Activity Two: Drilling on the Moon

EDUCATOR NOTES

Learning Objectives

Students will

- Compare and contrast the properties of ice to simulated icy-regolith on the Moon's south pole
- Design and build a drill bot that will be able to drill through simulated icy-regolith

Challenge Overview

Students will explore the properties of water, comparing ice to the icy-regolith found on the Moon. Students will then design a drill bot that will be able to drill through simulated icy-regolith to obtain in-situ resources needed for sustainability on the Moon.

Suggested Pacing

90 minutes

National STEM Standards

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-ETS1-2 Engineering Design Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • PS1.A: Structure and Properties of Matter Different kinds of matter exist and many of them can either be a solid or liquid, depending on temperature. ***Crosscutting Concepts*** • Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Influence of Science, Engineering and Technology on Society and the Natural World: The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by the differences in such factors as climate, natural resources, and economic conditions.	***Science and Engineering Practices*** • Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design an object, tool, process, or system. • Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. • Engaging in Argument from Evidence: Argumentation is the process by which explanations and solutions are reached. • Obtaining, Evaluating, and Communicating Information: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.
Technology (ISTE)	
Standards for Students • Innovative Designer: Students use a variety of technologies within a design process to identify and solve problems by creating new, useful, or imaginative solutions	***Standards for Students (continued)*** • Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally

Challenge Preparation

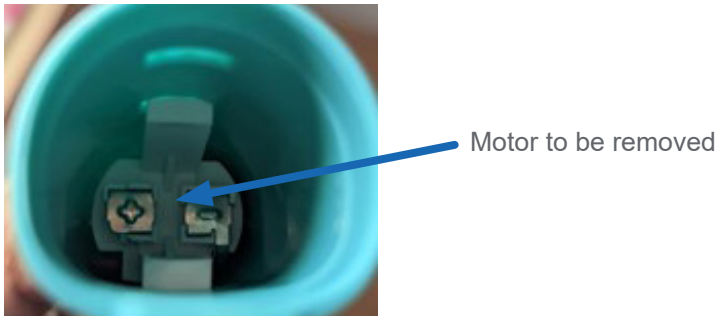
- Read the Introduction and Background section for this guide and the Educator Notes for this activity
- Print one student handout for each team

Materials

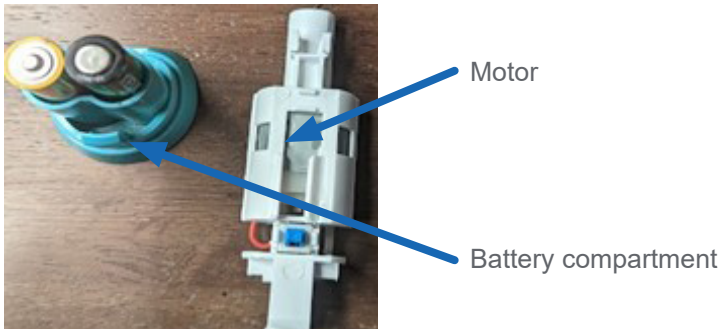
- Battery powered toothbrush (1 per team)
  Note to educator: You can check your local discount stores for this item.
- Foam noodle or plastic cup
- Rubber bands
- Electrical tape
- Metal washers or pennies
- Plastic spoon
- Craft sticks
- Chop sticks
- Push pin
- Paper clips

Directions for assembling the drill bot

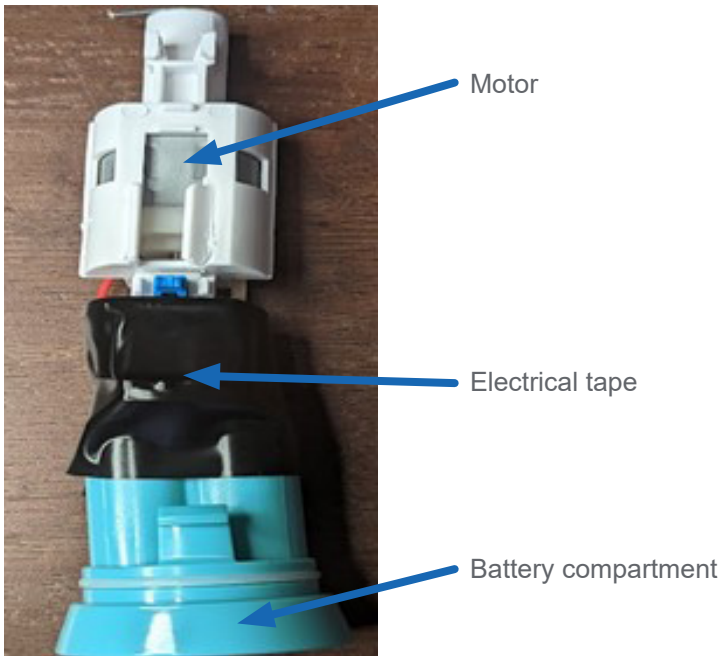
1. Assemble all supplies needed.
2. Remove the bottom end of the electric powered toothbrush. Remove the battery compartment. The motor will be underneath the battery compartment. Do not use a sharp object to pop the motor loose. Use eye protection for this step.



