# The Science of Snow

**Levels V-VI**

**Grades 9-12**

## Overview:

Students use the scientific method to conduct a lab measuring snow density and calculate snow water equivalent.

## Objectives:

The student will:
- formulate a hypothesis of snow density based on observations;
- test this hypothesis by measuring snow depth, volume and weight;
- calculate snow water equivalent to determine how much water the snow contains;
- revisit their hypothesis to determine if it was supported by their findings; and
- draw conclusions based on their findings.

## Materials:

- Clipboard and data sheets (1 per every three students)
- 1 meter yard stick (1 per every three students)
- 1 meter cylinder marked in centimeters (1 per every three students)
- Large metal spatula (1 per every three students)
- 2-gallon Ziploc bags (5 per every three students)
- Permanent marker (1 per every three students)
- Gram scale
- Thermometers (2 per every three students; a 2-meter long piece of colored string or yarn should be tied to one of the thermometers)
- STUDENT WORKSHEET: “The Science of Snow”

## GLEs Addressed:

*Science*
- [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.
- [10-11] 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] SA1.2 The student demonstrates an understanding of the processes of science by hypothesizing, designing a controlled experiment, making qualitative and quantitative observations, interpreting data, and using this information to communicate conclusions.
- [10] SA1.2 The student demonstrates an understanding of the processes of science by reviewing pertinent literature, hypothesizing, making qualitative and quantitative observations, controlling experimental variables, analyzing data statistically (i.e., mean, median, mode) and using this information to draw conclusions, compare results to others, suggest further experiments, and apply student’s conclusions to other problems.
- [11] SA1.2 The student demonstrates an understanding of the processes of science by recognizing and analyzing multiple explanations and models, using this information to revise student’s own explanation or model if necessary.
- [7] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical properties (i.e., density, boiling point, freezing point, conductivity) to differentiate among and/or separate materials (i.e., elements, compounds, and mixtures).

## Activity Procedure:

**Teacher's Note:** This lesson depends on a measurable amount of snow (between 15 cm and 100 cm) in an undisturbed area near the school. Some drifting is acceptable, as multiple samples will be taken and averaged. Students will collect snow samples and should dress appropriately for conditions. Data collection is based on the Alaska Lake Ice and Snow Observatory Network (ALISON), a snow and ice sampling curriculum developed by University of Alaska Research Professor Martin Jeffries. For further information see www.gi.alaska.edu/alison/ALISON_contact.html.

1. Explain that evidence from ice cores, lake sediment cores and tree rings indicate a warming in Earth's average temperature over the last 200 years. In Alaska, temperatures have increased enough over the past 30 years to cause drier summers, and later, shorter and warmer winters. Ask students to give examples of changes that have come about because of this increase in temperature *(more forest fires, thinner sea ice, etc.)*

   One way scientists study annual climate change is to measure snow depth and calculate snow density. Over many years the data from such measurements can provide a good picture of climate change in a village or watershed.

2. Remind students that snow cover and ice have a high albedo and reflect solar radiation back into the atmosphere, while exposed soils and water absorb solar radiation. In addition, snow and ice provide an insulation layer that allows the soil temperature to stay warmer than the air. Ice on a lake or stream allows the water below to maintain above-freezing temperatures, while a thick blanket of snow keeps soil temperatures from becoming as cold as air temperatures during the coldest part of the winter.

3. Ask students how animals like voles benefit from snow cover. *(They live under the snow during the coldest days of winter to keep warm.)*

   In fact, on a cold day in January, the air temperature may be -30 ˚C (-22 ˚F), but under two feet of snow the temperature may be just below freezing at -1˚C (31 ˚F). That is 29 ˚C (49 ˚F) warmer! A small vole will have a much better chance of surviving under the snow during cold periods than it will on the snow surface. Like the vole, ice forms an insulation layer over a lake, maintaining a liquid habitat for fish. Anyone who ice fishes on a cold day knows how fast fish freeze when they are pulled from a lake and exposed to the air just a few feet above the water underneath.

