# PERMAFROST IN A BOX

## Overview:

Students review permafrost as the foundation of the Arctic then build a model representing permafrost conditions and record changes over time.

(**NOTE:** This lesson requires several days to complete.)

## Objectives:

The student will:

- play a vocabulary game to review permafrost terminology;
- build a class model of permafrost features then record changes over time; and
- design a presentation about the class model to share with others.

## Targeted Alaska Grade Level Expectations:

*Science*

[10-11] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[9] SA2.1 The student demonstrates an understanding of the attitudes and approaches to scientific inquiry by formulating conclusions that are logical and supported by evidence.

[10] SG4.1 The student demonstrates an understanding that advancements in science depend on curiosity, creativity, imagination, and a broad knowledge base by recognizing the role of these factors on scientific advancements.

## Whole Picture:

Traditional Athabascan housing did little to permanently damage the ground upon which it was built, largely because most communities were semi-permanent. Housing was built to suit the season. In the spring, families traveled to fish camps. In the winter, homes were built and insulated with available material. Because the homes were often disassembled in the spring, permafrost was not damaged.

Modern communities are permanent. More and more land is used to build homes, businesses and roads. The result is the thaw of ice-rich permafrost and damage to structures above due to settling.

Building on permafrost requires consideration of potential thaw. While permafrost can extend hundreds of feet deep, it is only the top section that concerns builders. This poses a problem, because permafrost usually does not begin until several feet below ground level. As long as it remains frozen, it is very strong and stable. If the frozen ground is subject to heat transfer, it will thaw. For this reason, structures built on top of permafrost can gradually sink; any heated areas will sink more rapidly. Over the years, this can cause the structure to buckle and even collapse.

The most common way to preserve permafrost is by insulating the structures to be built on top of it. One way to do this is to build on pilings that allow air to circulate between the structure and the ground. Another way of preserving underlying permafrost is to raise the construction ground with gravel to the height of the foundations, or to dig down to permafrost and replace the soil with gravel. A modern way to preserve underlying permafrost is through refrigeration, using thermal pilings or freeze tubes. Such refrigeration works well with minimum maintenance so long as the climate and structure of the soil remains consistent.

## Vocabulary:

**active layer** – the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost

**advection** – the transfer of heat energy through liquids and gases that move

**conduction** – the flow of energy, such as heat or an electric charge, through a substance; in heat conduction the energy flows by direct contact of the substance's molecules with each other

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**continuous permafrost** – geographic areas in which permafrost occurs everywhere beneath the exposed land surface

**convection** – the transfer of heat energy through liquids and gases by the movement of molecules; when molecules of liquid or gas come in contact with a source of heat, they move apart and away from the heat (become less dense) then cooler molecules take their place

**discontinuous permafrost** – permafrost occurring in some areas beneath the exposed land surface throughout a geographic region where other areas are free of permafrost

**drunken forest** – trees leaning in random directions caused by thawing permafrost

**dry permafrost** – permafrost containing neither free water nor ice

**frost action** – movement due to alternate freezing and thawing of moisture in soil, rock and other material

**frost heave** – the upward or outward movement of the ground surface (or objects on or in the ground) caused by the formation of ice lenses in the soil

**hummock** – a rounded knoll of mineral soil and ice rising above the general level of the land surface

**ice lens** – horizontal, lens-shaped body of ice under ground

**ice vein** – an ice-filled crack or fissure in the ground

**ice wedge** – narrow ice mass that is three to four meters wide at the ground surface and extends as much as 10 meters down; formed when cold temperatures lead to cracks in the ground; during spring these cracks fill with meltwater and sediment, then freeze when the temperature drops again

**massive ice** – large masses of ground ice, including wedges, pingo ice, buried ice and large ice lenses

**permafrost** – ground that remains at or below freezing for two or more consecutive years

**piling/pile** – a long slender column usually of timber, steel, or reinforced concrete driven into the ground to carry a vertical load

**pingo** – a term, borrowed from the Eskimo language, for a perennial frost mound consisting of a core of massive ice with soil and vegetation cover

**radiation** – the movement of energy through space or a medium such as air

**thaw slump** – a slope failure resulting from thawing of ice-rich permafrost

**thermal piling** – a foundation pile on which natural convection or forced circulation cooling systems or devices have been installed to remove heat from the ground

