 2024, a ***total solar eclipse*** *will cross North and Central America creating a* ***path of totality****, shown in the dark path with the purple circles. During a total solar eclipse, the Moon is closer to the Earth, completely blocking the Sun while it passes between the Sun and Earth for those standing in the path of totality. The sky will* *darken as if it were dawn or dusk and those standing in the path of totality may see the Sun's outer atmosphere (the corona), if weather permits.* ***Solar eclipse glasses may be removed for those in the path of totality, briefly, when the Moon completely blocks out the Sun.***

Everyone in the continental US, and Alaska, outside of the paths, will experience a ***partial solar eclipse,*** *during both the 2023 and 2024 eclipses.* ***Solar eclipse glasses must be worn during the entire duration of the eclipse, or use a pinhole projector.***

You cannot see the Sun's ***corona*** *during an* ***annular solar eclipse*** *or during a* ***partial solar eclipse****, but they are still fun and inspiring to observe!*

2023 & 2024 Solar Eclipse Map
Credit: NASA

Find more information about how the solar eclipse map was made: [The 2023 & 2024 Solar Eclipses: Map and Data](#).

Activity 3 Major Concepts

- To view the **corona**, we need a way to block the light from the **photosphere**, which is a million times brighter than the **corona**.
- Parker Solar Probe's WISPR instrument takes images of the **corona** by using the heat shield to block the light from the **photosphere**, the same way **coronagraphs** work.
- A **total solar eclipse** occurs when the Earth falls into the Moon's shadow, completely blocking out the Sun.
- A **total solar eclipse** also gives scientists an opportunity to view the **corona**. Before sophisticated scientific equipment, this was the only opportunity for scientists to study the **corona**.
- An **annular solar eclipse** occurs when the Moon is farther away from Earth in its orbit, only blocking 90% of the Sun's disk. You cannot see the **corona** during an annular solar eclipse.

Evaluate: What did you learn about the challenges of studying the Sun?

Overview of Activity (15 Minutes)

At the end of the session, learners complete the KWL chart, adding what they learned to the [Learn] column.

Encourage learners to look through Session 3 in the Helio Youth Guide, and to review the activities and the observations they recorded during the activities, to help them summarize what they learned during the session.

Materials

- Handout_KWL

Instructions

A. **Direct learners to page 38** in the NASA NASA Helio Club Youth Guide, or print the Handout_KWL. [Slide 25]

B. Have learners complete the **[Learn Column]** of the KWL chart.

   Emphasize to learners that they should also be correcting any misconceptions they had prior to the session, from the [Know] column, and answering any questions from the [Wonder] column, if they are able to.

Session 3 Major Concepts

- The energy produced in the **core** moves outward through each layer, the **radiative zone, convection zone, photosphere, chromosphere,** and **corona.**
- Scientists are interested to know why the Sun's atmosphere, the **corona**, is hotter than the **chromosphere** and the **photosphere**.
- Parker Solar Probe will fly closer to the Sun than any other mission ever has.
- Parker carries a variety of instruments that are designed to measure the different properties of the **corona.**
- A **gravity assist**, or a slingshot, is when a spacecraft takes some of this energy from an orbiting planet or moon and transfers it to the spacecraft as a way to speed its journey to its planned destination.
- Parker Solar Probe will use seven gravity assists from Venus to travel within 3.83 million miles (6.16 million kilometers) of the Sun.
- The Sun is hot! The **corona** can reach up to 2-3 million degrees F.
- Parker Solar Probe has several ways to keep itself cool, including a heat shield and a cooling system.
- While the **corona** is hot (temperature), the **corona** is not dense; the **plasma** molecules are very far apart. This makes the heat (energy) transfer from the **corona** to the spacecraft much more manageable (the spacecraft is simply touching fewer molecules).
- To view the **corona,** we need a way to block the light from the **photosphere**, which is a million times brighter than the **corona**.
- Parker Solar Probe's WISPR instrument takes images of the **corona** by using the heat shield to block the light from the **photosphere**, the same way **coronagraphs** work.
- A **total solar eclipse** occurs when the Earth falls into the Moon's shadow, completely blocking out the Sun.
- A **total solar eclipse** also gives scientists an opportunity to view the **corona**. Before sophisticated scientific equipment, this was the only opportunity for scientists to study the **corona**.
- An **annular solar eclipse** occurs when the Moon is farther away from Earth in its orbit, only blocking 90% of the Sun's disk. You cannot see the **corona** during an annular solar eclipse.

