6th Grade - Grading Period 2 Overview

Ohio's New Learning Standards

- Soil is unconsolidated material that contains nutrient matter and weathered rock.
- Rocks, minerals and soils have common and practical uses.
- All matter is made up of small particles called atoms.
- Changes of state are explained by a model of matter composed of atoms and/or molecules that are in motion.

Clear Learning Targets

"I can...":

1. ____ investigate how soil forms at different rates and has different measurable properties through soil sampling and testing.
2. ____ explain how soil is formed into layers called horizons based on measurable properties.
3. ____ identify and describe Ohio's soil as it relates to formation and soil properties.
4. ____ identify examples of different ways the soil, rock and minerals can be used.
5. ____ recognize the characteristics of soil, rock and minerals to determine how they can be used.
6. ____ recognize that all matter is made up of atoms.
7. ____ explain that atoms take up space, have mass, and are in constant motion.
8. ____ create models of elements, compounds, and molecules to show atomic differences.
9. ____ describe the composition of substances in terms of elements and/or compounds.
10. ____ measure the mass and volume of a substance, and calculate density by dividing mass by the volume.
11. ____ compare substances by the amount of mass a substance has in a given amount of volume (density).
12. ____ construct and interpret mass vs. volume graphs.
13. ____ explain that thermal energy is a measure of the motion of the atoms and molecules (kinetic energy) in a substance.
14. ____ describe the factors that affect thermal energy.
15. ____ investigate temperature change in order to infer changes in thermal energy.
16. ____ describe solids, liquids, and gases in terms of motion of and spacing and attractions between particles.
17. ____ model and explain how mass is conserved when substances undergo a change of state.
6th Grade - Grading Period 2 Overview

Essential Vocabulary/Concepts

6.ESS.4
- Minerals
- Soil Horizon
- Soil Profile
- Soil Properties
- Soil Region

6.ESS.5
- Nonrenewable
- Open-Pit
- Ore
- Quarries
- Reclamation
- Strip Mining
- Subsurface Mining
- Surface Mining

6.PS.1
- Atoms
- Compounds
- Density
- Element
- Mass
- Matter
- Molecules
- Particles
- Pure Substance
- Volume

6.PS.2
- Gas
- Kinetic Energy
- Liquid
- Mass
- Particles
- Solid
- Temperature
- Thermal Energy
6th Grade Science Unit:
Thinking Like A Soil Scientist

Unit Snapshot

Topic: Rocks, Minerals, and Soil

Grade Level: 6

Duration: 11 days

Summary:
The following activities engage students in exploring soil, soil formation, and soil properties, through various investigations involving soil sampling and testing.

Clear Learning Targets

"I can"...statements

____ investigate how soil forms at different rates and has different measurable properties through soil sampling and testing.

____ explain how soil is formed into layers called horizons based on measurable properties.

____ identify and describe Ohio's soil as it relates to formation and soil properties.

Activity Highlights and Suggested Timeframe

Engagement: The objective of this activity is to engage students and formatively assess their knowledge of soil properties through a sampling and observations of soil from the school yard or other sources.

Exploration: Students will explore the composition of soil through a soil particle separation investigation.

Explanation: The objective of the following activities is to give students the opportunity to develop their knowledge and vocabulary related to soil horizons through a guided notes activity.

Elaboration: The objective of the following activity is to give students the opportunity to gain deeper understanding of how environment affects the formation of soil, specifically Ohio's soil through map reading, and a close reading.

Evaluation: Formative and summative assessments are used to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to soil formation and horizons. A teacher-created short cycle assessment will be administered at the end of the unit to assess all clear learning targets (Day10).

Extension/Intervention: Based on the results of the short-cycle assessment, facilitate extension and/or intervention activities.
NEW LEARNING STANDARDS:

6.ESS.4 Soil is unconsolidated material that contains nutrient matter and weathered rock.

- Soil formation occurs at different rates and is based on environmental conditions, types of existing bedrock and rates of weathering. Soil forms in layers known as horizons. Soil horizons can be distinguished from one another based on properties that can be measured.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering) that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Framework for K-12 Science Education Scientific and Engineering Practices

COMMON CORE STATE STANDARDS for LITERACY in SCIENCE:

CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

*For more information: [http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf](http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)

STUDENT KNOWLEDGE:

Prior Concepts Related to Soil

K-2: Objects have physical properties, properties of objects can change and Earth's nonliving resources have specific properties.

Grades 3-5: Rocks and soil have characteristics. Soil contains pieces of rocks. Soil investigations measure color, texture, ability for water to pass through soil, moisture content and soil composition. Objects are composed of matter.

Future Application of Concepts

Grades 7-8: Biogeochemical cycles and the role of soil within them, soil erosion and runoff issues, hydrologic cycle including percolation and infiltration rates, and sedimentary environments are studied.

High School: The formation of elements, the importance of soil in an ecosystem, and issues with soil degradation and soil loss are explored. In grades 11/12 Physical Geology, depositional environments, soil mechanics, issues with mass wasting including soil/sediment contamination issues and the classification of soil is found.
### MATERIALS:

#### Engage
- Access to school yard soil
- Soil Sampling Tube or PVC piping
- Copies of student sheet: Soil Sampling and Observations

#### Explore
- 4’ plastic column, one end sealed; *Plastic bottles/cylinders can be used instead (all other needed materials will decrease proportionally in amount)*
- Cloth or heavy duty plastic bags larger than a sandwich bag (for crushing soil into fine particles). Book, wooden block, rolling pin or other heavy item for crushing soil. (Should have at least a ½ - ¾ cup of dry, crushed soil sample.)
- 3-5 cups water/detergent solution (see below for mixing directions)
- Powdered electric dishwasher detergent (not hand washing soap, laundry soap, or laundry detergent)
- Baking soda
- Water
- Small Styrofoam coffee cup for measuring (usually 1 cup)
- Squeeze bottle for washing soil down sides of tubes
- Funnel (cut from the spout end of a plastic gallon milk bottle for dumping soil mix into tubes)
- Copies of Student Sheets: What's In My Soil?

#### Explain
- Science Textbooks
- Guided Reading and Study Worksheets from textbook teaching resources
- Optional: Review and Reinforce worksheets from textbook teaching resources
- Computer/Projector/Internet
- Student Journals or paper for foldable

#### Elaborate
- Student copies of Different Soils for Different Climates - textbook teaching resources
- Copies of Ohio Soil Regions Map and Brochure Information
- Copies of Students Sheets: Soil Regions of Ohio

### SAFETY
- Optional: Students may want to wear gloves and/or goggles when handling soil.

### ADVANCED PREPARATION
- Gather materials for laboratory investigations
- Copy student worksheets and articles

### VOCABULARY:
- **Primary**
  - Soil Horizon
  - Soil Properties
- **Secondary**
  - Minerals
  - Soil Profile
  - Soil Region
### Objective:
The objective of this activity is to engage students and formatively assess their knowledge of soil properties through a sampling and observations of soil from the school yard or other sources.

**What is the teacher doing?**

**Uses of Soil (Day 1)**
- Ask students to brainstorm as many specific uses for soil as they can.
  - Consider writing student responses on the board or use post-it notes.
- Follow-up with a discussion using probing questions. See teacher page.

**Soil Sampling (Days 1-2)**
- See TEACHER PAGE
- Take students outside to gather soil samples using a Soil Sampling tube or PVC pipe (see directions for making PVC pipe sampling tubes.) Students may also want to bring in samples from home.
- Facilitate as students observe their soil samples and compare with other groups.

**What are the students doing?**

**Uses of Soil (Day 1)**
1. Students are engaged in discussion led by teacher.

2. Use a Soil Sampling tube or PVC pipe to gather samples of soil around the school yard and/or at home.
3. Students make observations of soil and compare with other group's samples.

### Objective:
The objective of the following activities is to give students the opportunity to explore soil composition through an investigation of soil particle separation.

**What is the teacher doing?**

**What's in My Soil? (Days 3-5)**
- Discuss the various components of soil.

- See TEACHER PAGE
- Facilitate soil separation activities.
- Follow-up with a class discussion related to results.

**What are the students doing?**

**What's in My Soil? (Days 3-5)**
1. Watch the video clip and discuss the various components of soil.

2. Students create a soil separation tube/container.
3. Students add various soils into solution and let sit overnight.
4. Students observe layers.
5. Complete the provided related worksheets that accompany the activities.
**Objective:** The objective of the following activities is to give students the opportunity to develop their knowledge and vocabulary related to soil horizons through a guided notes activity.

<table>
<thead>
<tr>
<th>What is the teacher doing?</th>
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<tbody>
<tr>
<td><strong>Soil Profiles and Horizons</strong></td>
</tr>
<tr>
<td><strong>Textbook activities (Days 6-7)</strong></td>
</tr>
<tr>
<td>• Assist student with reading Science Text and completing the Guided Reading and Study</td>
</tr>
<tr>
<td>• Consider the Review and Reinforce p. 48 for intervention. Consider the following in addition or as a supplement - Use The Soil Profile: <a href="http://alamoworldgeography.weebly.com/uploads/9/2/9/2/9292252/soilprofile.pdf">http://alamoworldgeography.weebly.com/uploads/9/2/9/2/9292252/soilprofile.pdf</a> like a PowerPoint to help facilitate a discussion about soil profiles and horizons. Students will be writing notes to summarize the important features of each slide. Consider using a foldable.</td>
</tr>
<tr>
<td>• Highlights should include: - 6 Soil Roles - 5 Factors of Formation - What is a soil profile? - What is a soil horizon - O, A, E, B, C, R Horizons - OPTIONAL: How to make a soil profile activity</td>
</tr>
<tr>
<td>• Assessment checkpoint: Project the provided graphic of a soil horizon on the board and have students identify the various horizons.</td>
</tr>
<tr>
<td>5. Assessment checkpoint: Identify the soil horizon layers on each soil profile.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What are the students doing?</th>
</tr>
</thead>
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<td><strong>Soil Profiles and Horizons</strong></td>
</tr>
<tr>
<td><strong>Textbook activities (Days 6-7)</strong></td>
</tr>
</tbody>
</table>

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**EXPLAIN**

(2 days)

(What products could the students develop and share? How will students share what they have learned? What can be done at this point to identify and address misconceptions?)
**Objective:** The objective of the following activity is to give students the opportunity to gain deeper understanding of how environment affects the formation of soil, specifically Ohio's soil through map reading, and a close reading.

<table>
<thead>
<tr>
<th>What is the teacher doing?</th>
<th>What are the students doing?</th>
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</thead>
<tbody>
<tr>
<td><strong>Different Soils For Different Climates (Day 8)</strong></td>
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</tr>
<tr>
<td>• Distribute student worksheet - <em>Different Soils for Different Climates.</em></td>
<td>1. After being divided into 6 groups, each group is responsible for responding to one of the 6 questions related to the diagram on the <em>Soils for Different Climates</em> worksheet.</td>
</tr>
<tr>
<td>• Divide students into 6 groups</td>
<td></td>
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<tr>
<td>• Assist groups in answering their assigned questions.</td>
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<tr>
<td>• Facilitate a class discussion.</td>
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</table>

<table>
<thead>
<tr>
<th><strong>The Soil Regions of Ohio (Day 9)</strong></th>
<th><strong>The Soil Regions of Ohio (Day 9)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Print, Copy and distribute the following map and brochure to students, as well as the student hand-out.</td>
<td>2. As a class, read the first page of the article related to soil. Provide 3 important facts about soil from the text and record on student sheet.</td>
</tr>
<tr>
<td>• As a class, facilitate a reading of the first page of the article related to soil.</td>
<td>3. Using the soil regions map and brochure, students answer questions on the student sheet.</td>
</tr>
<tr>
<td>• Project the picture of the Soil Region Map on the board and/or have students look at a paper copy.</td>
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<tr>
<td>• Assist students as they use the brochure information to complete the guided questions.</td>
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<tr>
<td>• Facilitate a follow-up discussion.</td>
<td></td>
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</tbody>
</table>

**ELABORATE**

(2 days)

(How will the new knowledge be reinforced, transferred to new and unique situations, or integrated with related concepts?)
Objective: Formative and summative assessments are used to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to soil formation and horizons. A teacher-created short cycle assessment will be administered at the end of the unit to assess all clear learning targets (Day 8).