## Materials:

- Clear plastic rectangular tub or terrarium (approx. 18" x 12")
- Small plastic food storage container (3 of them, approx. 3 cups)
- Ice-cube tray
- Measuring cup
- Disposable protective gloves (two pair)
- Sand
- Water
- P-gravel
- Air-activated disposable hand warmers (12)
- Foam craft sheets
- Modeling clay (any color except white)
- Craft sticks (two packages)
- Milk cartons (pint or half-pint)
- Glue
- Scissors
- Access to a freezer
- Digital camera/video camera
- Foam core
- Bubble wrap

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- Masking tape
- Index cards (one pack)
- Permanent marker
- STUDENT INFORMATION SHEET: "Permafrost Defined"
- TEMPLATE: "Paper Box"
- STUDENT LAB: "Box-O-Frost"

## Activity Preparation:

**NOTE:** If this lesson is completed during months when outside temperatures remain below freezing all day, preparations and lab work can be accomplished using outdoors as your freezer. If not, a large amount of freezer space will be needed for two to three days.

1. One day prior to beginning the lesson, fill three small plastic food storage containers each about 2/3 full of water and place outside or in a freezer. Fill an ice-cube tray and place in the freezer.
2. The lesson calls for time-lapse photography to capture simulated thawing permafrost. Consider the most appropriate way to document the lab in order to capture a picture periodically during school hours (and beyond, if possible). See Activity Procedures 7 through 9. Use a timer. Assign different students specific hours of the day and provide a five-minute pass for each with a note and the time. Prior to taking each picture, students should write the date and time on an index card then place it in view of the camera as the shot is taken to help ensure photos are easy to sort.
3. Prepare the foam core needed on Day 2 ahead of time. Cut a piece to measure slightly larger than the base of the terrarium. The terrarium will sit on foam core beginning Day Two. Cut pieces to be placed over bubble wrap around the sides of the container. The top will remain open.
4. Review the section in the lesson titled "Extension Idea" and consider including temperature measurements in the lab. Create a data sheet for recording temperature or ask students to note the temperature on the index card along with the date and time of each photo.

## Activity Procedure:

**NOTE:** Plan time for teacher preparation one day prior to beginning. Plan time during three class periods for this lesson: Two days for set up and a final day for observation and documentation. Days two and three will not take the entire class. For planning purposes, read through the lesson, including Activity Preparation, to determine the day to begin.

1. Review permafrost terminology and concepts as needed. Consider playing vocabulary Pictionary using STUDENT INFORMATION SHEET: "Permafrost Defined." Write the vocabulary words on the board, leaving adequate space for students to draw during the game. Students must draw a word without making any sound, or writing letters or numbers. Play in teams or simply with one student drawing and allowing the whole class to yell the word when they know it.
2. Ask students to assist in preparing for an upcoming demonstration about permafrost. Hand out STUDENT INFORMATION SHEET: "Box-O-Frost." This will assist you in leading students through the set up of a model that represents different permafrost conditions.

   During the day assigned to set up, divide students into groups. The first activity, DAY 1 – Planning, requires students to make items that will be used to create a community on the surface of the permafrost model. Using milk cartons, craft sticks, foam craft sheets, Model Magic® and other items scavenged from the classroom ask students to build items that will be placed on the model. TEMPLATE: "Paper Box" is included in the lesson, if needed for building structures. Students are prompted to consider building homes, schools and other larger buildings, and roads. Divide different tasks among groups. The instructions do not prompt students to consider the insulating properties of the structures. As you circulate to observe student work, consider suggesting students consider this in planning. Perhaps one structure could use foam craft sheets as foundation material. One structure could be slightly elevated on "pilings" using craft sticks. Roads could be made of foam, Model Magic® or P-gravel.

3. Remove the three small plastic storage containers and the ice-cube tray from the freezer. Review different types of permafrost such as ice wedge, ice vein and ice lens. Discuss the best way to represent different features, including size and shape, using the ice from the containers. Break into chunks and wedges. Move on to DAY 1 – Set Up. As appropriate, ask student volunteers to assist with set up as well as photographing/video recording the progress. As you proceed through each section, discuss what each represents.