References

John Hopkins University/Applied Physics Lab. (2018, August 7). *Parker Solar Probe Instruments: WISPR.* Retrieved on June 5, 2023, from https://www.youtube.com/watch?v=w3ngdm6GTbc

John Hopkins University/Applied Physics Lab. (2021, January 31). *Parker Solar Probe Science Gateway: WISPR Image Browser.* Retrieved on June 5, 2023, from https://sppgway.jhuapl.edu/wispr_gal?date=2021-01-31&camera=inner

NASA. (2023, June 1). *Eclipses.* Retrieved on June 5, 2023, from https://science.nasa.gov/eclipses/

NASA. (2021, February 19). *STEREO.* Retrieved on June 5, 2023, from https://science.nasa.gov/mission/stereo/

NASA Astronomy Picture of the Day. (2021, January 7). *Total Solar Eclipse 2020.* Retrieved on June 5, 2023, from https://apod.nasa.gov/apod/ap210107.html

NASA/GSFC. (2021, February 8). *Parker Solar Probe.* Retrieved on June 5, 2023, from https://science.nasa.gov/mission/parker-solar-probe/

NASA/GSFC. (2018, August 13). *How will Parker Solar Probe Get to the Sun?* Retrieved on June 5, 2023, from https://www.youtube.com/watch?v=5OeiGw9EZVo

NASA/GSFC. (2018, July 20). *Parker Solar Probe - Mission Overview.* Retrieved on June 5, 2023, from https://www.youtube.com/watch?v=i_z19KPvV1w

NASA/GSFC. (2013, January 22). *The Sun.* Retrieved on June 5, 2023, from https://www.nasa.gov/image-article/sun/

NASA/GSFC. (2018, July 19). *Why Won’t it Melt? How NASA’s Solar Probe Will Survive the Sun.* Retrieved on June 5, 2023, from https://www.youtube.com/watch?v=TN6rZF5dSRg&t=5s

NASA/GSFC/Scientific Visualization Studio. (2023, March 8). *The 2023 & 2024 Solar Eclipses: Map and Data.* Retrieved on June 5, 2023, from https://svs.gsfc.nasa.gov/5073

NASA/GSFC/Scientific Visualization Studio. (2013, May 7). *NASA's Heliophysics Fleet Captures May 1, 2013 Prominence Eruption and CME.* Retrieved on June 5, 2023, from https://svs.gsfc.nasa.gov/10785

University of Alaska/Museum of the North. *Eclipse Chalk Art.* Retrieved on June 5, 2023, from https://www.uaf.edu//museum/education/educators/heliophysics-aurora-outre/activities/pdfs/Eclipse-Chalk-Art-Activity.pdf

University of Colorado/Teach Engineering (2021, May 18). *Slingshot to the Outer Planets.* Retrieved on June 5, 2023, from https://www.teachengineering.org/activities/view/cub_solar_lesson07_activity1

University of Colorado/Teach Engineering (2013). *What Is the Best Insulator: Air, Styrofoam, Foil or Cotton?* Retrieved on June 5, 2023, from https://www.teachengineering.org/activities/view/the_best_insulator

This product was developed by the NASA Heliophysics Education Activation Team (NASA HEAT), part of NASA's Science Activation portfolio. Publication number NP-2023-6-077-GSFC.