<table>
<thead>
<tr>
<th>Evaluate</th>
<th>Formative</th>
<th>Summative</th>
</tr>
</thead>
<tbody>
<tr>
<td>(on-going)</td>
<td><strong>How will you measure learning as it occurs?</strong></td>
<td><strong>What evidence of learning will demonstrate to you that a student has met the learning objectives?</strong></td>
</tr>
<tr>
<td><strong>EVALUATE</strong></td>
<td>• Consider developing a teacher-created formative assessment</td>
<td>1. Teacher-created short cycle assessment will assess all clear learning targets.</td>
</tr>
<tr>
<td>(What opportunities will students have to express their thinking? When will students reflect on what they have learned? How will you measure learning as it occurs? What evidence of student learning will you be looking for and/or collecting?)</td>
<td>1. Soil Brainstorm (engage) and soil sampling can be used to assess students’ prior knowledge of soil characteristics.</td>
<td></td>
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<tr>
<td></td>
<td>2. What's in my Soil? Lesson can be used to assess students' progression of knowledge towards mastery of knowledge related to soil composition.</td>
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<tr>
<td></td>
<td>3. Textbook activities can be used to assess student mastery of soil profiles, formation, and horizons.</td>
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<td></td>
<td>4. Ohio’s Soil Region activity can assess student's ability to explain how Ohio's soil was formed and how Ohio's soil is categorized by regions.</td>
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<table>
<thead>
<tr>
<th>EXTENSION/INTERRUPTION</th>
<th>EXTENSION</th>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 day or as needed)</td>
<td>1. <strong>Comparing Soils Consumer Lab</strong> in Earth Science Textbook Teaching Resources pp. 50-51</td>
<td>1. <a href="http://www.discoveryeducation.com">www.discoveryeducation.com</a> related videos</td>
</tr>
<tr>
<td></td>
<td>- Students study how the soil beneath a building influences the buildings stability. This activity is associated with the NOVA program “Fall of the Leaning Tower” about the Leaning Tower of Pisa.</td>
<td></td>
</tr>
</tbody>
</table>
### COMMON MISCONCEPTIONS
- All soil has the same composition
- Soil is solid
- All soil is brown
- Soil is only found in certain areas
- Soil is only a few years old
- Soil comes from plants

**Strategies to address misconceptions:**
Misconceptions can be addressed through the use of video clips, pictures/diagrams of soil profiles, as well as through the use of models.

### DIFFERENTIATION
**Lower-level:** Provide additional text resources (tradebooks, articles) that are appropriate for the reading level of the student. For the Investigation Labs consider mixed grouping strategies. Integrate www.unitedstreaming.com videos into instruction.

**Higher-Level:** Consider having students create their own soil properties investigation that they can complete using soil from their home or neighborhood. Consider assigning extension activities.

**Strategies for meeting the needs of all learners including gifted students, English Language Learners (ELL) and students with disabilities can be found at ODE.**

### ADDITIONAL RESOURCES
**Textbook Resources:**
*Holt Series Science* Textbook
- How Soil Forms
- Soil Conservation

**Websites:**

**Discovery Ed:**
- How Soil is Formed [3:17] [http://app.discoveryeducation.com/player/view/assetGuid/E05BA269-0E80-44D7-A7D8-80C7EFBD2EC](http://app.discoveryeducation.com/player/view/assetGuid/E05BA269-0E80-44D7-A7D8-80C7EFBD2EC)
• Conserving Prairie Soil: The Components of Prairie Soil [3:53]
  http://app.discoveryeducation.com/player/view/assetGuid/2172DB3A-57D4-4B24-A2CD-2B07C405A7B3

Literature:
Instruct students to brainstorm as many uses of soil as they can think of. Consider writing student response on the board or using post-it notes.

Discussion Questions:
1) Is all soil the same?
   - No, soil composition depends on the parent material, climate, topography, biological factors, and time.
2) Where do you think soil comes from?
   - Soil forms from the weathering, and other processes that act upon the parent material (usually rock).
3) Is Soil living or non-living?
   - The soil itself is non-living as it was formed by the breakdown of rock, however, may contain organic materials within the particles due to biological factors (i.e. plants, animals, and bacteria.)

Use soil sampling tubes to extract soil from various areas of the school yard.
Soil Sampling and Observations

1. Spread newspaper on a desk or table. Using paper towels and all of the collected soil samples, place a small amount of each soil sample on a paper towel. Put the paper towels on the newspaper.

2. **OBSERVE** Use a pencil to push around the soil a little bit. Observe each soil sample with the hand lens. Record your observations of each soil sample.

3. **CLASSIFY** Use the pencil tip to classify the particles of each sample into two piles—pieces of rock and pieces of plant or animal material.

4. **OBSERVE** Put four drops of water on each sample. After a few minutes, check which sample leaves the biggest wet spot on the newspaper.

Post-Lab Questions:

1. What kinds of material make up each soil sample?

2. How do the particles you sorted in each soil sample compare by size? By color?

3. Describe the properties you observed in each sample.

4. Which sample observed the most water? How can you tell?
Background:
Sand, silt, and clay make up 40-80 percent of soil. These components are present in different proportions giving soils their different characteristics and textures. For example, a soil can have a sticky character if it contains mostly clay particles, velvety smooth if it has high silt content, gritty if it contains mostly sand, or spongy if it is high in organic matter.

Some soil components may constitute a small, but important percentage of the whole. For example, the organic component *humus* possesses important textural characteristics that allow good infiltration of precipitation.

Though humus normally makes up only 5 percent of the soil or less, it is an essential source of nutrients and adds important textural qualities that are critical for plant growth. Humus, which is rich in nitrogen, is the result of the cycle of plant and animal growth and decay. Besides plant matter, humus includes *macroscopic* organisms (such as insects and other arthropods, and worms), and *microscopic* organisms (such as bacteria). Humus also acts as a buffer against changes in pH.

Animal life contributes to soil development in two ways: it adds to humus by helping decompose dead plant and animal material, and by adding organic matter and nitrogen to the soil through its body wastes and by its own death and decomposition. Organic matter provides air space, insulation, and food for many soil-dwelling creatures. It also reduces surface runoff by absorbing water (as much as 2 pounds of water per pound of humus).

*Sand* helps increase permeability and lightness of the soil. Sand does not maintain nutrients or water very well (perhaps a mere 4 ounces of water per pound of sand) but helps water move downward toward the water table.

*Silt* has high capillarity, pulling water upward from the water table to plant roots. *Clay*, though often thought to be undesirable, is critical to a good soil composition due to its water-holding capacity and cation exchange capacity.

*Cations* are positively charged ions, and cation exchange capacity is a measure of the exchange sites in the soil which is influenced by the amount and type of clay and the amount of organic matter. Cation exchange influences the ability of a soil to retain important nutrients. Important nutrients include nitrogen (N), phosphorus (P), and potassium (K) (which represents the "NPK" values found on fertilizer labels) plus calcium, iron and magnesium.

The grouping of identifiable layers of different components and characteristics that make up a soil in a given area is referred to as a *soil profile*. Each individual soil layer is referred to as a *horizon*, termed 0, A, B, and C.
• The 0 Horizon, is usually a thin top layer of organic material—dead leaves, plants or grasses that have collected and begun to break down.

• The A horizon, or "topsoil," is dark-colored, rich in nutrients, and lies directly below the 0 horizon. Most soil-dwelling animals and plants are found in this layer, and their presence helps loosen and aerate this horizon.

• The B horizon, or "subsoil," lies beneath the A horizon. Although this horizon can contain sandy or silty layers, it is mostly characterized by clay-sized particles. This layer is usually much more compact than the A horizon. If a B horizon is thin or missing because weathering processes have not been at work long enough, a soil is said to be immature. If a soil profile contains at least three layers above the unweathered bedrock, it is said to be mature.

• The C horizon exists beneath the B horizon. The C horizon has no properties typical of the overlying horizons, but it has been affected by weathering processes such as oxidation. It is composed of unconsolidated material that may or may not be like the material from which the soil presumably formed. Directly underneath this horizon, and therefore beneath the entire soil profile, lies consolidated bedrock.

• Water and air are also critical components of soil, sometimes comprising up to 40 percent of the soil volume. Water, because of its cohesive characteristics, helps hold soil particles together. Plants and other organisms living in soil need both air and water to survive.

• Water’s ability to sort sediment according to size provides an effective means by which the components of a soil can be analyzed.

Particle and Sieve Sizes*

<table>
<thead>
<tr>
<th>Particle Type</th>
<th>Geological Size Range</th>
<th>Soil Science Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>(2.00-0.05 mm)</td>
<td>(2-.02 mm)</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>2.00-0.5 mm</td>
<td>4.75-2.4 mm</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>.5-0.125 mm</td>
<td>2.4-.42 mm</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.125-0.062 mm</td>
<td>0.42-0.07 mm</td>
</tr>
<tr>
<td>Silt</td>
<td>0.05-0.002 mm</td>
<td>0.02-0.002 mm</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.002 mm</td>
<td>&lt;.002 mm</td>
</tr>
</tbody>
</table>

Materials for each student group

• One, 4' plastic column, one end sealed; Plastic bottles/cylinders can be used as well (all other needed materials will decrease proportionally in amount)
• Cloth or heavy duty plastic bags larger than a sandwich bag (for crushing soil into fine particles). Book, wooden block, rolling pin or other heavy item for crushing soil. (Should have at least a \(\frac{1}{2} - \frac{3}{4}\) cup of dry, crushed soil sample.)
• 3-5 cups water/detergent solution (see below for mixing directions)
• Powdered electric dishwasher detergent (not hand washing soap, laundry soap, or laundry detergent)
• Baking soda
• Water
• 1 small Styrofoam coffee cup for measuring (usually 1 cup)
• Ring stands or duct tape (see below)
• Squeeze bottle for washing soil down sides of tubes
• Funnel (cut from the spout end of a plastic gallon milk bottle for dumping soil mix into tubes)

Preparation of Water/Detergent Solution:
In a convenient container, such as a 1 gallon milk jug or a bucket, mix powered dishwasher detergent with water and then add baking soda, in the following proportions:

1 gallon water to 1/4 tsp (1.25 ml) powdered dishwashing detergent to 1/4 cup (62.5 ml) baking soda. Each group will need 4 cups of this mixture. (Baking soda is a dispersing agent used to separate the organics out of the soil samples. It reacts with the air in the organics to make them float to the top of the column. Powdered dishwasher detergent contains sodium phosphate, which also acts as a dispersing agent providing good particle separation. Regular dish soap will not have the same effect as it is too sudsy. The sodium phosphate separates clay and silt from sand and organic materials, critical when using the settling method to separate particles.)

[Note: More is not better! Too much detergent will keep particles in suspension for too long. You want as much soil to settle overnight as possible, and clay sized particles are so small and light they can easily stay in suspension for more than 24 hours if too much detergent is used.]

Soil Samples
• Samples of soil will be needed for this activity. Students can bring a sample from home or samples can be collected in the course of a field trip. If students collect the soil samples, have them bring in slightly more soil than you will need (approximately 1 cup) and have them transport it in closed plastic bags.

• It is helpful to have the soil dry so spread it out thinly and leave it to dry for a day or two. (Process can be hurried along by placing the spread out soil on a heater or in a slightly warm oven.)

Then, before actually beginning this activity with students, do the following:
• Test the column with water (80% to 90% full) to ensure a tight fit of the stopper.

Activity Sheet A: What's in My Soil?-Separation.

1. Have students put the dry soil back into heavy duty plastic or cloth bags for separating into smaller particles. (Soil can be broken up by tapping the bag against a wall or table or by tapping the bag with book, wooden block or even a rolling pin. Soil must be dry to loosen the particles so that there are no large clumps of material going into the tubes. Do not crush gravel or sand since this would create size fractions not representative of the original sample. Students will need approximately ½ - ¾ cup of the mixed dry soil. (Small paper, plastic or Styrofoam cups are good containers for this amount of soil.)