   During STEP 1, the P-gravel is put in place for drainage purposes, however, discuss the fact that not all permafrost contains water. The definition of permafrost is based on temperature. Dry permafrost, for example, is defined as permafrost containing neither free water nor ice. Ask students if the ground would shift if dry permafrost increased to a temperature above freezing. (*The answer is no.*)

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   **NOTE:** Don't forget to ask students to take pictures/video during each step. Ask students to take just a few seconds worth of footage if using a digital video recorder.

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   During STEP 2, the soil is mixed with water to create soil with water content. Most permafrost has about 50 percent water content.

   During STEP 3, the damp soil is layered and chunks of ice are put in place. The demonstration will obtain a dramatic result if you place a long piece of ice in a vertical orientation. Discuss that soil conditions vary in most places where permafrost is present. Ice wedges, ice lenses and ice-rich soil are intermingled in regions with continuous and discontinuous permafrost. Most Alaska communities rest on some permafrost. Permafrost can be hidden, undetectable from the surface view. The active layer (in this model, the dry top soil) and vegetation can further disguise what lies beneath.

   Ask students what is represented by the hill formation with an ice interior created in STEP 4 (pingo). Ask students if it would be wise to build a structure on a pingo? Why or why not?

   STEP 5 requires the entire container to freeze thoroughly to create permafrost. The active layer freezes in the winter, then thaws in the summer. Place the entire terrarium in a freezer or, if temperatures will remain below freezing, place the container outside in a place it will not be disturbed. Allow the container to freeze for at least 24 hours.

4. Once the container has had the opportunity to freeze throughout for at least 24 hours, bring it back into the classroom. Place the planned community and allow students time to sketch the set up on the sheet, STUDENT LAB: "Box-O-Frost." This is when the hand warmers are placed. Ask students what the hand warmers intend to simulate (home heating units). Use no more than six warmers, saving the remainder for the following day. Students must note the date and time. Be sure to document with pictures and/or video, as well. Once students have sketched it and photographed it, wrap the bottom and sides in foam core and bubble wrap (outside). Secure with masking tape. Explain this it to help simulate the way actual permafrost thaws from the top down.

   Students can now begin observing and documenting. (See STUDENT LAB: "Box-O-Frost," DAY 2) This will also require teacher involvement, as student will not be able to continually monitor the model unless they remain in the same room all day. Decide the best way to record the progress over the next couple of days. (See Activity Preparation 2)

5. Set a timer to alert you to take a picture of the model every hour (or as often as is possible) for the next two days. Place a permanent marker and a stack of index cards next to the container. Each time a photo is taken, write the date and time on an index card and place it in the photo. Students will observe and document on days two and three, as well. Place pictures/video of the demonstration in a file accessible to students for later use.

6. On DAY 3 replace hand warmers in the structures and allow time for students to make observations. Ask students to sketch the model after 24 hours then describe their observations. Discuss the results as a class. Ask the following:
   a. What, if anything, has happened over the last 24 hours?
   b. How did the heat get from the hand warmers to the permafrost? (energy transfer, conduction, radiation)

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   c. Besides the hand warmers, were there any other sources of heat thawing the permafrost? (the heated classroom, radiation, convection)
   d. What permafrost feature suffered the most amount of damage?
7. On DAY 4 allow time for students to make observations. Ask students to sketch the model after 24 hours then describe their observations. Discuss the results as a class. Ask the following:
   a. What has happened over the last 48 hours?
   b. Are the results in any way surprising?
8. Ask students to complete any remaining lab observations and the critical thinking questions.
9. Divide students into groups. Ask students to use video software, such as *iMovie®* or *Comic Life*, or presentation software such as *Microsoft Office PowerPoint™* or *Mac Keynote®*, to place the pictures or clips into a presentation format. Ask students to add text and other elements to explain the demonstration, both purpose and outcome. Students must use at least five vocabulary words from STUDENT INFORMATION SHEET: "Permafrost Defined" in their presentation. Teacher's discretion should determine the amount of time students are allowed to work on the presentation and whether presentations will be shared with peers or in other classes. Consider saving the best to present at the Climate Expo. Students can use the presentation (or parts) in their stewardship project, if desired.

## Ideas for Filming:

**NOTE:** Students will create a short film about permafrost for the final project associated with this UNITE US unit. Each lesson leading to the final project contains ideas about what students might film as they compile clips. Students are not limited to the list and are encouraged to use their imagination and creativity when filming.

Use the pictures and/or digital video recorded during set up and documentation.

