A BLANKET OF SNOW

Overview:

In this lesson students investigate the ecological impact of winter snowfall. Students record snow temperatures in different locations and depths and then view multimedia components to explore the impact of snow cover on permafrost.

Objectives:

The student will:
- Observe and record temperature measurements and make qualitative observations about snow cover;
- Explain that energy can be transferred from one place to another; and
- Relate snow cover and the presence of trees to the condition of underlying permafrost.

Targeted Alaska Grade Level Expectations:

[9] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[10] 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] SC3.1 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by describing the carbon and nitrogen cycle within an ecosystem and how the continual input of energy from sunlight keeps the process going.

[10] SC3.1 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by relating the carbon cycle to global climate change.

Vocabulary:

conductive heat flow – the process by which heat is directly transmitted through a substance due to a temperature gradient between adjoining regions

density – a measure of the compactness of a substance; equal to the amount of mass per unit volume

energy transfer – the movement of energy from one body to another

insulate – to cover or surround with a material that prevents the loss or transfer of heat, electricity, or sound

solar energy – energy produced by or derived from the sun

snow – crystals of ice that form from atmospheric water vapor and fall to Earth

sublimation – the process of changing from a solid to a gas, or from a gas to a solid, without passing through an intermediate liquid phase

subnivean – a zone that is in or under the snow

temperature gradient – an increase or decrease in the magnitude of temperature

thermal conductivity – the rate at which heat passes through a material; measured in watts per kelvin per meter (W/K/m)

Whole Picture:

The Alaska Native people have recognized the insulative properties of snow for thousands of years. Native ways of knowing teach to protect yourself from the cold of winter if caught out in the elements by building a snow cave and burrowing in. In the passage recommended from the book Shadows on the Koyukuk: An

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Alaskan Native's Life Along the River, Sidney Huntington tells the story of how his mother, Anna, survived a journey in the coldest winter months by doing just that. "Each night she wrapped herself in a blanket and burrowed into a snow bank for the insulation it provided," Sidney recalls.

The insulative properties of snow are one of the variables that affect permafrost temperature and condition. (Others include climate, vegetation, active layer depth, ice content, etc.)

Because snow is an insulator, it keeps heat energy in the ground (accumulated from solar energy in spring, summer and fall) from escaping during the winter. Increased snow depth generally means the ground will lose less heat during cold winter months. Little or no snow means the soil cools more rapidly. This can be detrimental for animals surviving in the subnivean space (under the snow) and for human infrastructure (water pipes, etc.).

Snow cover is not uniform from top to bottom. As soon as it hits the ground snow begins to change structure. Freshly fallen snow is still fairly fluffy and full of air. The bottom layer is compacted with far less room for air. Air provides most of the insulative value of snow, and so fluffy, fresh snow is a better insulator than compacted snow.

From the Geophysical Institute ALISON (Alaska Lake Ice and Snow) website (website is no longer available as the project has concluded):

"[Snow density can be] converted to a thermal conductivity value. Thermal conductivity is a measure of how well (or how poorly) a material conducts heat. Another way to look at it is to think of thermal conductivity as a measure of how good (or how poor) an insulator a particular material is. Dry snow is a good insulator (a poor heat conductor) because it has a relatively low density, i.e., there is a lot of air trapped between the snow crystals. It is the air that provides most of the insulation offered by a snow cover.

The product of the snow temperature gradient and the thermal conductivity is the conductive heat flow. That is, the snow temperature gradient multiplied by the thermal conductivity tells us how much heat is being conducted through the snow cover and in which direction."

Coniferous trees are another variable to consider when studying permafrost temperature and condition as it relates to the insulative value of snow. Trees provide a vehicle for energy transfer in the winter. Tree branches form an umbrella that shelters the ground beneath from accumulating snow. The result is an area with little or no snow, called a tree well, that allows heat to escape from the ground beneath, however, the dark color and shape of evergreen trees also absorb more radiant solar energy than a treeless landscape (which would tend to reflect more energy.)