3. There will be 2 separate compartments that will need to be taped together with electrical tape for a complete motor.

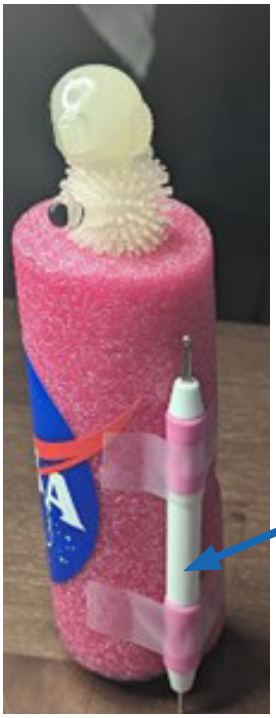


Note: Each toothbrush motor looks different, so the motor removed may not look like the one above.



4. Once the motor and battery compartment are taped together using electrical tape, insert the two parts into your noodle. *Note: It is easier to cut a small hole in the front of the noodle to allow access to the on/off switch for the motor. All exposed connections must be taped. The power must be off and completely taped with electrical tape to cover all exposed wires and conductive (metal) parts and exposed connections. All students must have the educator review their "build" before it is used to ensure all exposed conductive parts have been taped.*

5. Test to make sure that the drill bot can move easily before adding the drill or any decorations.
6. Add your drill and test using the water ice provided. The students will decide what their drill will be (e.g., plastic spoon, craft stick, etc.).



Here are some examples of problems students may encounter and some suggestions:

- The drill bot moves too fast around the icy-regolith
  - The student should consider adding some weight (washers or pennies may be used). Students need to determine where the weight should be added to make the drill bot more stable.
- The motor is not rotating freely
  - The student can enlarge the hole of the foam noodle to allow for more vibration for movement

Materials for simulated Icy-regolith

- Container (ice cube tray, plastic cup, etc.)
- Sand
- Water

Preparation for Icy-regolith

You will fill half the container with water and half with sand and place container in the freezer overnight. If you are using an ice tray, it is easier to use a teaspoon or tablespoon as a scoop to fill the tray halfway up with sand, then fill to the top with water and place in the freezer (preferably overnight). Simulated icy-regolith taken out of the freezer must be used immediately.

Safety

Ensure that

- Students wear eye protection when building and drilling the simulated icy-regolith
- Students practice safe cutting techniques when building and testing their drill. Carefully support the piece being cut. Be careful with placement of non-scissor holding hand.
- Students avoid moving about the room with scissors or other sharp objects
- Students tape with electrical tape the terminal ends of the batteries when they are not stored in their original packaging
- Students tape all bare wire and any exposed electrical connections with electrical tape. Students must review their build with the educator before turning it on.

Introduce the Challenge

- Provide context for this activity using the Introduction and Background section in this guide. Discuss the importance of drilling on the Moon.
- Share the video "The Polar Resources Ice Mining Experiment-1 (PRIME-1)." https://youtu.be/8WWUCusBHKY
- Group students into teams of three to five. Consider assigning roles and tasks to individual students within the team. See the Teamwork section at the beginning of the guide for suggestions.
- Distribute the student handout and scratch paper to each team.
- Explain the challenge to students.
  - Each team will be designing a drill that will be able to penetrate the simulated icy-regolith that have been given to you by your educator.
  - The drill must be able to obtain enough sample that can be transported.
  - Teams can only use the materials available to them.

Criteria	Constraints
Students cannot use their hands to move the drill bot.	Students must only use the materials provided by the educator.
Students cannot apply objects other than what is provided to add weight on their drill bot.	Students must not apply any additional weight to the drill.

Facilitate the Challenge

ASK

- Share this question with students: What is the difference between ice and icy-regolith?
- Have students brainstorm for a few minutes all the properties that they know about water and all the properties they know about ice.