## Extension Idea:

In addition to documenting permafrost thaw, consider recording temperature changes as the thaw progresses. Use a digital probe thermometer and record the temperature at the same time the photo is taken. Record the data on a chart or on each index card then use the data to create a temperature graph.

## Answers:

1. – 4. Answers will vary.
5. The most likely answer circled will be: a small change.
6. Answers will vary.
7. Answers should reflect an understanding that through conduction and radiation the warmth from the hand warmers thawed the permafrost in the model.
8. Answers will vary.
9. The most likely answer circled will be: a big change.
10. Answers will vary.
11. Answers should reflect an understanding that the ice in the soil melted and drained away, leaving a void, causing the soil to collapse.
12. the hand warmers and the air in the room
13. Home heating system, such as a furnace or a wood stove.
14. Answers will vary, but may reflect the observation that insulated structures thawed the ground beneath more slowly.
15. It is important to either avoid building on permafrost or insulate it well enough to protect the permafrost.
16. Answers will vary.

# PERMAFROST DEFINED

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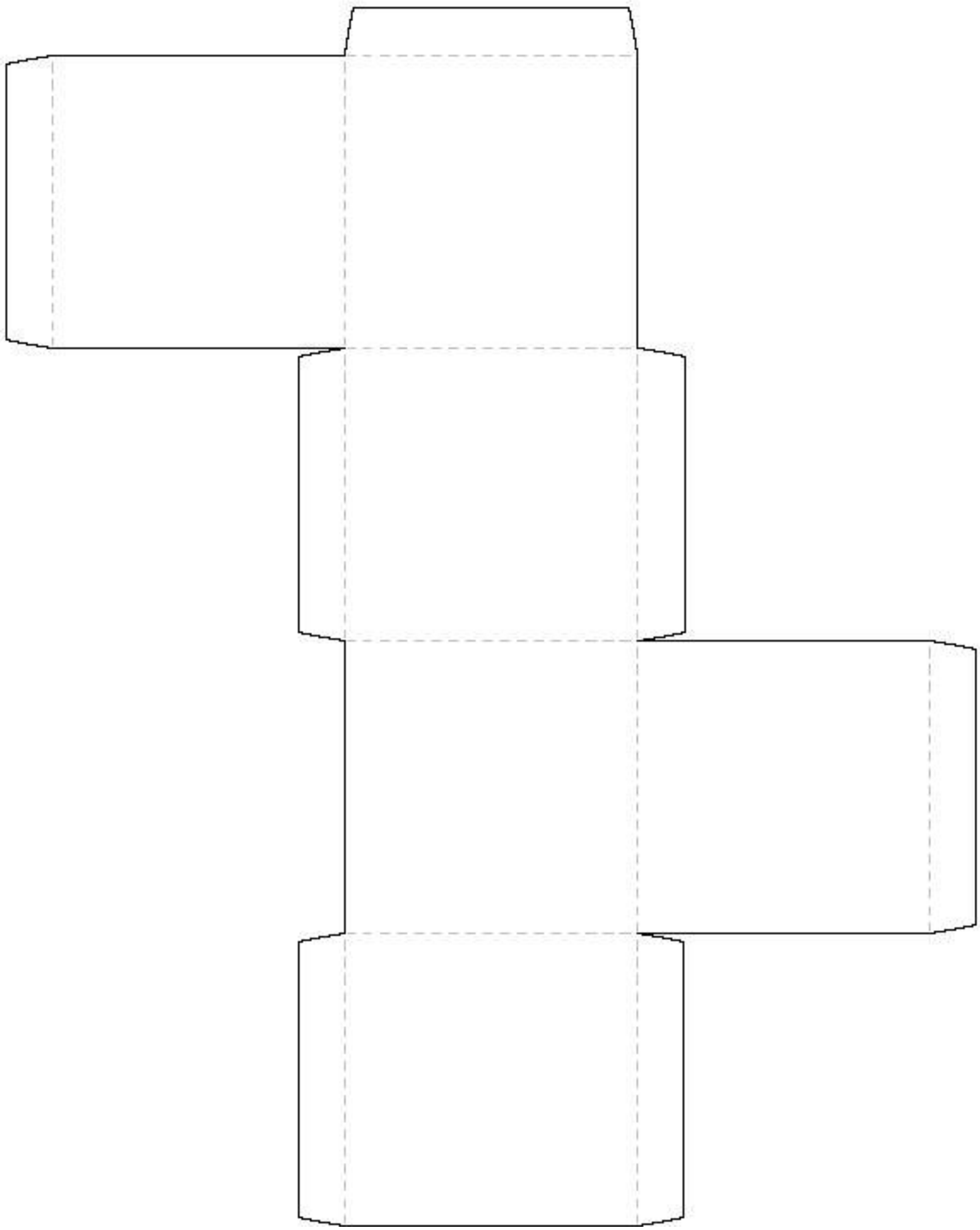
|---|---|
| **active layer** | the layer of ground above permafrost that thaws in the summer and is biologically active (plants can grow, animals can burrow, etc.) |
| **continuous permafrost** | regions where permafrost occurs everywhere beneath the exposed land surface; mean annual soil surface temperatures are typically below -5° Celsius |
| **conduction** | the flow of energy, such as heat or an electric charge, through a substance; in heat conduction the energy flows by direct contact of the substance's molecules with each other (meaning energy flows when things are touching) |
| **convection** | the transfer of heat energy through liquids and gases by the movement of molecules; when molecules of liquid or gas come in contact with a source of heat, the move apart and away from the heat (become less dense) and cooler molecules take their place |