Materials:

- Book "Shadows on the Koyukuk" by Sidney Huntington
- Clipboard (one per student)
- Waterproof digital thermometer (three)
- VIDEO: "Ecosystems and Permafrost"
- VISUAL AID: "Spruce Trees"
- VISUAL AID: "Snow as an Insulator"
- VISUAL AID: "Snow Metamorphism"
- VISUAL AID: "Come Down Out of the Cold!"
- STUDENT WORKSHEET: "Snow Insulates the Ground"
- STUDENT WORKSHEET: "Ecosystems and Permafrost"
- STUDENT WORKSHEET: "Snow Observations"

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Activity Preparation:

NOTE: Portions of this lesson can only be completed if there is sufficient snow cover! This lesson also requires the presence of evergreen trees.

Locate places near the school where students can observe snow cover. The activity requires areas with trees and areas without trees. Decide ahead of time a good location to take the temperature measurements described in step two of the procedure.

Activity Procedure:

1. Explain today's lesson will look at energy transfer in soil/snow. The focus will be on snow and trees and how each impacts the temperature of permafrost. Tell students they will be going outside to observe snow cover. While outside, the class will take three temperature measurements: one at the base of a tree, one on the top of snow away from trees, and one under the snow, also away from the trees. Ask students to predict which will be warmest and which will be coolest. Ask students to find a partner and take two or three minutes to share their prediction as well as the reasoning behind it.
2. In the book, *Shadows on the Koyukuk*, by Sidney Huntington (as told to Jim Rearden), Huntington tells the story of his grandmother Anna. In the winter of 1904 Anna was waylaid in Nome. No riverboats would run until breakup. Wanting desperately to return home to her children, she decided to travel more than 400 miles on foot to reach her home. Read students this story from the book (starting on page 17 and ending on page 22 in the sixth edition of the book, published in 2000). Ask students to listen for ways that Anna was able to survive when forced to camp out in the cold. (Examples in the book include burrowing into snow banks and getting in under the trunks of big spruce trees.) Discuss if/how this story supports or counters their predictions made above.
3. Hand out STUDENT WORKSHEET: "Snow Observations" with clipboards. Take students outside to an area with spruce trees, then to an area that is free of trees, to view the snow cover. Ask students to closely observe the difference between snow cover in forested areas (especially under the trees) compared to treeless areas. Students should record their observations on the worksheet. Students should also record the prediction they made.
4. Ask a student to place one digital thermometer at the base of a large evergreen tree. Another student can place a second digital thermometer on top of the snow in an area completely away from trees. Instruct students to wait a few minutes until the temperature stops moving or changing and then to read the temperature aloud to the class. Ask all students to record each temperature measurement on their observation sheet.
5. Return to the classroom. Give students a few minutes to finish STUDENT WORKSHEET: "Snow Observations."
6. Show students VISUAL AID: "Spruce Trees." Ask students if they observed a similar pattern under the trees they viewed. (Lack of snow or less snow creates a "well" under the tree.) Ask students to brainstorm reasons for and implications of this. Use the following questions as discussion starters, if needed:
    a. Why isn't there any, or as much, snow within the trees' drip line?
    b. Is it solely from the umbrella affect of the tree branches or is there another contributing factor? What might that be? *(Thinner snow means more heat can escape and that changes the snow pack. In warm temperatures, it may even melt. Also, the trees can absorb energy from the sun, contributing heat.)*
    c. From your observation sheet, where did we find the warmer temperatures? Why do you think that is? Where is the heat coming from? (*See above.*)
    d. What would happen if you placed the thermometer on a dark surface (outside)?
7. Show students the VISUAL AID: "Snow as an Insulator." Discuss.
8. Show VISUAL AID: "Come Down Out of the Cold!" Hand out STUDENT WORKSHEET: "Snow Insulates the

Ground." Read the worksheet aloud together. Suggest the air temperature in the image might be -30° Celsius. Ask students what they would expect the temperature at ground level to be. (The temperature at ground level should remain at 0° Celsius because of the insulating value of the snow. This allows small animals like lemmings and voles to survive in the "subnivean space" all winter.) Ask students to estimate the temperatures they would expect to find throughout the rest of the range and to fill them in on the lines provided.