[You may wish to introduce marked variations in soil samples by adding some coarse sand, fine sand, silt, or clay to a basic mix. A mix of coarse yellow builder's sand, fine white "play" sand, and common red clay can give a very colorful and striking separation.]

Begin the sorting process. Have the students follow Activity Sheet A: What's in My Soil?-Separation.

2. It is ideal to use 4 foot plastic tubes, but large clear containers/jars will work as well. Stand 4-foot plastic tubes on the floor, supported and fastened securely in an area where they can remain undisturbed overnight. It is important that the soil mixture produces visible layers. Ring stands are ideal to keep the columns upright, but, if they are not available, use masking or duct tape to secure the columns to any stable object such as the side of a desk, table or chair. (It is advisable to stand the tubes in a bucket or other container where they will not be moved once activities begin.)

3. Pour the pre-mixed detergent solution into each group's tube or give each group enough solution to fill at least half of the container and pour into the tubes themselves.

4. Soil material should then be dropped into the tube with one quick dump so that all particles have equal opportunity to arrive at the bottom first. Adding the soil too slowly will prevent distinct layers from forming. Don't pour it in slowly! (A funnel made from the wide mouth bottle neck portion of a gallon plastic jug will help students dump the mixture into the column quickly and easily.) Although you do not want to shake the column you can rinse the dry soil stuck on the wet sides of the tube with a bit more solution sprayed from a squeeze bottle.

5. Let the settling tubes stand overnight (or, better yet, over the weekend) so that more of the particles have time to settle out. Be sure the tubes are well secured and cannot be moved. On returning to the tubes after settling time has elapsed, students will observe a layer consisting only of organic material.

**Activity Sheet B: What's in My Soil?-Observations and Activity Sheet C: What's in My Soil?-Computations.**
Determine and plot component percentages. Have the students follow Activity Sheet B: What's in My Soil?-Observations and Activity Sheet C: What's in My Soil?-Computations.

1. Have students measure and record the thickness of the humus layer, the clay layer, and the silt layer.

2. Add all the thicknesses together to get the total thickness of humus plus particle layers.

3. Calculate the percentage of humus. \(\text{Thickness of humus layer divided by total thickness x 100}\)

4. Have students compare their humus contents with those of other groups.

**OPTIONAL: Activity Sheet D: What's in My Soil?-Good Soil Mix, then plot their data on Activity Sheet E: What's in My Soil?-3-Point Diagram.**

Have students review Activity Sheet D: What's in My Soil?-Good Soil Mix, then plot their data on Activity Sheet E: What's in My Soil?-3-Point Diagram.

[Note: The 3-point (ternary) diagram is provided so that students can see the composition of their soil and how close it may be to the "good soil mixture" in the center of the diagram. Soils closer to the center are better for growing plants because that mixture allows, among other things, far better water infiltration and retention than soils falling outside the center.]

6. Have all students plot their soil data on a single three-point diagram to see what similarities and differences exist between the samples. The following figure is a more detailed three-point diagram, which breaks out names for different proportions of sand, silt, and clay.

7. Discuss how different environments (i.e., a forest as opposed to an open area) may contribute to the differences in soil composition.

8. Point out that there is only a small percentage (0-5 percent) of humus in most soils.

9. Point out that the various calculated percentages represent volume. Ask the students how they could determine the various percentages by weight?

Activity Sheet A: What's in My Soil? - Separation

Materials for each group
Activity Sheets
1 clear 4' plastic column, one end sealed or other designated container
Dry soil sample, crushed to a powder
Water/detergent solution
Masking or duct tape
Bottle-top funnel

1. At your teacher's direction, pound or crush a dry soil sample to eliminate any clumps or clods.

2. Stand the column/container (with plugged end at bottom) upright on the floor inside a bucket or other container to hold leaks. Attach to a ring stand or tape the column to a desk or chair to make certain it remains upright.

3. Pour enough water solution in the column/container to fill half way.

4. With one quick dump, pour all of the soil into the water filled column. The column should not be disturbed.

5. Allow the column to remain undisturbed overnight.

Activity Sheet B: What's in My Soil? - Observations

Observe the soil that settled in the bottom of the column of water. You should find three noticeable layers. (If one layer appears to blend into another, choose one line that would best separate them.) The bottom layer is sand, the top layer is clay, and the layer in between is silt.

1. Why do you think the clay and silt settled on top of the sand?

2. The material floating near or on top of the water is organic material called humus (HYOU-muss). Why do you think it is floating near the top of the water column?

3. Sand, silt, and clay are the components of a mineral soil. Measure the height of each layer and record your findings below.

   Clay = ___________ cm

   Silt = ___________ cm

   Sand = ___________ cm

   Total height of soil in tube = ___________ cm

Activity Sheet C: What's in My Soil? - Computations

Compute the percent (%) volume for each of the mineral layers by dividing the height of each layer by the total height and then multiplying your answer by 100.

Here’s how to set up the problem:

\[
\frac{\text{Height of Layer}}{\text{Total Height of Soil}} \times 100 = \text{______ \%}
\]

1. Compute the percent by volume for Sand.

\[
\frac{\text{Height of SAND Layer}}{\text{Total Height of Soil}} \times 100 = \text{______ \% Sand}
\]

2. Compute the percent by volume for Silt.

\[
\frac{\text{Height of SILT Layer}}{\text{Total Height of Soil}} \times 100 = \text{______ \% Silt}
\]

3. Compute the percent by volume for Clay.

\[
\frac{\text{Height of CLAY Layer}}{\text{Total Height of Soil}} \times 100 = \text{______ \% Clay}
\]

Activity Sheet D: What’s in My Soil? - Good Soil Mix

Does your sample qualify as a "good" soil mixture? Good soil is a combination of organic matter and inorganic particles (sand, silt, and clay). To determine whether you had a good mix of inorganic particles, plot your component percentages on a 3 point diagram.

Before you plot your percentages on Activity Sheet E, read through the following sample computation. The left side of the soil triangle represents the percentage of clay, the right side is the percentage of silt, and the bottom side is the percentage of sand.

On Activity Sheet E, plot the percentages of your soil mix. Fill in the percentages from Activity Sheet C.

% Clay ________ % Silt ________ % Sand ________

Circle the intersection of your three lines and then answer the following questions:
1. Did your soil qualify as a "Good Soil Mixture"?
2. If not, how could you change it to make it a good mixture?
3. Why is it important to have a good mixture?

Activity Sheet E: What’s in My Soil? - 3-Point Diagram

Activity Sheet F: What's in My Soil? - Grain Size

Silt and clay are so small compared to sand, that it is difficult for us to see individual particles with the naked eye. Let's compare the relative sizes of fine sand, silt, and clay, using the three "blown, up" models below. These are actual size relationships.

Using the scale, measure and record the diameter of each model and complete the following:

The diameter of the sand particle is ____. It is ____ times larger than clay.

The diameter of the silt particle is ____. It is ____ times larger than clay.

The diameter of the clay particle is ____.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DIAMETER (Average range in . . .)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Millimeters</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.40–0.05</td>
</tr>
<tr>
<td>Silt</td>
<td>0.05–0.002</td>
</tr>
<tr>
<td>Clay</td>
<td>less than 0.002</td>
</tr>
</tbody>
</table>

SOIL PROFILES and HORIZONS - TEACHER PAGE

1. THE SOIL PROFILE

2. The 6 Soil Roles
- Seahorses
- Emitting and absorbing gases
- Providing habitat
- Interacting with water
- Recycling nutrients
- Supporting human settlements

3. The 5 Factors of Formation
- Parent Material
- Climate
- Topography
- Biological Processes
- Time

4. What is a Soil Profile?
- A Soil Profile is a vertical cross-section of layers of soil found in a given area. Below are two examples of soil profiles.

5. What is a Soil Horizon?
- Soil horizons are the layers in a soil profile used to classify soil types.
- Horizons based on color, texture, roots, structure, rock fragments, and any unique characteristics worth noting.
- Master Soil Horizons are depicted by a capital letter in the order (from top down): O, A, E, B, C, and R.

6. O-Horizon
- The "Organic Mottled" Horizon
- Surface layer, up to 2 feet
- Dark in color, soft texture
- Mottled, rich in organic material, root and animal activity, and biological degradation
- Leaf litter, leaves, needles, moss, in situ, that are not decomposing
- Several O-layers can occur in some soils, consisting only of O-horizons

7. A-Horizon
- "Topsoil" or "Biolastic" Horizon
- Top portion of mineral soil, at depths of 2 to 12 inches
- Sometimes nutrient, carbon in color than layers below
- Biolastic - root biological productivity, nutrients, fungi, and bacteria live in this layer
- Smallest and finest soil particle

8. E-Horizon
- The "Leaching Layer" Horizon
- Small layer between A & B Horizons
- At depths of 10 to 15 feet
- Light in color, sandy soil, and
- Puts mineral and clay content due to leaching - the loss of water retaining plant nutrients to the water table
- Soil particle sizes larger than in A horizon, but smaller than in B horizon
How to Make a Soil Profile

**Ingredients List**
- 3-4 copies of Master Soil Horizons Worksheet
- 20 sticky notes per group (2 per person)
- 3-4 pairs of gloves
- 1 large glass bowl
- 1 one cup measuring cup
- 1 whisk
- 1 spatula
- 3.5 cups skim milk
- 2 packages vanilla instant Jello pudding mix
- 1 small Ziploc bag Crushed Oreos (or cookies)
- 1 medium Ziploc bag Chocolate chips & Vanilla wafers & gummy worms
- 1 small Ziploc bag crumbled Vanilla wafers only
- 1 medium Ziploc bag crumbled graham crackers
- 1 large Ziploc bag crumbled Oreo cookies
- 1 large Ziploc bag crumbled chocolate chips

**Directions**
1. In large glass bowl, whisk 3.5 cups milk with 2 pkgs. vanilla instant Jello pudding mix until smooth. Let stand 5 minutes.
2. While waiting, refer to your version of “The Soil Profile” powerpoint to review order that horizons should be. You have A, E, B, R, O, C, and vegetation as horizons. It’s up to you to order it!
3. After 5 minutes, use spatula to scoop pudding in middle of bowl, allowing for the “dry ingredients” (the bags of various crushed up cookies) to encircle the pudding along the sides of the glass bowl. This creates a vertical cross-section of soil layers visible to you.
4. Use sticky notes to label each horizon on outside of bowl.
5. Fill out Master Soil Horizons Worksheet using observations of Soil Profile Dessert.
6. Turn in worksheet to teacher. Only until you and your team members turn in their worksheet can you enjoy the delicious snack. You’re finished!
SOIL PROFILE - TEACHER ANSWER KEY

Label the Horizons

- O
- A
- B
- C
- R
Soil is one of our most basic natural resources, but we rarely see more than its surface - and even that is usually hidden by pavement, crops or trees. To most people, the soils of Ohio all look and feel pretty much the same. However, farmers and builders know that soils differ within most fields and city blocks. Soils are also different from region to region across the state.

The vast majority of soils are composed mostly of mineral material - small bits of decomposed rock. But soil is more than a collection of mineral particles. Pore spaces between these particles contain air and water required by the plants and animals living in the soil. Most soils also contain organic matter (from plants and animals), which darkens the uppermost layer of soil and affects the way in which soil particles hold together. While many people think of soil as “dead”, soil literally teems with life, from roots, insects and worms to molds, fungi and bacteria that number in the billions.

Soils form slowly over time as the mineral particles from geologic or “parent” materials are changed by the effects of weather, plants and animals in a landscape setting. Soils vary between regions largely because there are so many different types of parent material across the state.

This publication describes how, over the past century, soil scientists have identified more than 400 different kinds of soils, called series, in Ohio. It also describes how the soil regions are related to geologic regions and to four nationally recognized agricultural regions. Finally, this publication provides information about five basic soil characteristics in each of the soil regions.
WHAT ARE SOIL SERIES?