| **discontinuous permafrost** | regions where some areas beneath the land surface have permafrost underneath but other areas do not |
| **drunken forest** | trees leaning in random directions caused when thawing permafrost makes the ground unstable and tree roots lose stability |
| **dry permafrost** | permafrost containing neither free water nor ice |
| **frost action** | movement due to alternate freezing and thawing of moisture in soil, rock and other material; water expands when it freezes |
| **frost heave** | the upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice lenses in the soil |
| **hummock** | a rounded knoll of soil and ice rising above the general level of the land surface |
| **ice lens** | horizontal, lens-shaped body of ice under ground |
| **ice vein** | an ice-filled crack or fissure in the ground |
| **ice wedge** | narrow ice mass that is three to four meters wide at the ground surface and extends as much as 10 meters down; formed when cold temperatures lead to cracks in the ground; during spring these cracks fill with melt water then freeze |
| **massive ice** | large masses of ground ice, including wedges, pingo ice, buried ice and large ice lenses |
| **permafrost** | ground that remains at or below freezing for two or more consecutive years |
| **piling** | a long slender column usually of timber, steel, or reinforced concrete driven into the ground to carry a vertical load |
| **pingo** | a term, borrowed from the Eskimo language, for a perennial frost mound consisting of a core of massive ice with soil and vegetation cover |
| **thaw slump** | a slope failure resulting from thawing of ice-rich permafrost |
| **thermal piling** | a foundation piling on which natural convection or forced circulation cooling systems have been installed to remove heat from the ground |
| **radiation** | the movement of energy through space or a medium such as air |