9. Ask students to view VIDEO: "Ecosystems and Permafrost."
   Students should complete STUDENT WORKSHEET: "Ecosystems and Permafrost" as they go.

Ideas for Filming:

Students will complete 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.

- Assign one student from each small group to film while the class goes outside to make snow observations.
- Film one or both of the extension activities listed below.

Extension Ideas:

1. If the snow is two or more feet deep, consider the supplemental STUDENT LAB SHEET: "Snow Pit Measurements." Discuss the data collected.
2. If there is enough snow accumulation, build a snow cave. Measure the temperature difference outside the cave and inside the cave before it is inhabited. Then measure again with one person, two people, and three people after they've spent varying amounts of time in the cave.
3. Consider teaching a winter wilderness survival lesson. In "Shadows on the Koyukuk" Sidney Huntington recounts one of his tails of survival in extremely cold temperatures. The story begins midway on page 142 of the book, "My dictionary says…" (in the sixth edition of the book, published in 2000). The Alaska Tsunami Education Program has a lesson titled "I Will Survive" that includes emergency winter survival and how to build a snow pit shelter.

Answers:

STUDENT WORKSHEET: Snow Observations

Answers will vary.

STUDENT WORKSHEET: Ecosystems and Permafrost

1. Tundra is a vast arctic landscape with no trees.
2. Summer
3. Little
4. Snow acts as an insulator.
5. The raised clumps or uneven ground makes walking difficult.
6. Drawing should indicate heat escapes from the spaces between the tussocks where there is little snow.
7. Permafrost
8. Spruce trees have a shallow root system and are able to thrive in a shallow active layer.
9. Tree branches block snow from covering the ground.
10. Heat escapes from areas under the trees with little snow.

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SNOW OBSERVATIONS

11. Tundra permafrost would be more protected from thawing with a thinner layer of snow because it allows heat to escape. The permafrost would remain colder with a thinner layer of snow. A thicker layer of snow keeps the energy absorbed in the summer months from escaping. This can actually warm the permafrost.
12. The open area under evergreen trees provides a way for heat to escape, therefore it helps keep the permafrost cold.
13. Answers will vary but students should indicate that snow insulates and can be used to create shelter from the elements.

STUDENT WORKSHEET: Snow Insulates the Ground

Students should have filled in 0° Celsius at ground level and -30° Celsius as the air temperature. The values in between will vary but should reflect a gradual cooling from ground to air.

Directions: Observe the snow cover in your community. Note the difference between areas with trees and areas that are free of trees. Are there areas free of snow? Are there areas where it is unusually deep? Use the space below to write about, and/or draw, your observations.

1. Write your prediction. Where do you think you will find the warmest temperature: at the base of the tree, on top of the snow, or under the snow at ground level?

____

____

Complete the remainder of the worksheet as your teacher takes temperature measurements.

2. What is the temperature at the base of the tree? ______________________________

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ECOSYSTEMS AND PERMAFROST

3. What is the temperature on top of the snow, away from the tree? ______________________________

4. What is the temperature under the snow at ground level? ______________________________

5. Does the data support your prediction?

____

____

____

Directions: View VIDEO: "Ecosystems and Permafrost." Complete questions 1 - 10 as you explore the activity, then complete the critical thinking questions.

TUNDRA

1. What is tundra? ______________________________

2. During the ______________________________ heat from the sun radiates into the ground.

3. (Circle one.) During early winter heat escapes from the ground in areas of **great / little** snowfall.