   Combined, the depth and density of snow and ice determine how well it insulates. One foot of dense ice doesn't insulate as well as one foot of fluffy snow. Like a fluffy down sleeping bag, small air pockets trapped inside the snow inhibit convection, reducing the warmth that escapes.

   Snow depth can be determined by using a meter stick to measure how deep the snow is in an undisturbed area.

4. Ask students why it is helpful to know snow depth. *(Snow depth may make hunting easier or more difficult. Greater snow depth can benefit small animals that live under the snow, but tire animals like moose and caribou that must walk through it. More snow means higher soil temperatures.)* Demonstrate by using a meter stick to measure an imagined depth of snow 30 cm deep.

   Snow density is measured by collecting a vertical core of snow. (Demonstrate by holding up a tube-shaped metric cylinder and show how to twist it into the snow vertically.) The volume is a measure of how much of the cylinder is filled by snow. The cylinder of snow is then emptied into a Ziploc bag and weighed. (Demonstrate by emptying the snow, imagined or real, into a Ziploc bag and weighing it on a scale.) This weight is the mass (in grams) of the snow in the cylinder. (The weight of the Ziploc bag will be subtracted later.)

5. Density is a measure of mass (weight in grams) per unit of volume. The symbol for density is r (the Greek symbol rho). The equation for snow density is therefore: r = Mass (g)/Volume ($cm^3$).

   **For example:**
   A cylinder contains 25 $cm^3$ of snow with a weight of 5.3 grams:

   $$r = 5.3\ g/25\ cm^3 = 0.212\ g/cm^3$$

6. Does heavy, wet snow have greater density than light, fluffy snow? (Yes)
7. Which would insulate better, dense snow or light, dry snow? (Light, dry snow because it contains more air, which reduces heat loss.)
8. Why is it useful to know snow density? (Dense, heavy snow should be removed from roofs to prevent them from collapsing. Travel in dense, cold snow may be easier than travel in light snow because dense, cold snow supports weight better. Snow density can make it possible to predict avalanches and the amount of spring runoff.)
9. Once snow depth and snow density are known, scientists can determine the actual amount of water present in the snow. This is known as the snow water equivlen (SWE). Imagine a huge water storage tank filled to the top with snow. SWE describes the depth of water that would result if all the snow in the storage tank were to melt suddenly.
10. Calculating the SWE of a watershed (the area draining into a lake or stream) will let villages know in advance how much water will run off into streams and lakes in the spring. They may be able to determine if flooding is likely to occur during breakup, or to know how much water will be available to refill water storage tanks.

    Snow water equivalent (SWE) is measured by multiplying snow depth by snow density and dividing this number by the density of water (which is 1g/$cm^3$). The equation for SWE is therefore:

    $$\frac{\text{SWE} = \text{depth (cm) x density } (g/cm^3)}{1\ g/\ cm^3}$$

    **For example:**
    Snow that measures 30 cm deep has a density of .212 g/$cm^3$

    $$\frac{\text{SWE} = 30\ \text{cm x } .212\ g/cm^3}{1\ g/\ cm^3} = 6.36\ \text{cm}$$

    This means that in the above example, 30 cm of snow melted to produce 6.36 cm of water (or 12 inches of snow produced 2.5 inches of water).

    Ask students to read the complete STUDENT WORKSHEET: “The Science of Snow” before going outside to conduct the lab experiment. A few practice measurements and collections outside before they gather actual data will help students to work through any problems. They will conclude the experiment back in the classroom.

## Answers:

Answers will vary depending on snow conditions.

Name:____________________________

# The Science of Snow

## Student Worksheet (page 1 of 4)

**Levels V-VI**

Snow cover provides insulating warmth for small mammals and tender plants. When the snow melts it fills lakes and streams, providing habitat for fish, water birds and aquatic insects. More snow should mean more water, but does it? Heavy, dense snow contains more water than light dry snow. By measuring snow depth and determining snow density it is possible to determine how much water is contained in the winter's snow cover.