# PAPER BOX



**Directions:** Print the template on heavy paper to make a sturdy structure, if desired. Cut out along black lines, fold on the dotted lines, then glue the tabs to the inside of the box. Do not glue the top flap - you will need to be able to open and close the box.



**NAME:** ______________________________

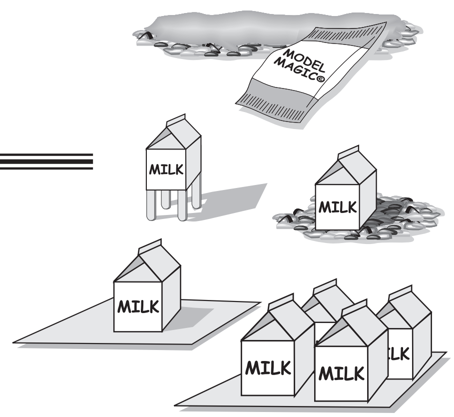
**BOX-O-FROST**

**Directions:** Using the materials listed, and other scavenged items, build a class model of permafrost conditions then observe and record changes over time.

**Materials**

- Clear plastic rectangular tub or terrarium (approx. 18”x12”)
- Measuring cup
- Disposable protective gloves
- Sand
- Water
- P-gravel
- Air-activated disposable hand warmers (12)
- Foam craft sheets
- Modeling clay (any color except white)
- Craft sticks
- Milk cartons (pint or half-pint)
- Foam core*
- Bubble wrap*
- Masking tape
- Glue
- Scissors
- Attached TEMPLATE: “Paper Box”
- Ice
- Ice cubes

*enough to wrap the bottom and sides of the terrarium




## DAY 1

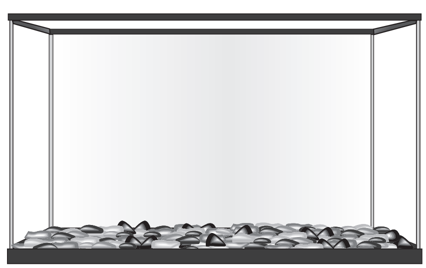
**Planning**

The permafrost model the class will be building and observing will have a community sitting on the surface. Using milk cartons, craft sticks, foam craft sheets, modeling clay and other items scavenged from the classroom, to plan and build structures to represent a community. Consider building homes, a school and roads. Remember the total surface of the terrarium is 18” x 12.”

**Set Up**

Your teacher may ask for help in documenting (photos and/or video) and setting up the following:

STEP 1: Pour enough P-gravel into the bottom of the terrarium to measure about 1 inch in depth.

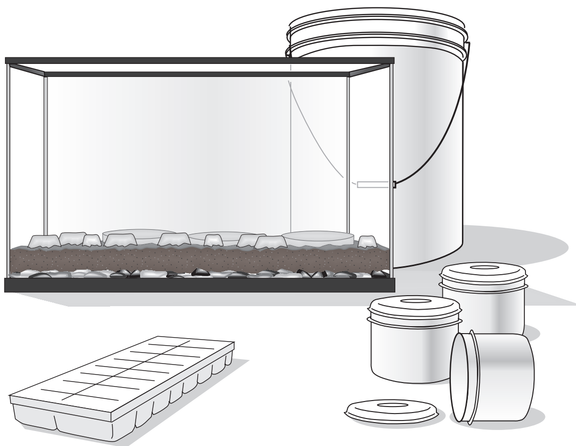



STEP 2: Pour sand into a container (not the terrarium) until it is about half full. Slowly pour 2 cups of water over the soil, mixing with a gloved hand as you pour. Distribute the water evenly. It should be damp. Add more water as necessary.

**NAME:** ______________________________

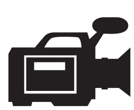
**BOX-O-FROST**

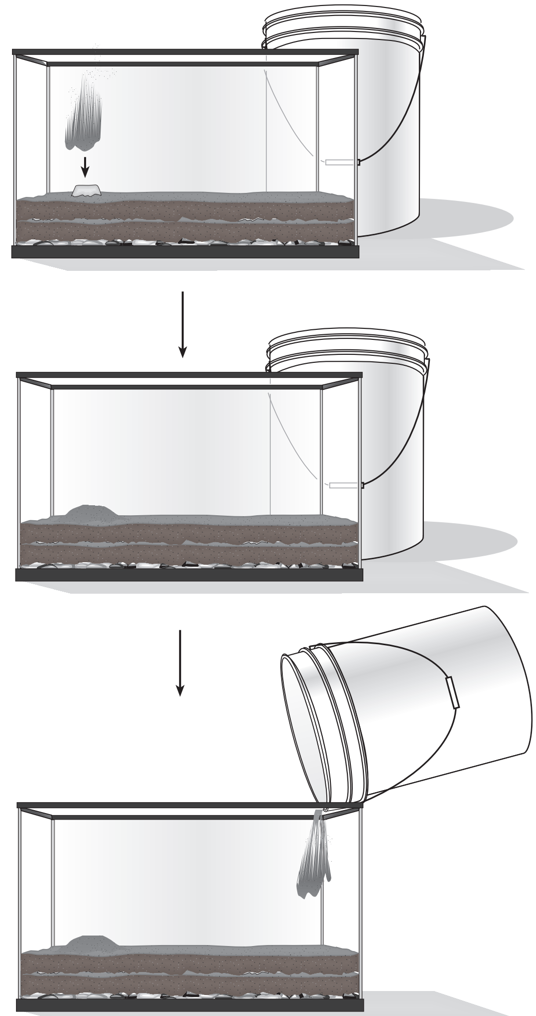
STEP 3: Layer the damp sand over the P-gravel in the terrarium to a depth of about 2 inches. Place large chunks of ice and ice cubes on the sand. (Reserve one ice cube for STEP 4.) Gently press the ice into the sand. Cover the ice with more damp sand, mixing more as necessary. Gently compact the soil to make an even surface. Leave room for a ½-inch+ layer of dry topsoil to sit on the top without spilling over.