4. What prevents heat from escaping the ground in late winter? ______________________________

____

TUSSOCKS

5. Why are tussocks nicknamed ankle breakers? ______________________________

____

6. Draw a diagram of tussocks in early winter that shows where the heat escapes the ground. Label your diagram.

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ECOSYSTEMS AND PERMAFROST

BLACK SPRUCE

7. The presence of black spruce trees often signals ____________________ below.

8. Why can black spruce survive in the thin active layer above permafrost? ____________________

____

9. In a black spruce forest, what keeps the snow from covering the ground? ____________________

____

10. In a spruce forest, where does heat to escape? ____________________

____

Critical Thinking

11. By definition, permafrost is ground that remains below 0° Celsius or 32° Fahrenheit for more than two years. Would tundra permafrost be more protected from thawing by a thick layer of snow or a thin layer of snow? Explain.

____

____

____

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SNOW INSULATES THE GROUND

12. Under black spruce trees the area under the branches often has little snow. How does this open "well" help keep the permafrost underneath from thawing?

____

____

____

____

13. If you found yourself in an emergency situation, faced with spending a winter night in the wilderness in sub-zero temperatures, how would you use your knowledge of the insulating properties of snow to help you survive? (Illustrate in the space below, if desired.)

____

____

____

____

Alaska experiences very cold temperatures each winter, but these temperatures are not transferred to the ground because of the protective covering of snow. In the north, if snow doesn't fall until after the first cold snap, buried water pipes and septic systems can freeze for lack of insulation. Cabins that hold snow in the roof are warmer than those that do not, and without the snow cover, permafrost would be thicker and more extensive than it is now.

The structure and content of snow makes it a good insulator. Snow contains anywhere from 50% to 80% air, making it as good an insulator as a down parka or feather quilt. The air content of the snow is not uniform from top to bottom. As soon as snow hits the ground it begins to change form, which changes the air space between snow crystals. Three forces shape and change the snow pack: wind, temperature gradient, and heat.

- Wind blows the snow and pulverizes it into fine grains.
- Warm temperatures melt snow.
- Temperature differences from one part of the snow pack to another (temperature gradient) spur sublimation and condensation. Left over heat energy from the summer sun, stored in the ground, radiates upward.

Look at the image below. Your teacher will tell you the air temperature. Fill in the temperatures you would expect to find throughout the snow and at ground level.