Scientists have classified the world’s soils according to a six-level system, much as plants and animals are classified. The system follows a “most general to most specific” arrangement; order-suborder-great group-subgroup-family-series. Soil “series” are at the most specific level in the system. A soil series corresponds to the “species” level in the classification system for plants and animals. Soil series are commonly named for cities or towns near where the soils were first studied. Soils classified in the same series have horizons (or layers) that are similar in composition, thickness, and arrangement.

Soils in the Miamian series, for example, are well drained. They typically have a very dark grayish brown to brown silt loam or loam topsoil layer (“A horizon”) 5 to 10 inches thick. They commonly have a brown or yellowish brown subsoil layer (“B horizon”), 8 to 35 inches thick, with a higher clay content than the A horizon. Below the subsoil, soils in the Miamian series have a brown to light olive brown substratum (“C horizon”) that is slightly or moderately alkaline and has a lower clay content than the B horizon.

HOW WERE THE SOILS IDENTIFIED?

Soil surveys in Ohio have been conducted on a county by county basis by soil scientists with shovels, augers and other tools since 1899. The Soil Survey of Montgomery County, Ohio, published in 1900, recognized only one soil series (Miami). A statewide soil survey was conducted in 1912, and 24 different soil series were recognized.

By 1992, soil surveys had been completed in every county in the state. Modern soil surveys must be much more detailed than the early surveys in order to provide the information needed to manage Ohio’s soil resources. Today, soil maps for Montgomery County show 38 different soil series, delineated in areas as small as five acres. More than one hundred soil series are recognized on detailed soil maps in the area identified as Miami in the 1912 survey. (The most common soil series in this part of the state, corresponding to Soil Regions 3 and 4, are Miamian and Blount.)

HOW WAS THIS MAP PREPARED?

In the late 1980s, information on thousands of detailed Ohio soil maps was analyzed for the Natural Resources Conservation Service to develop a statewide geographic soil data base known as STATSGO. This data base identified 166 different groupings, or “associations,” of soil series that are common in areas that could be mapped at a scale of 1:250,000. The Soil Regions of Ohio map was prepared by combining these associations into twelve regions at a scale of 1:2,500,000, with the assistance of ODNR’s Division of Real Estate and Land Management’s geographic information system (GIS).

LAND RESOURCE REGIONS IN OHIO

Lake States Fruit, Truck, and Dairy Region: The most common soils in Ohio Soil Regions 1 and 2 formed in lake and beach sediments and in glacial till associated with glacial lakes. Region 1 is part of the Erie-Huron Lake Plain (MLRA 99) and Region 2 is part of the Erie Fruit and Truck Area (MLRA 100). Region 1 is characterized by nearly level crop fields with drainage ditches and subsurface drains. Coarser-textured and sloping or steep soils are more common in Region 2, which is also more urbanized.

Central Feed Grains and Livestock Region: Ohio Soil Regions 3, 4, 5 are part of the Indiana and Ohio Till Plain (MLRA 111). The glacial deposits in Region 4 are coarser-textured than those of Regions 3 and 5, and well drained soils such as the Miamian soil are more common in this region than elsewhere in MLRA 111 in Ohio. Region 7 is associated with the Southern Illinois and Indiana Thin Loess and Till Plain (MLRA 114). Because the soils in this region formed in older glacial deposits than the soils in MLRA 111, they are more weathered and less fertile for crop production.

Northeastern Forage and Forest Region: Ohio Soil Regions 6 and 8 are in the Eastern Ohio Till Plain (MLRA 139). The glacial deposits in Region 6 range from coarse-textured to fine-textured, but coarser-textured and better drained soils are more common in the southern portion of the region. Dairy farms are still common, but many areas that were once farmed are now in urban or wooded areas. Many areas in Region 8 have soils similar to those in Region 11 (note Westmoreland). Glacial deposits are relatively thin in Region 8, and have eroded from many of the steeper areas.

### Significance of Selected Characteristics

**Slope:** Slope, expressed as a percent, measures the change in elevation over a distance of 100 feet. For example, an 8 percent slope has a change in elevation of 8 feet over a horizontal distance of 100 feet. Soils on slopes of more than 8 percent generally do not meet the criteria for “prime farmland,” because of the hazard of erosion on cropland. Soils on slopes steeper than 8 percent commonly have at least moderate limitations for urban uses.

**Organic Matter Content in the Upper 10 Inches:** As plants and animals live and die on and in soil, they contribute organic matter that is then decomposed by microorganisms in the soil. Organic matter contributes to the fertility and stability of the topsoil. The soils in Ohio that have more than 3 percent organic matter in the upper 10 inches are most commonly associated with areas that were in prairie grasslands and elm-ash swamp forests at the time of settlement. The higher organic matter content in these soils makes them appear darker in color at the soil surface than the more common soils in Ohio.

**Clay Content in the Topsoil:** Clay particles are very small (less than .002 millimeters in diameter), but they have a big effect on soil texture, and determine how “sticky” the soil becomes when it is wet. Topsoil with a silt loam texture has less than 27 percent clay, and such topsoil is dominant in all but one soil region in the state. Topsoil with a silty clay loam, clay loam, silty clay or clay texture is generally more difficult to till or excavate, especially when it is wet.

**Depth to Seasonal High Water Table:** Water accumulates in soils that receive rainfall or runoff from adjacent slopes faster than it can move through the soil. Soils that are not saturated for more than a few days in the typical year are generally the easiest to manage for a wide variety of uses. Wetlands are common in soils that are saturated in the upper 12 inches for a month or more during a typical year.

**Depth to Bedrock:** Glacial material, hundreds of feet thick in places, covers the bedrock in much of the western and northeastern parts of the state. Bedrock is encountered in construction projects more commonly in the other areas of the state. Crop growth on soils with bedrock less than 40 inches below the surface is restricted during part of many growing seasons because of insufficient moisture available to the root system.

Soil surveys in the state are conducted under the guidance of the Ohio Soil Inventory Board, whose membership includes representatives from the Ohio Department of Natural Resources, Division of Soil and Water Conservation; United States Department of Agriculture, Natural Resources Conservation Service; and Ohio Agricultural Research and Development Center.

---

Soil Regions of Ohio

1. Read the 1st page of the Soil Regions of Ohio Article. List what you think are the three most important sentences from the article.

X _____________________________________________________________________________________

_____________________________________________________________________________________

X _____________________________________________________________________________________

_____________________________________________________________________________________

X _____________________________________________________________________________________

_____________________________________________________________________________________

2. Soil Regions of Ohio Map and Legend

• Columbus is a part of Franklin County. Based on the map, what soil region(s) does Columbus belong to? ______________________________________________________________

• How did Ohio's Soil Series (regions) get their names?
   ___________________________________________________________________________________
   ___________________________________________________________________________________

• How are the soils in the same series classified? What do they have in common?
   ___________________________________________________________________________________

Article Sections:

Geology and Soil Regions

• Describe the how Columbus' soil region formed. ________________________________
   ___________________________________________________________________________________
   ___________________________________________________________________________________

• What rock types make up Columbus' most common bedrock? _________________
   ___________________________________________________________________________________
**Land Resource Regions in Ohio**

- Compare each of the Land Resource Regions by describing the soil in each region.

<table>
<thead>
<tr>
<th>Land Resource Region</th>
<th>Soil Area Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake States Fruit, Truck, and Dairy</td>
<td>Example: Soil formation is associated with glacial lakes. Soil Region 1: characterized by level crop fields Soil Region 2: characterized by coarse-texture and sloping</td>
</tr>
<tr>
<td>Central Feed Grains and Livestock</td>
<td></td>
</tr>
<tr>
<td>East Central Farming and Forest Region</td>
<td></td>
</tr>
<tr>
<td>Northeastern Forage and Forest Region</td>
<td></td>
</tr>
</tbody>
</table>

- Which Land Resource Region is Columbus a part of? _______________________________________
Soil Characteristics By Region

- The following characteristics help in the identification and categorization of Ohio's soils.
  1) Define each of the characteristics.
  2) Explain how each characteristic can impact the use of soil in Ohio

Slope -

Organic Matter Content -

Clay Content -

Depth to Seasonal High Water Table -

Depth to Bedrock -
Soil Regions of Ohio

1. Read the 1st page of the Soil Regions of Ohio Article. List what you think are the three most important sentences from the article.

X _____________________________________________________________________________________
X _____________________________________________________________________________________
X _____________________________________________________________________________________

Answer Will Vary

2. Soil Regions of Ohio Map and Legend

• Columbus is a part of Franklin County. Based on the map, what soil region(s) does Columbus belong to? **Regions 4 and 5 (very small part is Region 3)**

• How did Ohio’s Soil Series (regions) get their names? **Soil series are commonly named for cities or towns near where the soils were first studied.**

• How are the soils in the same series classified? What do they have in common? **Soils classified in the same series have horizons that are similar in composition, thickness, and arrangement.**

Article Sections:

**Geology and Soil Regions**

• Describe the how Columbus’ soil region formed. **Columbus' soil was formed by glacial deposits during one or more glaciations.**

• What rock types make up Columbus’ most common bedrock? **Limestone, Dolomite, and Shales**
Land Resource Regions in Ohio

- Compare each of the Land Resource Regions by describing the soil in each region.

<table>
<thead>
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<td>Lake States</td>
<td>Example:</td>
</tr>
<tr>
<td>Fruit, Truck, and</td>
<td>Soil formation is associated with glacial lakes.</td>
</tr>
<tr>
<td>Dairy</td>
<td>Soil Region 1: characterized by level crop fields</td>
</tr>
<tr>
<td></td>
<td>Soil Region 2: characterized by coarse-texture and sloping</td>
</tr>
<tr>
<td>Central Feed</td>
<td>Soil Region 4: Coarser texture than Regions 3,5.</td>
</tr>
<tr>
<td>Grains and Livestock</td>
<td>Soil Region 7: More weathered and less fertile due to older glacial deposits.</td>
</tr>
<tr>
<td>East Central</td>
<td>Soil areas are heavily wooded.</td>
</tr>
<tr>
<td>Farming and Forest</td>
<td>Soil Regions 10, 11, 12: include areas where coal has been surface mined.</td>
</tr>
<tr>
<td>Region</td>
<td>Region 10: associated with remnants of an ancient stream system.</td>
</tr>
<tr>
<td></td>
<td>Region 11: Wide ridgetops and valleys.</td>
</tr>
<tr>
<td></td>
<td>Region 12: clay, red or yellowish brown subsoil are common.</td>
</tr>
<tr>
<td>Northeastern</td>
<td>Region 6: soil ranges from coarse to fine texture</td>
</tr>
<tr>
<td>Forage and Forest</td>
<td>Region 8: similar soil to Region 11; thin glacial deposits.</td>
</tr>
<tr>
<td>Region</td>
<td></td>
</tr>
</tbody>
</table>

- Which Land Resource Region is Columbus a part of?

   Central Feed Grains and Livestock Region
Soil Characteristics By Region

- The following characteristics help in the identification and categorization of Ohio's soils.
  1) Define each of the characteristics.
  2) Explain how each characteristic impacts the use of soil in Ohio.

Slope -

1) **Measures the change in elevation over a distance of 100 feet.**
2) **Soils on slopes of more than 8% generally do not meet the criteria for "prime farmland".**

Organic Matter Content -

1) **As plants and animals live and die on and in soil, they contribute organic matter that is then decomposed by microorganisms in the soil.**
2) **Organic matter contributes to the fertility and stability of the topsoil which can impact farming.**

Clay Content -

1) **Clay particles are very small which have an effect on soil texture and how "sticky" the soil becomes when it is wet.**
2) **Topsoil with clay texture is more difficult to till or excavate.**

Depth to Seasonal High Water Table -

1) **Water accumulation in soil that receives rainfall or runoff faster than it can move through the soil.**
2) **Soils that are not saturated for more than a few days are easier to manage for a variety of uses.**

Depth to Bedrock -

1) **The depth of glacial materials that covers the bedrock.**
2) **Can impact construction projects and crop growth.**
6th Grade Science Unit:
What is in that?