STEP 4: Place one ice cube on the surface. Take about 1 cup of damp potting soil and form a hill around the ice cube, pressing lightly to keep it in place. Make sure the ice is completely covered. Place the remaining ½ inch of dry topsoil on the container surface, leaving the pingo to stand out.

STEP 5: Place the entire terrarium in a freezer or, if outside temperatures will remain below freezing, outside in a place it will not be disturbed. Allow the container to freeze for at least 24 hours.





Don't forget to take pictures and/or video while putting together the model!

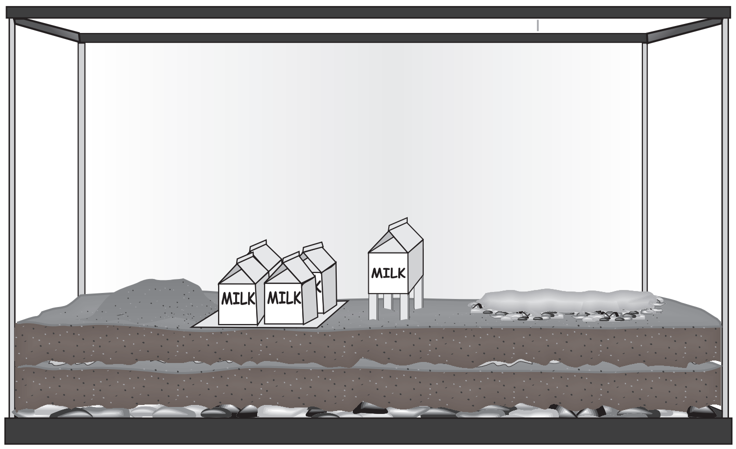
**NAME:** ______________________________

**BOX-O-FROST**

**DAY 2**

**Set Up**

STEP 1: Bring the container into the classroom. Take a picture or brief video (no more than 5 seconds) of the container prior to setting up the community. Place the structures planned and created on DAY 1 on the surface of the permafrost (buildings, roads, etc.).




STEP 2: Open the air-activated disposable hand warmers and shake until activated. Place one hand warmer inside each structure. (Use no more than six. Save the remaining for tomorrow.)

Take a picture or 5-second video as soon as everything is in place.

STEP 3: After you sketch the model, wrap the outside bottom and sides in foam core and bubble wrap to insulate. Secure with masking tape.

**Student Observation**

1. Sketch the model in the space below.

Date: __________________ Time: __________________

**NAME:** ______________________________

**BOX-O-FROST**

Write a **prediction** about what you think will happen to the permafrost model:

2. Over the next three hours:

___________________________________________________________________________

___________________________________________________________________________

3. Over the next 24 hours:

___________________________________________________________________________

___________________________________________________________________________

**DAY 3**

**Student Observation**

4. Sketch the current state of the model in the space below, then replace the hand warmers in each structure.

Date: __________________ Time: __________________

Complete the following questions based on your observations of the model:

5. ***Circle one.*** After 24 hours there is **no change** / **a small change** / **a big change** in the model.

6. Describe differences you see in the model from Day 1 to Day 2.

___________________________________________________________________________

___________________________________________________________________________

7. Describe what kind of **energy transfer** caused the changes in the model over the last 24 hours.

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

**NAME:** ____________________________

**BOX-O-FROST**

**DAY 4**

**Student Observation**

8. Sketch the model in the space below.

Date: __________________ Time: __________________

Complete the following questions based on your observations of the model:

9. ***Circle one.*** There is **no change** / **a small change** / **a big change** in the model from Day 1.

10. Describe differences you see in the model from Day 1 to Day 3.

______________________________________________

______________________________________________

**Follow-up Questions**

11. What caused the collapse of the soil surface?

______________________________________________

12. In the model, what were the sources of heat that caused the ice to melt?

______________________________________________

13. What does the source of heat inside each structure in the model represent in an actual home?

______________________________________________

14. How can you explain any differences in the way thawing occurred beneath different kinds of structures?

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______________________________________________

**NAME:** ____________________________

**BOX-O-FROST**

15. When building a structure, how can you prevent the heat from melting the ice and thawing the permafrost?

**Critical Thinking**

16. If permafrost thaw is a consequence of climate change, what can you do in the design of a house to keep it stable?