NAME: ______________________________

SNOW INSULATES THE GROUND

Temperature Gradient

Air temperature
____

Snow surface
____

____

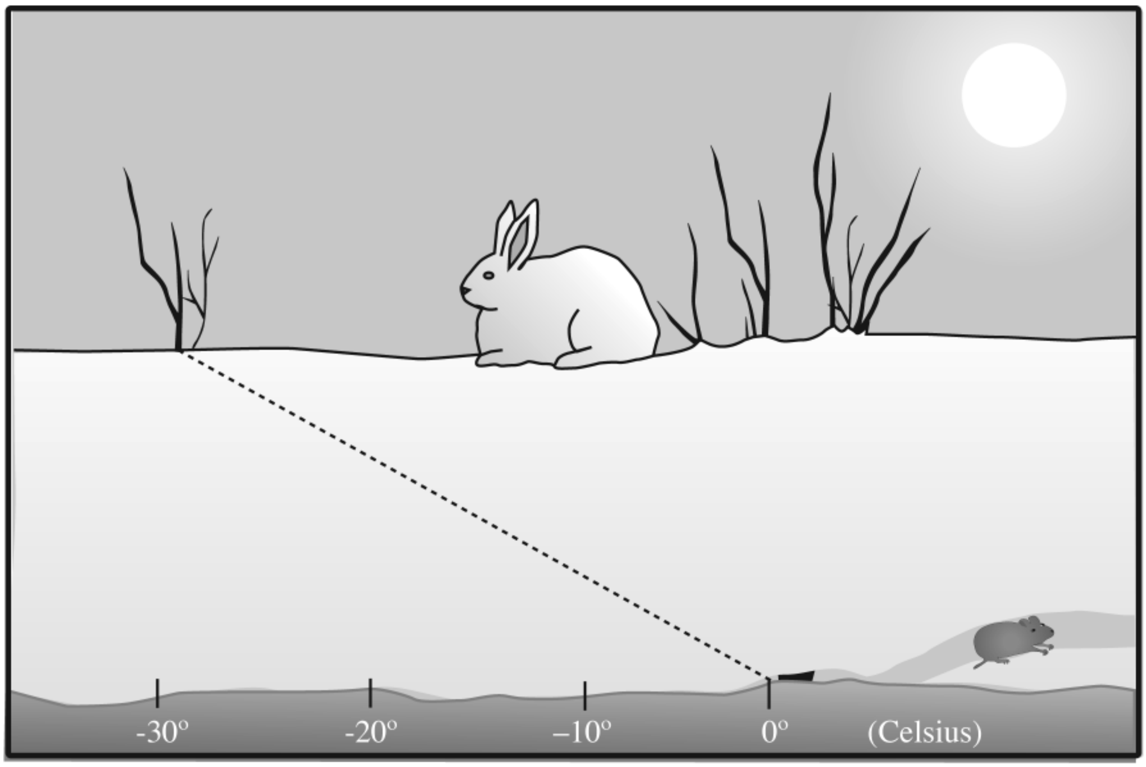
____

____

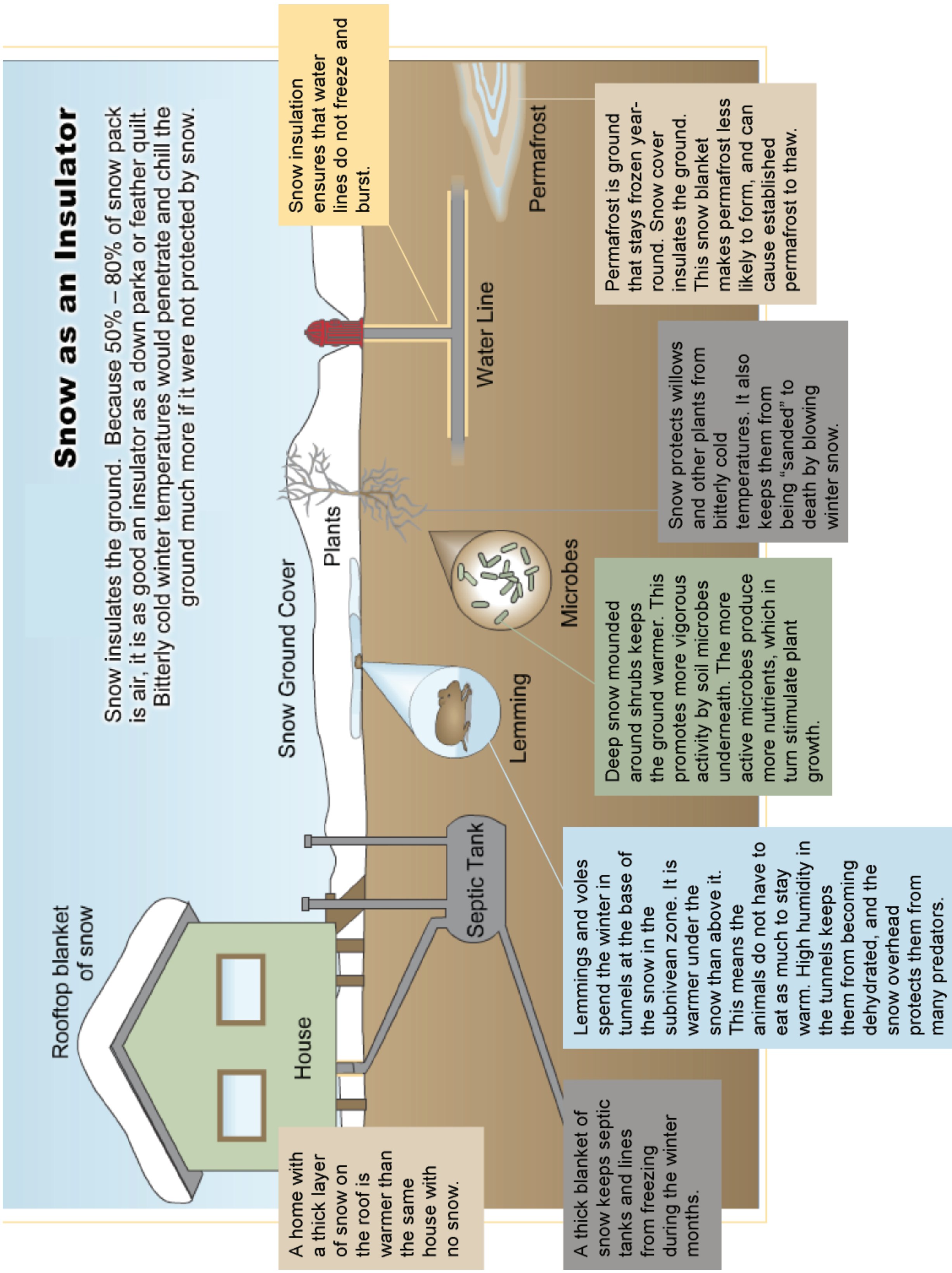
Ground level
____

SPRUCE TREES

COME DOWN OUT OF THE COLD!



COME DOWN OUT OF THE COLD!



NAME: ______________________________

SNOW PIT MEASUREMENTS

Directions: Working in a small group you will dig a snow pit then take measurements to determine if there is a temperature gradient in the snow pack. Appoint a recorder to note observations and measurements. Take turns with data collection. Follow the steps below to complete the lab.

Step One: Hypothesis

Choose One. Mark with an X.