Unit Snapshot

Topic: Rocks, Minerals and Soil

Grade Level: 6

Duration: 9 days

Summary
The following activities engage students in exploring the properties of rocks, minerals, and soil. Students will discover how rocks, minerals, and soil can be used based on their properties.

CLEAR LEARNING TARGETS
"I can" statements

_____ identify examples of different ways the soil, rock and minerals can be used.

_____ recognize the characteristics of soil, rock and minerals to determine how they can be used.

Activity Highlights and Suggested Timeframe

Day 1
Engagement: Students will try to identify what resources have in common using materials in the classroom, and give explanations to why properties of materials are important.

Day 2
Exploration: Students will learn about mining rocks and minerals, how they are important in manufacturing, and where can we find them in our everyday lives.

Days 3-4
Explanation: Students will conduction and use research to choose a rock or mineral to mine, explain its use, and identify where in the world the rock or mineral can be found.

Days 5-7
Elaboration: Students design an investigation that can test slope stability and landslides by creating mountains out of different materials.

Day 8 and on-going
Evaluation: Formative and summative assessments are used to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to the uses of rocks, minerals, and soil. A teacher-created short cycle assessment will be administered at the end of the unit to assess all clear learning targets (Day 6).

Day 9
Extension/Intervention: Based on the results of the short-cycle assessment, facilitate extension and/or intervention activities.
NEW LEARNING STANDARDS:

6.ESS.5 Rocks, minerals and soils have common and practical uses.
- Nearly all manufactured material requires some kind of geologic resource. Most geologic resources are considered nonrenewable. Rocks, minerals and soil are examples of geologic resources that are nonrenewable.
- Nonrenewable energy sources should be included (such as fossil fuels).

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering) that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Frame-work for K-12 Science Education Scientific and Engineering Practices

COMMON CORE STATE STANDARDS for LITERACY in SCIENCE:

CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

*For more information: [http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf](http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)

STUDENT KNOWLEDGE:

Prior Concepts Related to Energy Transfer
K-2: Objects have physical properties, properties of objects can change and Earth's nonliving resources have specific properties.
Grades 3-5: Rocks and soil have characteristics, Earth's resources can be used for energy, renewable and nonrenewable resources, some of Earth's resources are limited.

Future Application of Concepts
Grades 7-8: Biogeochemical cycles (including the hydrologic cycle) are related to erosion and weathering of rock, minerals and soil. The history of Earth (including the formation of nonrenewable resources) from the interpretation of the rock record are studied.
High School: The formation of elements, chemical bonding and nuclear energy are found in the Physical Sciences. In grades 11/12 Physical Geology, Earth's resources and specific laws pertaining to the resources are explored at a greater depth.
### MATERIALS:

**Engage**
- "Resources in our classroom" handout for each student

**Explore**
- "What is Mining" handout for each student
- Internet access to [http://www.middleschoolscience.com](http://www.middleschoolscience.com)
- Press Cancel for username and password
- Day 2: students need access to the internet to research common rocks and minerals.

**Explain**
- Internet access/Computers/ipads
- "Mining Rocks and Minerals" handout
- "What's Mine is Mine" handout

**Elaborate**
- 1 Wallpaper tray or square dish pan
- 1 Gallon of fine sand
- 2 Wood blocks same size
- 1 Long wood block for smoothing sand
- 3 One-gallon buckets
- 1 Plastic cup for dipping
- 1 Tube, narrow and flexible, 60 cm long
- 1 Paraffin or plastic block
- 1 Acetate or plastic dam
- 6 Cotton swabs
- 1 Box food coloring
- Paper towels and water
- Stream Table Handout

### VOCABULARY:

**Primary**
- Nonrenewable
- Ore
- Reclamation
- Subsurface Mining
- Surface Mining

**Secondary**
- Open-Pit
- Quarries
- Strip Mining

### SAFETY

- Remind students to following basic science laboratory rules.
- Students may want to wear aprons when using food coloring.

### ADVANCED PREPARATION

- Build a Stream Table or Purchase a stream table.
- Website resources for making a stream table
  - [http://www.brady.edu/dotAsset/c645ab3d-126d-4ce0-b23a-e32d904f6699.pdf](http://www.brady.edu/dotAsset/c645ab3d-126d-4ce0-b23a-e32d904f6699.pdf)
  - [http://www.geo.arizona.edu/sites/www.geo.arizona.edu/files/Stream%20Table1.pdf](http://www.geo.arizona.edu/sites/www.geo.arizona.edu/files/Stream%20Table1.pdf)
<table>
<thead>
<tr>
<th><strong>ENGAGE</strong></th>
<th><strong>EXPLORE</strong></th>
<th><strong>EXPLAIN</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong>: The objective of this activity is to engage students and formatively assess their knowledge related to the common and practical uses of rock, minerals, and soils.</td>
<td><strong>Objective</strong>: The objective of the following activities is to give students the opportunity to work and develop a basic understanding of the mining of rocks, mineral, and soils; with an emphasis on the resources it provides to most manufactured materials.</td>
<td><strong>Objective</strong>: The objective of the following activities is to give students the opportunity to explain what they have learned about the importance of mining, what products use mined material, and where these rocks and minerals can be found.</td>
</tr>
<tr>
<td><strong>What is the teacher doing?</strong></td>
<td><strong>What is the teacher doing?</strong></td>
<td><strong>What is the teacher doing?</strong></td>
</tr>
<tr>
<td><strong>Resources in our classroom</strong> (Day 1)</td>
<td><strong>What is Mining?</strong> (Day 2)</td>
<td><strong>Mining Rocks and Minerals</strong> (Day 3)</td>
</tr>
<tr>
<td>• Distribute the “Resources in our classroom handout”</td>
<td>• Distribute the &quot;What is Mining&quot; guided notes.</td>
<td>• If possible, it is recommended to have computer/internet available for student use.</td>
</tr>
<tr>
<td>• Facilitate as students complete their charts. Some may want to use the internet, at teacher discretion.</td>
<td>• Facilitate using the provided PowerPoint. <a href="http://www.slideshare.net/ajoyrajsaikia/mining-ppt-2014">http://www.slideshare.net/ajoyrajsaikia/mining-ppt-2014</a></td>
<td>• Distribute the Mining Rocks and Minerals sheet.</td>
</tr>
<tr>
<td>• Use proximity to facilitate questions and keep students on task.</td>
<td></td>
<td>• Facilitate as students research and collect information.</td>
</tr>
<tr>
<td>• Share answers with a different group.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Use proximity to facilitate questions and keep students on task.</td>
<td><strong>What is Mining?</strong> (Day 2)</td>
<td><strong>Mining Rocks and Minerals</strong> (Day 3)</td>
</tr>
<tr>
<td>1. With a partner, students complete the handout &quot;Resources in our classroom&quot;</td>
<td>1. Student will fill in the blank as the teacher/student review the PowerPoint.</td>
<td>• Students use the internet to research each rock/mineral and identify the type or rock/miner and their importance of in manufacturing.</td>
</tr>
</tbody>
</table>
| 2. When teacher instructs the class students can share answers with another group. | 2. Ask Clarifying questions. | • Possible web sites: - [http://geology.com](http://geology.com)  
[http://library.thinkquest.org/05aug/00461/rocks.htm](http://library.thinkquest.org/05aug/00461/rocks.htm)  
[http://www.rocksandminerals.com/uses.htm](http://www.rocksandminerals.com/uses.htm) |
| | | • Record research on provided worksheet. |
### What's Mine is Mine (Day 4)
- Facilitate "What's Mine is Mine" activity. This will be a summary of their research and allow each student to come up with their own mining company.
- Peer editing will be helpful to check that all information is in the student's writing.
- Adaptation: Students develop an advertisement that shares the same information.

### Objectives
The objective of the following activity is to give students the opportunity to gain deeper understanding of how the effects streams paths is a result of various factors.

### What is the teacher doing?
#### Slope Stability - Stream Tables (Day 5-7)
- See Teacher Page
- Set up stream table ahead of time.*
  - If you have more than one class, you will need to set up additional tables for your other classes because the materials will become too saturated. (directions attached)
- You can have student groups with stream table or as a demonstration depending on supplies.
- Add outside objects to enhance lesson such as: sticks, rocks, miniature houses or people.
- Have students make observation with each trial-run.
  1. Ask students the following questions: Do you feel that the stream moved quickly?
  2. What part did the water seem to change direction? Why?
  3. Did the speed of the stream increase or decrease after it changed directions?

### What are the students doing?
#### Slope Stability - Stream Tables (Days 5-7)
1. Follow teacher directions when handling the stream table and its materials.
2. Students will work with their group (if grouped) or will observe teacher demonstration.
3. Teacher or students will build a hill with three different materials (sand, clay, and gravel) in three different trays.
4. Students will slowly pour water onto stream table.
5. Students will make observation of the direction of the stream and its impact on the landform (mountain) and material in the stream table. (ex. sand)
6. Repeat for all three materials until desired outcome occurs.
7. Students will discuss essential questions with classmates and teacher.

---

**ELABORATE**
(3 days)
(How will the new knowledge be reinforced, transferred to new and unique situations, or integrated with related concepts?)
**Objective:** The objective of the assessments is to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to common uses of rocks, minerals, and mining.

<table>
<thead>
<tr>
<th>Formative</th>
<th>Summative</th>
</tr>
</thead>
<tbody>
<tr>
<td>How will you measure learning as it occurs?</td>
<td>What evidence of learning will demonstrate to you that a student has met the learning objectives?</td>
</tr>
<tr>
<td>• Consider developing a teacher-created formative assessment.</td>
<td>1. A teacher created short-cycle assessment can be used to assess all learning targets.</td>
</tr>
<tr>
<td>• &quot;Resources in the classroom&quot; activity can formatively assess students' knowledge related to resources and materials.</td>
<td></td>
</tr>
<tr>
<td>• Activities throughout the unit can be used to assess the progression of student knowledge towards mastery of learning targets.</td>
<td></td>
</tr>
</tbody>
</table>

**Extension**

1. Create a map of Ohio describing their rock, mineral, soil resources they provide. Create a chart in the use of Ohio's resources.
2. Have students write down their observations and describe the differences they observed with using different materials. Have them explain why there were differences.

**Intervention**

1. Students can complete What Is The True Color of a Mineral on in Science.

**Common Misconceptions**

1. Soil is sterile. Remind students that life exists in soil. If it were sterile, there would be no life inside of it.
2. All soil is brown. Most have bits of red, yellow and orange, and then you get black from organic matter. The more unusual colors—blue, green, purple—you'll find in wetlands or from some unusual minerals. They also have a lot of texture. Run your hand over soils, and you'll find some are smooth, some are bumpy, some have huge rocks in them.
3. Soil is only found in certain areas. Soil is found everywhere.

**Differentiation**

Lower-Level: Provide additional text resources (trade books, articles) that are appropriate for the reading level of the students. For the group work, consider mixed grouping strategies. Consider modeling through a demonstration and then allowing students to explore these topics through guided inquiry. The information sheets for "Mining in Ohio or the different uses of rocks and minerals in Central Ohio" are of varying levels of reading difficulty. Consider assigning the appropriate level information sheet to particular students.
Higher-Level: Consider having students create their own investigations related to rocks, minerals, mining, and the importance of rocks and minerals in Central Ohio, including pursuing research about these topics based on real-world applications (i.e. mining coal, mining other minerals, mining rocks.)

Strategies for meeting the needs of all learners including gifted students, English Language Learners (ELL) and students with disabilities can be found at ODE.