  Give teams 4-6 ice cubes and 4-6 of the icy-regolith ice cubes (water and sand mixture). Tell students that they are going to compare how ice cubes and the icy-regolith melt under different conditions. *Note: This can also be done as a classroom demonstration, having teams just do one of the conditions below. You may also want students to time how long it takes the ice cubes to melt.*
- Ask students to predict what will happen to the ice and icy-regolith under the following conditions: (Icy-regolith

cubes will melt the faster than regular ice cubes in each of the conditions below, but especially in the hot water.)
  - Both placed in a dish of room temperature water
  - Both placed in a dish of hot water
  - Both placed under flowing room temperature water
  - Both placed under flowing hot water
- Ask students the following questions:
  - Which ice cubes melted fastest? Icy-regolith or ice?
  - Were your predictions and results similar? Different?

IMAGINE

- Share the video "NASA's Break the Ice Challenge" https://youtu.be/wXS0uCLisu8
- Allow students to see all the materials before building their drill bot
- Have students create their own individual sketches of their drill, and then the group, as a whole, will incorporate the strengths of each design into one final idea

PLAN

- Each team will now create one sketch of their drill bot design, complete with labels and descriptions of the materials used. Have students keep in mind the following questions:
  - How will you ensure that the drilling device will not break?
  - What mechanism will you use to ensure that the drill is breaking up the water ice?
- After reviewing each group's drawing, allow students to retrieve the needed material to construct their drill bot

CREATE

- Be sure to confer with students during the activity.
- Have teams construct their drill bot
- Their drill bot must use only one device for drilling (e.g. Chopsticks, craft sticks, paper clip, etc.)

TEST

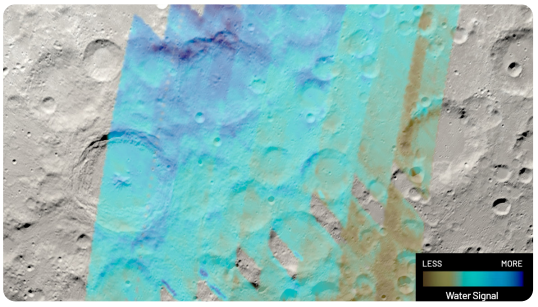
- Now that students have created their own drill bot, allow them to test their drill bot on the simulated icy-regolith
- Ensure that teams are not adding any additional weight to their drill bot and are not using their hands

IMPROVE

- Now that teams have built and tested their drill bot, they may need some help in troubleshooting their designs if failures occur. Be sure to visit and spend some time with each team and ask the following probing questions:
  - Is the design working as expected? What can be improved to change it?
  - What are the weaknesses in the design, and what can be done to overcome the weaknesses?
  - Do you think additional weight needs to be added to the drill bot? If so, where would you add it?

Share With Students

Brain Booster



First detailed wide-area map of water on the Moon.

Did you know that scientists thought there was water on the Moon in 1645? Discover the history of how scientists discovered water on the Moon in an interactive timeline.

Learn more:https://moon.nasa.gov/inside-and-out/water-on-the-moon/

On Location

VIPER, Volatiles Investigating Polar Exploration Rover, will travel on four hollow wheels with ribs for traction in powdery, abrasive Moon dust. So how did scientists test VIPER? The team used a dust chamber at NASA's Johnson Space Center in Houston and the Simulated Lunar Observation Laboratory (SLOPE) at NASA's Glenn Research Center.

Learn more:
https://ares.jsc.nasa.gov/projects/simulants/dust-testing-facilities/johnson-space-center.html (Johnson Dust Testing)
www.nasa.gov/specials/slope360/# (Slope Lab Tour)

SHARE

- Engage students with the following discussion questions:
  - What are some of the difficulties your team faced during the initial design and build process, and how did you overcome them?
  - Were you surprised at how difficult it was to drill through simulated icy-regolith?
  - What was something about another team's model that impressed you?
  - How were you able to improve your design through the improve phase? What changes did you make and how did they improve your bot's performance?
- Optional: The above questions can be used as a written self-reflection for students
- Optional: Have student groups share the drill bot they have invented with other classes or grade levels
- Optional: Share student results on social media using #NextGenSTEM. Be sure to include the module and activity name

Extensions

- Have students design and create a drill using simple machines or a robotics kit
- Explore the Break the Ice Challenge: https://breaktheicechallenge.com/
- "Explore Polar Resources Ice Mining Experiment-1 (PRIME-1)": www.nasa.gov/directorates/spacetech/game_changing_development/projects/PRIME-1

Reference

- Melting Ice Experiment: www.jpl.nasa.gov/edu/teach/activity/melting-ice-experiment/

Activity Two: Drilling on the Moon

STUDENT HANDOUT

Your Challenge

In this challenge, you will be working in teams to construct a drill bot that is able to drill through icy-regolith.