**Directions:** Work in groups of three to collect and record data and calculate average snow depth, density, and the water content of the snow. **Read through the whole experiment in order to understand how to perform each step before going outside.**

1. From the facts given below, make a hypothesis about current snow conditions. Write your hypothesis in the space provided.

   Fact 1: Dry, light snow is easy to shovel, but not good for making snow shelters.

   Fact 2: Heavy, dense snow is hard to shovel, but good for making snow shelters.

   Fact 3: 75 cm of dry snow can melt to produce 2.5 cm of water.

   Fact 4: 75 cm of wet snow can melt to produce 12.5 cm of water.

   Based on these facts, write a hypothesis about the snow outside (for example—the snow is light and fluffy, therefore it would be expected to produce very little water for every cm of snow).

   **Hypothesis:** ____________________________________________________________

   ______________________________________________________________________

   **Materials:**

   - clipboard and data sheets
   - 1-meter yardstick
   - 1-meter cylinder marked in centimeters
   - large metal spatula
   - 5 2-gallon Ziploc bags
   - permanent marker
   - gram scale
   - 2 thermometers (one with a 2-meter long piece of colored string attached)

2. **Site selection:** Look for an undisturbed area to sample (away from foot or snow machine traffic). A site that is not wind-swept or drifted is best. Several measurements and samples will be taken from this site, so disturb it as little as possible during the data gathering process in order to obtain the best results. Describe the site below:

   ______________________________________________________________________

   ______________________________________________________________________

Name:___________________________

# The Science of Snow

## Student Worksheet (page 2 of 4)

3. **Snow surface and bottom temperature:** Place one thermometer on the surface of the snow and shade it from direct sunlight with paper or some other cover. Use the meter stick to push the second thermometer (with string attached) down to the bottom of the snow. Allow the thermometers to reach their correct temperature by waiting two or three minutes. Remove the thermometers and quickly record the readings below in degrees Celsius. This data will be used in a later lesson.

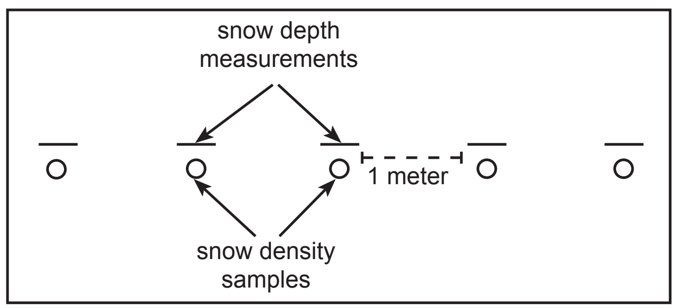
   Surface Temperature: _____________ Bottom Temperature: _____________

4. **Snow Depth:** Use a meter stick to measure the depth of snow to the closest cm in an undisturbed location. Leave an area of undisturbed snow near each of the measurement sites for collecting the snow density samples. Take measurements from five locations about one meter apart to form a row. Record the snow depth below in centimeters.

| ___________ | ___________ | ___________ | ___________ | ___________ |
|---|---|---|---|---|
| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |

5. **Snow Density Sample Collection:** Use a meter-long cylinder to collect snow from the study site. Collect one sample near each of the snow depth measurements taken above (see diagram below).

   To collect the samples, twist the cylinder while pushing it straight down into the snow until it reaches the ground. Without moving the cylinder, carefully clear enough snow away from it so that a spatula can be slipped between the cylinder and the ground, forming a "cap" that will prevent the snow from sliding out of the cylinder as you move it. This will require two people. Ask a third person to write the site number on a Ziploc bag with a permanent marker.