Textbook Resources:
• *Holt Series Science* Textbook:
  Rocks
  Minerals
  Weathering and Soil Formation

Websites:
• The Earth's Natural Storehouse: [http://www.mineralseducationcoalition.org/sites/default/files/uploads/naturesstorehouseactivity_0.pdf](http://www.mineralseducationcoalition.org/sites/default/files/uploads/naturesstorehouseactivity_0.pdf)
• Soils Alive [https://soilsalive.com/article-attachments/Soils_Alive_Soil_Building_Program.pdf](https://soilsalive.com/article-attachments/Soils_Alive_Soil_Building_Program.pdf)
• Mineral Education Coalition: [http://www.mineralseducationcoalition.org/grades-6-8](http://www.mineralseducationcoalition.org/grades-6-8)
• Rocks and minerals mined in Ohio and their uses: [http://www.dnr.state.oh.us/Portals/10/pdf/GeoFacts/geof11.pdf](http://www.dnr.state.oh.us/Portals/10/pdf/GeoFacts/geof11.pdf)

Literature:
• *Landslides, Slumps, and Creep (First Books--Earth & Sky Science)* Author Peter H. Goodwin
• *Landslides (Nature's Fury)* John Hamilton (Author)
• *Landslides: Mass Wasting, Soil, and Mineral Hazards (The Hazardous Earth)* (Author) Ph.D. Kusky Timothy
• *Landslides and Avalanches in Action (Natural Disasters in Action)* by Louise A. Spilsbury and Richard Spilsbury (Sep 1, 2008)
• *Landslides (Natural Disasters)* by Anne Ylvisaker (Jan 2006)
• *Growing Up in Coal Country* by Susan Campbell Bartoletti (Sep 27, 1999)
• *Boys in the Pits: Child Labour in Coal Mines* by Robert G. McIntosh (Nov 2000)
• *In Coal Country* by Judith Hendershot (Mar 12, 1987)
• *Trapped: How the World Rescued 33 Miners from 2,000 Feet Below the Chilean Desert*
• *Our Daddy Is A Coal Miner* by Casey Erwin (Dec 10, 2007)
Discovery Ed:
  Preventing Landslides in Malibu (5:55)
  Highway 101, WA: A Road Destroyed by Landslides (3:06)
  Bainbridge Island, WA: Victim of a Landslide (3:06)
  Mining (2:11)

Movies/Videos:
  • Diamond Mines: http://www.youtube.com/watch?v=aG_gCRI0Ppc
  • America Revealed: Where does Coal Come From PBS? (6:44)
    http://www.youtube.com/results?search_query=mining+coal&oq=mining+coal&gs_l=youtube.3...136909.141253.0.143097.17.6.0.0.0.0.1078.20006.1j1.2.0...0...1ac.1.11.youtube.rDH9joEmkhU
  • http://www.sciencekids.co.nz/videos/chemistry/mineralchemistry.html
### Resources In Our Classroom

Observe at the following supplies found in our everyday lives:

1. Identify the items necessary to make the product.
2. Explain the properties of each item and why it is best for the product.

<table>
<thead>
<tr>
<th>Item</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pencils</td>
<td></td>
</tr>
<tr>
<td>2. Paper</td>
<td></td>
</tr>
<tr>
<td>3. Desk or Table</td>
<td></td>
</tr>
<tr>
<td>4. Computer</td>
<td></td>
</tr>
</tbody>
</table>
Name: __ANSWER KEY__ - Possible student answers 

Date: ____________________ Period: 

### Resources In Our Classroom

Observe at the following supplies found in our everyday lives

3. identify the items necessary to make the product
4. explain the properties of each item and why it is best for the product

<table>
<thead>
<tr>
<th>Product</th>
<th>Item</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pencils</td>
<td>Wood</td>
<td>Wood: Renewable, easy to gather and change</td>
</tr>
<tr>
<td></td>
<td>Graphite compound</td>
<td>Resource that will leave a mark</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
<td>Resource that can be easy to change</td>
</tr>
<tr>
<td></td>
<td>Rubber</td>
<td>Petroleum is used due to its ability to make a large number of plastic like items.</td>
</tr>
<tr>
<td>2. Paper</td>
<td>Wood fibers</td>
<td>Ability to write on and make thin sheets</td>
</tr>
<tr>
<td>3. Desk or Table</td>
<td>Wood or Plastic</td>
<td>Ability to manipulate size and shape</td>
</tr>
<tr>
<td></td>
<td>Metal</td>
<td>Solid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resources are currently available</td>
</tr>
<tr>
<td>4. Computer</td>
<td>Glass</td>
<td>Resources are currently available</td>
</tr>
<tr>
<td></td>
<td>Plastic</td>
<td>Ability to manipulate size and shape</td>
</tr>
<tr>
<td></td>
<td>Metals</td>
<td></td>
</tr>
</tbody>
</table>
What is Mining?

Use with PPT http://www.middleschoolscience.com/What-is-Mining.ppt

Mining is extracting _____________ or _____________ from the ground. An _____________ is a natural material with a high concentration of _________________ valuable minerals that can be _____________ for a profit.

There are two types of mines:

1) _____________ Mining
   a. _____________ deposits are on or near the _____________ of the Earth and are removed.
   b. There are 3 types of surface mines:
      i. _____________: Remove large, near surface deposits of _____________ such as _____________ and copper. Mined downward in _____________
      ii. _____________: stone, crushed rock, sand, gravel
      iii. _____________ Removing surface _____________ in strips up to 50 meters wide x 1 Kilometers long.

2) _____________ Mining
   a. Minerals are located too _____________ for surface mining
   b. _____________ and _____________ are dug into the ground to reach the _____________ ground to reach the _____________
   c. Sterling Mine Museum
      i. Last operating _____________ mine in New Jersey.
      ii. Closed in _____________ after more than 138 years of almost continuous production.
      iii. Produced more than iv. _____________ million tons of _____________ Depths of more than _____________ ft below the surface through tunnels totaling more than _____________ miles in length.
Reclamation:
1) Mining can _______________ or disturb _______________

2) _______________ Products can _______________ water systems

3) When a mine is no longer being used, the land should be _______________ to its _______________ state or _______________ = Reclamation

4) Surface Mining and Reclamation Act of _______________

Why do we need mining?
1) You will use _______________ million pounds of _______________ and _______________ in your lifetime

2) List 6 examples of products made from mined materials:
   i. _______________
   iv. _______________

   ii. _______________
   v. _______________

   iii. _______________
   vi. _______________

3) If you can’t _______________ it, you have to _______________ it!
**Mining Rocks and Minerals**

Use the internet to research each rock/mineral and identify the type or rock/mineral and their importance in manufacturing.

Possible web sites:  
http://geology.com  
http://library.thinkquest.org/05aug/00461/rocks.htm  
http://www.rocksandminerals.com/uses.htm

<table>
<thead>
<tr>
<th>Name</th>
<th>Type of Rock</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marble</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obsidian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand/Gravel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slate</td>
<td></td>
<td></td>
</tr>
</tbody>
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<tr>
<th>Name</th>
<th>Type of Rock</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>Igneous</td>
<td>Used in road building materials</td>
</tr>
<tr>
<td>Calcite</td>
<td>Mineral</td>
<td>Used in cements and mortars and the production of lime</td>
</tr>
<tr>
<td>Coal</td>
<td>Sedimentary</td>
<td>plastic, papermaking, heat, perfume, rubber, charcoal, roofing shingles, glassmaking, and iron and steel.</td>
</tr>
<tr>
<td>Granite</td>
<td>Igneous</td>
<td>Used for buildings, monuments, and tombstones</td>
</tr>
<tr>
<td>Marble</td>
<td>Metamorphic</td>
<td>Used in building, floors, tile in bathrooms</td>
</tr>
<tr>
<td>Obsidian</td>
<td>Igneous</td>
<td>Used in making arrowheads and knives</td>
</tr>
<tr>
<td>Pumice</td>
<td>Igneous</td>
<td>Used in scouring, scrubbing, and polishing materials</td>
</tr>
<tr>
<td>Quartz</td>
<td>Mineral</td>
<td>Used in making glass, electrical components, and optical lenses</td>
</tr>
<tr>
<td>Sand/Gravel</td>
<td>Sedimentary</td>
<td>Use in streets, highways and sidewalks; in the foundation for your house and school; as decorative materials for yards and gardens; in water purification plants to protect your health and in the construction of buildings from the most modest of homes to the world's tallest skyscrapers.</td>
</tr>
<tr>
<td>Sandstone</td>
<td>Sedimentary</td>
<td>Used in the building industry for houses</td>
</tr>
<tr>
<td>Slate</td>
<td>Metamorphic</td>
<td>Used for roofs, chalkboards, and patio walks</td>
</tr>
</tbody>
</table>
What's Mine is Mine

You are going to invest in a mining company and you can only mine one type of rock or mineral. Your paragraph(s) should include the following information:

1. Which one rock or mineral will you decide to mine?
2. Explain why you choose this rock or mineral with the information that you've discovered with your research.
3. Identify a local company that may want to buy your rock or mineral resources and why your company would be the best.
4. Give the location of your mine company (anywhere in the world).
This lesson has been created to align with Ohio’s New Learning Standards 6.ESS.4 Vision Into Practice - Demonstrating Knowledge suggested performance task.

<table>
<thead>
<tr>
<th>What is the teacher doing?</th>
<th>What are the students doing?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slope Stability - Stream Tables</strong></td>
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</tr>
<tr>
<td>Set up stream table ahead of time.* If you have more than one class, you will need to set up additional tables for your other classes because the materials will become too saturated. (directions attached)</td>
<td>1. Follow teacher directions when handling the stream table and its materials.</td>
</tr>
<tr>
<td>• You can have student groups with stream table or as a demonstration depending on supplies.</td>
<td>2. Students will work with their group (if grouped) or will observe teacher demonstration.</td>
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<td>3. Teacher or students will build a hill with three different materials (sand, clay, and gravel) in three different trays.</td>
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<tr>
<td>• Have students make observation with each trial-run.</td>
<td>4. Students will slowly pour water onto stream table.</td>
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<tr>
<td>1. Ask students the following questions: Do you feel that the stream moved quickly?</td>
<td>5. Students will make observation of the direction of the stream and its impact on the landform (mountain) and material in the stream table. (ex. sand)</td>
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<tr>
<td>2. What part did the water seem to change direction? Why?</td>
<td>6. Repeat for all three materials until desired outcome occurs.</td>
</tr>
<tr>
<td>3. Did the speed of the stream increase or decrease after it changed directions?</td>
<td>7. Students will discuss essential questions with classmates and teacher.</td>
</tr>
</tbody>
</table>
Slope Stability

Objective: Design an investigation that can test slope stability and landslides, by creating slopes out of different materials (e.g., sand, gravel, clay soil). Water is added to test the stability of each material analyze data and write a conclusion to represent the findings.

Materials: sand, gravel, clay soil, 2L bottle, water, foil rectangle 9x13 in.

Step I:
1. Use the sand and build a slope in the foil rectangle container.
2. Do others have the same steepness?
3. Is there another way to build a steeper slope?
   a. Try different ways of pouring the sand to make the hill
   b. Try more or less sand
4. Was there a better way to build a steep slope with sand?
5. Observe other groups sand and share how you made your slope.

Step II:
Design an experiment to compare the various types of hills in order to investigate slope stability.
6. In designing the experiment, start by listing all the possible variables (things you can change or that can be changed).
7. Pick one variable to change, keep others unchanged.
8. Quantify all variables and measurements.
9. Repeat the experiment exactly as you already did to help identify any unknown variable or variations in the experiment that you are not controlling.
10. Compare results with others.
Lab Report - Teacher Page

Title: A descriptive complete sentence.

Introduction: This section should include an introductory paragraph discussing question(s)/problems in which you are trying to answer. This paragraph should also include preliminary observations or basic researched information about the subject as well as listing any formulas that will be used during the lab.

Hypothesis: This section requires you to write a possible solution for the problem found with in the introductory paragraph. Make sure this solution is testable and written as a complete sentence. (Use "If/Then" statements for 6th grade)

Materials: Create a bulleted list of all items used in the lab

Safety Concerns: Create a list of all safety precautions/concerns within the lab.

Procedure: This section will be numerically listed (1,2,3…) step by step list of instructions to complete the lab exercise. These steps must be written so that another person can use the directions to complete the activity.

Results/Data: This section should include all observations or additional notes you make during the lab. It must include appropriate labeled tables, graphs and charts needed to simplify your data. Add color when appropriate.