Criteria	Constraints
Students cannot use their hands to move the drill bot.	Students must only use the materials provided by the educator.
Students cannot apply objects other than what is provided to add weight on their drill bot.	Students must not apply any additional weight to the drill.

? ASK

- You will be performing an experiment to see the difference between ice and the icy-regolith found on the Moon
- Predict what will happen to the ice and icy-regolith under the following conditions:
  - Both placed in a dish of room temperature water
  - Both placed in a dish of hot water
  - Both placed under flowing room temperature water
  - Both placed under flowing hot water
- Perform the experiment and notice differences between how ice and icy-regolith melt
- Answer the following questions:
  - Which ice cubes melted fastest? Icy-regolith or ice?
  - Were your predictions and results similar? Different?

IMAGINE

- As a team, take some time to discuss how you want to construct your drill bot
- Have each member sketch their own idea; then the group can incorporate the strength of each design
- Make sure you see all the materials before sketching your drill bot

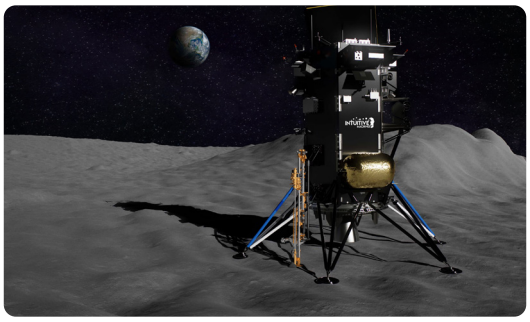
PLAN

- You will now create one sketch of your drill bot design, complete with labels and descriptions of the materials being used. Keep in mind the following questions:
  - How will you ensure that the drilling device will not break?
  - What mechanism will you use to ensure that the drill is breaking up the icy-regolith?
- After your educator approves your sketch, retrieve the materials needed to construct your drill bot

Share With Students

FUN FACT!

What do you think about when you hear PRIME-1? The Polar Resources Ice Mining Experiment-1 (PRIME-1) will be the first in-situ resource demonstration on the Moon. NASA will robotically sample and analyze ice from below the surface.



An artist's rendering of NASA's Polar Resources Ice Mining Experiment-1 (PRIME-1).

Learn more: www.nasa.gov/directorates/spacetech/game_changing_development/projects/PRIME-1

CAREER CORNER

Jacqueline Quinn. Credits:NASA

Jacqueline Quinn is the project manager for Polar Resources Ice Mining Experiment-1 (PRIME-1), which is compromised of the Mass Spectrometer Observing Lunar Operations (MSolo) and The Regolith and Ice Drill for Exploring New Terrains. MSolo will assess gases in the environment after Volatiles Investigating Polar Exploration Rover (VIPER) touches down on the Moon. The TRIDENT will dig as much as 3 feet below the lunar surface.

Learn more: https://youtu.be/7zkzlWeXk_M

CREATE

- Construct your drill bot and make sure that everyone on your team can help
- Make sure the drill bot contains only one device for drilling (e.g. chopsticks, craft sticks, paper clip, etc.)

TEST

Now it is time to test your drill bot.

- You will see if your drill bot can drill through the icy-regolith and obtain a small sample
- Ensure that you are not adding any additional weight to your drill bot by using your hands

IMPROVE

Now that you have built and tested your drill bot, you may need to improve it based on your results. Be sure to think about the following questions as you work to improve your design:

- Is the design working as expected? What can be improved to change it?
- What are the weaknesses in the design, and what can be done to overcomes the weaknesses?
- Do you think additional weight needs to be added to the drill bot? If so, where would you add it?

SHARE

Present your drill bot to the class; discuss any challenges your team faced and how you overcame those changes. Think about the following questions:

- What are some of the difficulties your team faced during the initial design and build process, and how did you overcome them?
- Were you surprised at how difficult it was to drill through simulated icy-regolith?
- What was something about another team's model that impressed you?
- How were you able to improve your design through the improve phase? What changes did you make and how did they improve your bot's performance?