A. __________ Based on the current weather conditions, I think I will find a **large** temperature gradient from the ground level to the surface of the snow pack.

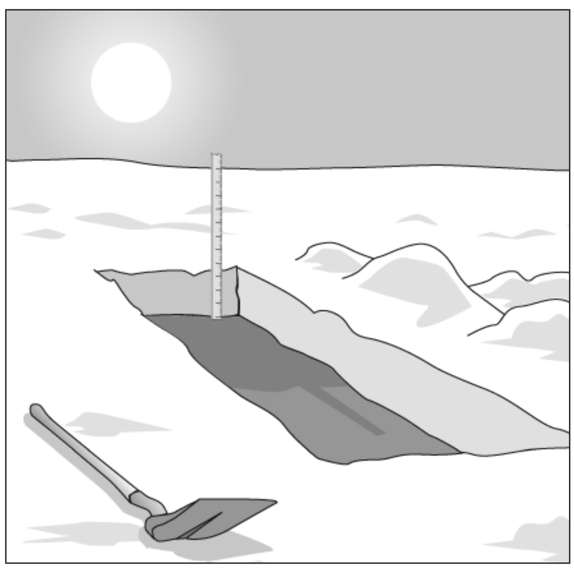
B. __________ Based on the current weather conditions, I think I will find a **small** temperature gradient from the ground level to the surface of the snow pack.

Lab Materials:

Clipboard
Pencil
Tongue depressors (10+)
Waterproof digital thermometer
Meterstick
Shovel

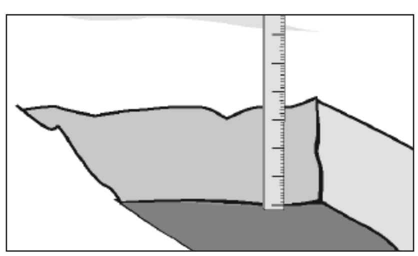
Step Two: Dig a Snow Pit

Dig a pit about three feet wide and six feet long. The pit should be perpendicular to the sun so that the exposed wall where you are taking measurements will be in the shade. Dig all the way to the ground.