Conclusion: The conclusion section of your lab should be at least a paragraph long. Your conclusion should begin with restating your hypothesis. Then you need to either support or reject your hypothesis based on your results and analyzed data taken from your lab. Explain why you supported or rejected your hypothesis-support your decision with facts from your lab. Additionally state one thing you learned from the lab and describe how it applies to real-life situations.

Diagram/Illustration (if necessary): Examples: Draw a visual representation of your lab set up describing what occurred/ draw what you saw under the microscope/ before and after illustration of the lab results. This will be determined by your teacher.

*Lab reports should be written using Third Person. However, use your best judgment when it concerns your students. (Modeling will help.)
Lab Report

Name: ______________________
Date: ______________________
Period: ____________________

Title: ____________________________

Introduction: ____________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

Hypothesis: ____________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

Materials: ____________________________________________

Safety Concerns: ________________________________________
________________________________________________________

Procedure:
1. 
2. 
3. 
4. 
5. 
Results/Data:

Conclusion: ____________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________
Stream Table Instructions
Caitlin Orem
Department of Geosciences
oremc@email.arizona.edu

<table>
<thead>
<tr>
<th>Materials</th>
<th>Where to Buy</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-qt Sterilite under-bed plastic storage box</td>
<td>Target, Walmart</td>
<td>$9</td>
</tr>
<tr>
<td>Waterproof Silicone Caulking</td>
<td>Home Depot, Lowes</td>
<td>$4</td>
</tr>
<tr>
<td>Nylon Hose Barb (1 per table) ½ in ID, ¾ in NIP</td>
<td>Home Depot, Lowes</td>
<td>$2</td>
</tr>
<tr>
<td>1 in hole saw bit</td>
<td>Home Depot, Lowes</td>
<td>$3</td>
</tr>
<tr>
<td>5/8 inch clear plastic tubing (10 ft, 2.5 ft per table)</td>
<td>Home Depot, Lowes</td>
<td>$5</td>
</tr>
<tr>
<td>Handheld power drill</td>
<td>Borrow or Own</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessories</th>
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<tr>
<td>Bricks or other block object</td>
<td>Borrow or Own</td>
<td></td>
</tr>
<tr>
<td>Plastic dinosaurs or houses</td>
<td>Dollar Tree</td>
<td>$1</td>
</tr>
<tr>
<td>Transparency Sheets</td>
<td>School or buy</td>
<td></td>
</tr>
<tr>
<td>Bucket</td>
<td>Home Depot, Lowes</td>
<td>$5</td>
</tr>
<tr>
<td>Plastic pop bottles</td>
<td>Buy anywhere</td>
<td></td>
</tr>
<tr>
<td>Bottle caps (three per table)</td>
<td>Collect from pop bottles</td>
<td></td>
</tr>
<tr>
<td>Dirt, sand, rock, etc.</td>
<td>Collect or go to local quarry</td>
<td></td>
</tr>
</tbody>
</table>

Instructions
Table draining system
1. Mark with a pen/marker a dot about 3-4 inches above bottom of box on one of the small ends.
Use this as a guide to drill a hole in that location with a handheld power drill with hole saw bit.
Use Exacto knife or fingers to remove any loose material around the edge of the hole.
*Power drills can be scary, if you aren’t comfortable have a friend, spouse, coworker, etc. help you out!

2. Screw in threaded end of nylon hose barb into hole just drilled. Screw about half way, and add caulkig around hose barb and screw in the rest of the way. Add a thick “bead” around the completely screwed in hose barb and on the back of the barb within the box. Let caulkig set at least 3 hours (directions on tube).
*The screwing of the hose barb can be difficult, helps to have someone with strong hands help out with this portion!

3. Cut plastic tubing to desired length (i used 2.5 ft.) for drainage and push tubing onto hose barb.

OR
1. If you do not want the tubing, you can also cut a deep notch into the end of the table for drainage and affix a string for the water to follow from the notch to the bucket.
*This will compromise the stability of the box, especially when filled with heavy dirt and water!
Figure 3. Effects of low (3a) and high (3b) stream discharge. Note the differing degrees of incision, braiding, and fan-delta deposition.

Figure 4. Effects of low (4a) and high (4b) slope angles. Note the differing degrees of incision, braiding, and fan-delta deposition.
Figure 5. Effects of medium discharge on a partially “vegetated” (5a) and on a partially “urbanized” (5b) watershed. Note the differing degrees of incision (especially at the downstream edge of the cover type).

Figure 6. Earthen dam and reservoir pre-breaching (6a) and post-breaching (6b). Note the deep incision in the dam and the well developed fan-delta in the reservoir downstream.
6th Grade Science Unit:
6.PS.1
Unit Snapshot

Topic: Matter and Motion

Grade Level: 6
Duration: ~3 weeks

Summary (as stated in Ohio's New Learning Standards for Science)
All matter is made of atoms, which are particles that are too small to be seen, even with a light microscope. There is empty space between the atoms that make up a substance. An element is a chemical substance that cannot be broken down into simpler substances.

There are approximately 90 different naturally occurring elements that have been identified. There are additional elements that were made in a laboratory, but these elements are not stable. All atoms of any one element are alike, but are different from atoms of other elements.

All substances are composed of one or more of elements. Compounds are composed of elements joined together chemically. Each compound has its own unique, unchanging composition of type and number of elements and atoms. Both elements and compounds can form molecules (e.g., elemental hydrogen is made up of molecules containing two atoms of hydrogen joined with one atom of oxygen). In addition to molecules, atoms may join together in large three-dimensional networks (addressed further in high school). All particles of a pure substance have nearly identical mass. Particles of different substances usually have different masses, depending upon their atomic composition. Computer simulations can be used to visualize this abstract material.

Matter has properties of mass and volume. Mass measures the amount of matter in an object (e.g., a wood block) or substance (e.g., water), and volume measures the three-dimensional space that matter occupies. Equal volumes of different substances usually have different masses. Some materials, like lead or gold, have a lot of mass in a relatively small space. Other materials, like a foam cup and air, have small mass in a relatively large amount of space. This concept of comparing substances by the amount of mass the substance has in a given volume is known as density.

While the mass and volume of a material can change depending upon how much the material there is, the density generally remains constant, no matter how much of the material is present. Therefore, density can be used to identify a material. The density of any object (e.g., a wood block) or substance (e.g., water) can be calculated from measurements by dividing the mass by the volume. Mass vs. volume graphs can be constructed and interpreted (e.g., to determine which material has the greater density.)

Note 1: Appropriate background knowledge such as graphics representing the atomic composition of the Substances involved or descriptions of how the matter can be formed, decomposed or separated, should accompany questions asking to clarify matter as an element, compound or mixture. The nature of chemical bonding is not appropriate at this age.

Note 2: Constructing and analyzing mass vs. volume graphs aligns with fifth-grade common core mathematics standards (Geometry 1 and 2). The volume of solids can be determined by water displacement or calculated from the dimensions of a regular solid (grade 5 Common Core Mathematics Standards, Measurement and Data 5).

Note 3: The structure of the atom, including protons, neutrons and electrons, is addressed in the high school physical science syllabus.
**Clear Learning Targets**

*I can*…*statements*

- _____ recognize that all matter is made up of atoms.
- _____ explain that atoms take up space, have mass, and are in constant motion.
- _____ create models of elements, compounds, and molecules to show atomic differences.
- _____ describe the composition of substances in terms of elements and/or compounds.
- _____ measure the mass and volume of a substance, and calculate density by dividing mass by the volume.
- _____ compare substances by the amount of mass a substance has in a given amount of volume (density).
- _____ construct and interpret mass vs. volume graphs.

**Activity Highlights and Suggested Timeframe**

<table>
<thead>
<tr>
<th>ENGAGE</th>
<th>EXPLAIN</th>
<th>EXPLORE</th>
<th>ELABORATE</th>
<th>EVALUATE</th>
</tr>
</thead>
</table>

(~3 Weeks)

Unit Activities posted below:
OHIO'S NEW LEARNING STANDARDS:

6.PS.1 Matter and Motion: All matter is made up of small particles called atoms.

- Each atom takes up space, has mass and is in constant motion. Mass is the amount of matter in an object.
- Elements are a class of substances composed of a single kind of atom.
- Molecules are the combination of two or more atoms that are joined together chemically.
- Compounds are composed of two or more different elements. Each element and compound has properties, which are independent of the amount of the sample.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering) that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

STUDENT KNOWLEDGE:

Prior Concepts Related to Matter:

PreK-2: Properties are descriptions that can be observed using the senses. Materials can be sorted according to their properties. Changes in materials are investigated.

Grades 3-5: Objects are composed of matter, which has mass* and takes up space. Matter includes solids, liquids, and gases (air). Volume is the amount of space an object takes up. The total amount of matter and mass* remains the same when it undergoes a change.

*While mass is the scientifically correct term to use in this context, the NAEP 2009 Science Framework (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level. In Ohio, students will not be assessed on the difference between weight and mass until grade 6.

Future Application of Concepts:

Grades 7-8: Differences between pure substances and mixtures and acids and bases are explored.

Elements in the periodic table can be classified as a metal, nonmetal or nonreactive gas based on their properties and position on the periodic table. Atoms can be joined together to form separate molecules or large three-dimensional networks. Changes are classified into two groups, chemical or physical, depending upon whether the atomic composition of the material changes.
High School: Protons, neutrons and electrons make up atoms. The relationship between atomic structure and the periodic table is explored. The nature of ionic, covalent and metallic bonding is also studied.
Atoms and Molecules

Objectives
This lesson will enable students to:

- Describe how atoms are the building blocks of matter
- Explain the relationship between atoms, elements, molecules and compounds
- Build a model of an atom and a molecule
- Interpret element information from the Periodic Table
- Discuss the historical development of the study of matter, including contributions of notable scientists.

Standards
This lesson aligns with the following National Science Content Standards:

- Physical Science, 5-8, 9-12
- History & Nature of Science, 5-8

Materials

Introduction

- Periodic Table poster
- Molecule building kit
- Periodic Table placemats

Atoms activity

- Large marshmallows - 2 different colors
- Small colored marshmallows
- Toothpicks
- "Atom Models" - Appendix A
- "Atoms" activity sheet - Appendix B

Molecules activity

- Small gumdrops (yellow only)
- Large gumdrops (green, black, red)
- Toothpicks
- Colored pencils (yellow, green, black, red)
- "Molecules" activity sheet - Appendix C
- "Molecules" pictures - Appendix D

Elements Extension

- "Periodic Table Cards" - Appendix E
- "Periodic Table" activity sheet - Appendix F
- Glue sticks
- 11" x 14" construction paper
- Colored pencils
- "Orbitals" activity sheet - Appendix G
- Small round colored stickers or colored markers

Miscellaneous

- Answer keys - Appendix H
- Periodic Table handout - Appendix I

Revision Date: 11/03/2008

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Preparation

Ask the teacher to divide the class into at least two groups. If there are enough volunteers, groups can be split to do identical activities, allowing for a greater hands-on experience. Build the molecules shown in Appendix D using the Molecule building kit. Make copies of the "Periodic Table" handout - Appendix I for each student and have available at the stations. If Periodic Table placemats are available, have one at each station. Put the Periodic Table poster where it can be referred to during the introduction.

Atoms activity:
(Set up two stations of this activity if there are enough volunteers)

Display "Atom Models" - Appendix A
Provide "Atoms" activity sheets - Appendix B, one per student. Only use the first page of the appendix for the standard activity; copy both pages back-to-back if the "Ions & Isotopes" extension is going to be used.
Put the large marshmallows in bowls or bins, one color to a bowl. Put all of the small marshmallows in one additional bowl. Have toothpicks available within easy reach of all students in the working group.

Molecules activity:
(Set up two stations of this activity if there are enough volunteers)

Provide "Molecules" activity sheet - Appendix C, one per student.
Sort the gumdrops by color. Have toothpicks available within easy reach of all students in the group. Use the "Molecules Pictures" - Appendix D as a reference. All students will need access to yellow, green, black and red colored pencils.

The Elements activity works best as an additional classroom activity to reinforce and review the structure of the Periodic Table.