   Determine and record the **volume of snow** in the cylinders by recording how many centimeters of snow are in the cylinder at each site:

| ___________ | ___________ | ___________ | ___________ | ___________ |
|---|---|---|---|---|
| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |

6. Lift the cylinder containing the snow so that it can be emptied into the Ziploc bag. Seal the bag and set it aside in a safe place. Collect snow from all five sites in the same manner. Be sure to record the site number on each Ziploc bag of snow.

   **Return to the classroom.**

7. Find the **average snow depth** by adding all the measurements taken in step 4 together and dividing by the total number of measurements taken (5). Record that number below:

   Average snow depth: _____________

Name:___________________________

# The Science of Snow

## Student Worksheet (page 3 of 4)

8. Use a gram scale to weigh an empty Ziploc bag and record that weight below:

   Weight of empty Ziploc bag: _____________

9. Weigh each of the bags containing snow and record their weights below:

| __________ | __________ | __________ | __________ | __________ |
|---|---|---|---|---|
| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |

10. Subtract the weight of the empty Ziploc bag from the actual weight of each bag of snow and record the results below:

| __________ | __________ | __________ | __________ | __________ |
|---|---|---|---|---|
| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |

11. Find the **average mass (weight) of the snow in the cylinders** by adding all the measurements above together and dividing by the total number of measurements taken (5). Record that number below:

    Average mass of snow: _______________

12. Find the **average volume of snow** collected at each site by adding all the volumes recorded in step 6 together and dividing by the number of measurements taken (5). Record that number below:

    Average volume of snow: _______________

13. **Determine snow density:** Density is a measure of mass per unit of volume. The equation for snow density is therefore **Mass (g)/Volume ($cm^3$)**. For example: a cylinder contains 45 $cm^3$ of snow and weighs 7.5 grams:

    $$\text{snow density} = 7.5\ g/45\ cm^3 = .167\ g/cm^3$$

    Use the average mass of snow (the answer from question 11) and the average volume of snow (the answer from question 12) to determine the density of snow at the test site:

    snow density = _______________ g / _______________ $cm^3$ = ________________ $g/cm^3$
    (average mass) (average volume)

14. Finally, to find out how much water is in the snow, calculate the snow water equivalent.

    Snow water equivalent (SWE) is measured by multiplying the average snow depth (the answer from question 7) by snow density (the answer from question 13) and dividing this number by the density of water (which is $1 g/cm^3$). The equation for SWE is therefore:

    $$\text{SWE} = \frac{\text{depth (cm)} \times \text{density } (g/cm^3)}{1\ g/\ cm^3}$$

Name:___________________________

# The Science of Snow

## Student Worksheet (page 4 of 4)

**For example:**

If the snow averages 60 cm deep has a density of .167 g/cm$^3$

$$SWE = \frac{60 \text{ cm} \times .167 \text{ g/cm}^3}{1 \text{ g/ cm}^3} = 10.0 \text{ cm}$$

Complete the formula below to determine the snow water equivalent of the test site:

SWE = ________________ cm X ________________ g/cm$^3$ ÷ 1 g/cm$^3$ = _________________ cm
(average depth) (average density)

15. Test the results of the snow water equivalent by allowing the snow to melt in the sealed Ziploc bags. Then pour it into a cylinder marked with centimeters. Record the volumes below:

| ___________ | ___________ | ___________ | ___________ | ___________ |
|---|---|---|---|---|
| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |

16. Find the average by adding all the numbers together and dividing by the number of samples (5). Record that number below:

    Average volume of water in the bags: ________________

17. How does the average volume of water in the bags (answer from question 16) compare to the results from question 14?

    ___________________________________________________________________________

    ___________________________________________________________________________

18. Do the results from the lab support the original hypothesis? If not, why?

    ___________________________________________________________________________

    ___________________________________________________________________________

19. Compare all findings with other students in the class. Are they similar or different? What might account for large differences?

    ___________________________________________________________________________

    ___________________________________________________________________________