Place the meterstick along face of the snow wall. Make sure the zero end of the stick is sitting on the ground.

Recorder: On the Observation Sheet, begin sketching the snow pit, focusing on the face of the snow wall. Sketch in the meterstick to the side for reference.



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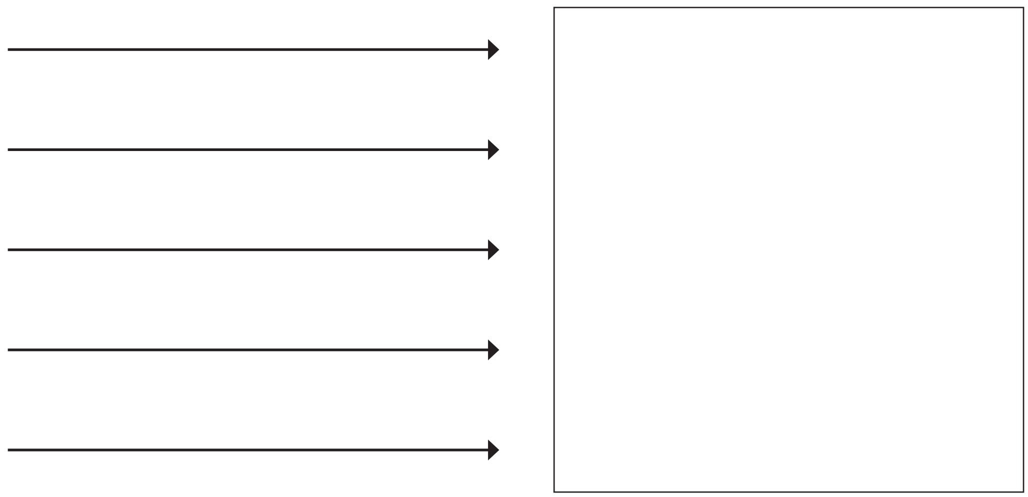
SNOW PIT MEASUREMENTS

Step Three: Observing Layers

Using a wooden tongue depressor like a knife, slice the snow pack slowly downward. You can feel the changes in the snow pack as you move through the snow. When you feel a change, place a tongue depressor sideways across the layer to mark it. Note the depth using the meterstick. Tell the recorder. Repeat this process until you reach the ground.

Recorder: Note each time a change occurs by marking a line on the illustration of the snow pit wall. Be sure to note the depth in centimeters. If you can see the layers, sketch them into your snow pit illustration. Note the layers in the box below, as well. Write notes below to describe the differences in layers observed by your group. Ask them to use describing words (harder, softer, crunchier, noisier, packed, fluffy, etc.) when describing the differences between layers.



Step Four: Measuring Temperatures

Using the waterproof digital thermometer, measure the temperature of the ground, air, and snow pack at 10 centimeters intervals. Tell the recorder the depth measurement in centimeters then the temperature measured. Be sure to note if you are measuring in Celsius or Fahrenheit.

Recorder: Use the chart on the observation sheet to record depth and temperature measurements.

Step Five: Back Inside

Using the notes taken by the recorder, transfer the notes, illustrations and data to your own lab packet.

Look at the temperature data then review your hypothesis. Did you data support your hypothesis?
Circle: Yes / No

NAME: ______________________________

SNOW PIT MEASUREMENTS

Observation Sheet

Directions: The group recorder will use this sheet to draw the snow pit and record observations.

ground level

Temperature Measurements
Start at the bottom and work up, noting the temperature every 10 cm. Use as many lines as needed until you reach the surface. Be sure to note the surface height!

Depth (cm)	Temperature
O cm	