Elements activity:

Divide class into groups of 5 or 6 students.
Prepare one set per group of "Periodic Table Cards" - Appendix E by copying them (onto cardstock, if possible) and cutting them apart ahead of time.
Provide "Periodic Table" activity sheets - Appendix F, one per student.
Have the following colored pencils available: green, pink, blue, purple, orange, red, tan and yellow.
Each group will also need a glue stick and an 11" x 14" piece of construction paper.

The Elements lesson extension may be included as a third station or used by itself.

Elements Upper Level extension:

Copy "Orbitals" activity sheets - Appendix D (onto cardstock, if possible). Provide small round stickers or a colored marker, one color per student.
Introduction

Have the volunteers introduce themselves and give a brief description of their backgrounds. Use the “Atoms” PowerPoint slides (http://www.micron.com/k12/resources) for the introduction.

Slide 1: Introduction
Q: What is everything made of? Every building, every person, every object?
A: Everything is made up of matter. Matter is anything that takes up space and has mass. Anything that is material is made of matter - in fact both words come from the same Latin root meaning "stuff."

Q: What is matter made of?
A: Matter is made up of molecules, and molecules are made up of atoms.

Slide 2: Democritus
About 2400 years ago, a Greek philosopher named Democritus (460-370 B.C.) thought a lot about what things were made of. One day while slicing an apple, he wondered how small he could slice it. He figured that everything that could be touched could be divided again and again until there was a piece left that was so small it couldn't be cut. It turns out that he had the right idea, and that smallest piece we now know as the atom. The word atom comes from an ancient Greek word that means "uncuttable." Democritus could not see an atom (as we can today), but he had figured out something very important. His atom is what we talk about today as an element.

Q: Give an example of an element.
A: Answers will vary; Examples include hydrogen, oxygen, gold, etc. Refer to a Periodic Table for additional elements.

In the mid 17th century, scientists began to prove the existence of specific elements, or pure substances that couldn't be "cut" into other pieces. This led scientists to discover the elements and atoms that make up all matter.

The types of scientists who study atoms are chemists and physicists. At the beginning of the 20th century, scientists found that Democritus’ atom actually could be cut into smaller pieces, called sub-atomic particles.

Slide 3: "Atom Models"
Q: What are the parts of an atom?
A: Nucleus, electron, proton, neutron
The nucleus is at the center of the atom. It is made up of protons and neutrons. Moving around outside of the nucleus are the electrons. In 1915 a scientist named Niels Bohr proposed a model of the atom that illustrates the atomic structure, called the planetary model or the Bohr model.

Refer to the picture of the atom on the slide and explain how the electrons look like planets orbiting the nucleus "sun."

Proton comes from the Greek word for "first."

Q: What type of charge does a proton have?
A: Protons have a positive charge.

Neutron comes from the Latin word for "neutral."

Q: What charge does a neutron have?
A: The neutron has no charge - it is neutral.

The third particle of an atom is the electron. Electrons are much smaller than the protons or the neutrons (almost 2000 times smaller). It is easy to illustrate them orbiting around the nucleus using the Bohr model, although they actually move in a cloud.

Q: What type of charge do electrons have?
A: Electrons are negative.

All atoms in the universe are made up of the same basic particles: the proton, the neutron and the electron. The different combinations of those particles combine to make different elements, which combine to make different molecules.
Slide 4: Periodic Table

All of the known elements are organized into a table called the Periodic Table of Elements. Each box on the Periodic Table represents an element, organized according to its atomic number and atomic mass. Each element is represented by a letter, or letters, which is its atomic symbol. Generally the symbol is the first one or two letters of the element's name, although several elements' symbols come from their name in Latin. Some elements have names that relate to famous scientists or where it was discovered.

Point out some of the names of the elements, specifically:
- Sodium (Na, #11) - name comes from the Latin "Natrium"
- Copper (Cu, #29) - name comes from the Latin "Cuprum"
- Einsteinium (Es, #99) - named after Albert Einstein
- Berkelium (Bk, #97) and Californium (Cf, #98) - named after the Berkeley, California lab where they were discovered.

Elements have a specific atomic configuration and properties. Each element has an atomic number, equal to the number of protons in that atom. In fact, the number of protons in an atom determines what element it is.

Q: How is the Periodic Table arranged with respect to the number of protons an atom has?
A: The Periodic Table is arranged in increasing Atomic Number, which corresponds to an increasing number of protons in each element.

Q: How many elements are there?
A: There are 117 known elements. 90 of them are naturally occurring elements, and scientists have been able to create 27 more in the laboratory.

If you are using the PowerPoint presentation included on the flash drive in the kit, you can click on the "♪" symbol on the slide to access a fun song about the Elements. You must be connected to the internet to access this song.

Note: In 1869, Dmitri Mendeleyev was credited with putting together the Periodic Table of Elements. He listed all of the known elements and grouped them together based on their properties. Mendeleyev was able to organize the table in its present form even though many of the elements hadn't been discovered yet. Although Mendelev is credited with developing the Periodic Table, many scientists contributed to its development. The organization was done in such a way that as new elements have been discovered, they fit right where they are supposed to on the Periodic Table. It is no coincidence that once the periodic table was arranged by atomic number, the elements that were close to one other ended up having very similar properties.
The elements in the Periodic Table are arranged according to their atomic structure. We can determine the number of protons, neutrons and electrons in an atom by looking at the information given in this table.

If you are using the flash drive PowerPoint, an additional click will pull up a large element box. Point out the location of specific parts of the element box, including the atomic number, atomic symbol, chemical name, atomic mass.

Slide 5: Sodium
Let's look at a familiar element, sodium.
Q: What is the atomic number for sodium? A: Sodium has an atomic number of 11.

Q: How many protons does it have?  
A: Sodium has eleven protons; eleven is the Atomic Number, which is equal to the number of protons.

The number of protons plus the number of neutrons equals the Atomic Mass of an element, because each one is approximately equal to one Atomic Mass Unit (AMU). The mass of the electrons is negligible because they are so small.

Q: If the number of protons as well as the Atomic Mass of an element is known, how can the number of neutrons be determined?  
A: The number of neutrons can be determined by subtracting the number of protons from the Atomic Mass (rounded to the nearest whole number).

Q: What is the atomic mass of sodium?  
A: The atomic mass of sodium is 22.99 (whole number = 23)

Q: How many neutrons does the sodium atom have?  
A: The sodium atom has twelve neutrons. Subtract the Atomic Number (11) from the Atomic Mass (23) to get 12.

Q: In order for the charge of the atom to be balanced, how many electrons does an atom have?  
A: An atom must have the same number of electrons (negative charge) as protons (positive charge) in order for it to be balanced. The atom will have no overall charge.

Q: How many electrons does the sodium atom have?  
A: The sodium atom has eleven electrons to balance the 11 protons.
Atoms are the building blocks of molecules, and molecules are the building blocks of matter. Molecules are extremely small. In one spoonful of sugar there are approximately 300 billion, billion molecules of sugar! Molecules can be made up of atoms of the same element, or molecules can be made up of a combination of atoms of different elements.

Q: Name a molecule that is made up of atoms of the same element.
A: Hydrogen (H₂), oxygen (O₂) and nitrogen (N₂).

A molecule is formed when two or more atoms join together chemically. Combinations of two or more elements are called compounds. All compounds are molecules but not all molecules are compounds. Molecules can also join together to form larger molecules.

Q: Name a molecule that is also a compound, or is made up of atoms of different elements.
A: The most familiar answers will be water (H₂O), carbon dioxide (CO₂) or salt (NaCl).

Look at the model of the water molecule. It is noted as H₂O. Since it is made up of more than one element, it is also a compound.

Q: What does the “2” represent in the formula for water?
A: There are two hydrogen atoms for every one oxygen atom in a molecule of water.

The molecular formula for table sugar is C₁₂H₂₂O₁₁. Write this compound formula on the board.

Q: What are the different elements in this compound?
A: Carbon, hydrogen and oxygen.

Q: How many atoms of each element are in the compound?
A: There are 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms.

This is how combinations of elements are noted in compounds; the element symbols followed by the number of atoms of that element in that compound. The number of atoms in the combination is determined by how the atom is structured - but that is a future topic!

Today we will be exploring the basic building blocks of atoms, and how atoms and elements form together to become molecules and compounds.

Have the class divide into four groups; two groups will do an Atoms station and two groups will do a Molecules station. If there are not enough volunteers, the groups can be combined for two stations.
Atoms Station

Refer to the "Atom Models" picture - Appendix A and the Periodic Table - Appendix I for this activity. Review with the students the basics of the atomic structure, including the names of the parts of an atom and their charges, the basis of what makes an element (number of protons), and how to determine the number of sub-atomic elements in an element.

Atoms Activity

Pass out the "Atoms" activity sheets - Appendix B, one to each student. Have students fill out their activity sheets to determine the numbers of sub-atomic particles in each atom on the activity sheet. Next have the students use the marshmallows to build an atom model. Suggest students start with a Helium atom. If time allows, have students build the Lithium or Beryllium atom. It will be required to build these additional atoms in order to do the Extension activity.

Step 1: Determine the number of sub-atomic particles in each atom and complete the activity sheet.

Step 2: Construct a helium atom model. Start with the nucleus. The large colored marshmallows are the protons, and the large white marshmallows are the neutrons. Connect the nucleus marshmallows together using toothpicks.

Step 3: Use small colored marshmallows for the electrons. Attach the proper number of electrons to the nucleus using the toothpicks.

Step 4: Construct additional atom models if there is time.
Atoms Extension - Ions & Isotopes

If it is desired to do the Atoms Extension activity, prepare the activity sheet by copying both pages of the “Atoms” activity sheet - Appendix B back-to-back. Use slide 10 - Ions & Isotopes for this extension.

A neutral atom is an atom with an equal number of electrons and protons, which is equal to the atomic number. The atoms you constructed are neutral atoms and have no net charge. Atoms can be altered by changing the number of neutrons or electrons.

Ions
Ions are atoms with extra electrons or missing electrons. The atom’s electron configuration determines if it is an ion. Two examples of elements that form ions are sodium (Na) and chlorine (Cl), which form an ionic bond to make Sodium Chloride, or table salt.

Q: Sodium loses an electron to bond with chlorine. Does it become a positive or a negative ion?
A: It becomes positive because it lost a negative charge, and is noted Na⁺.

Q: What happens to chlorine in order to bond to the sodium ion?
A: Chlorine gains an electron, becoming a negative ion noted as Cl⁻.

Students may have already constructed a lithium atom from the main activity. Have them use this atom to construct an ion.

Step 1: Construct a lithium atom with the marshmallows

Step 2: Turn it into an ion by removing one of the electrons.

Step 3: Record the information on the Atoms: Ions/Isotopes activity sheet.
Isotopes

Some elements have isotopes of that element. An isotope of an element has the same number of protons (and electrons) as that element, but a different number of neutrons. If you change the number of protons an atom has, you change what element it is. If you change the number of neutrons an atom has, you make an isotope of that element. Carbon is an example of this. Carbon has an isotope called carbon-14 (C-14), which is used to "carbon-date" organic objects.

Q: Based on the atomic number and atomic mass of carbon, how many neutrons does it have?
A: Carbon has 6 neutrons.

Carbon-14 has 8 neutrons, or 2 more than "regular" or elemental carbon.

Q: Why is it called carbon-14?
A: The 14 is the total number of protons and neutrons, or 6 + 8. All isotopes are noted in this way.

Have students use either the lithium or the beryllium atom they made from the previous activity to make an isotope.

Step 1: Take either the lithium or the beryllium atom you made and add or subtract a neutron to make an isotope.

Step 2: Record the information on the "Atoms: Ions/Isotopes" activity sheet.

Example: Beryllium, Be, Atomic number 9, has 4 protons and 5 neutrons. To make "Be-10," you need to add one neutron to the model of the Beryllium atom.
Molecules Station

Refer to the "Molecules" picture - Appendix D for this activity. Review with students the structure of molecules, noting the difference between same-element molecules, and multi-element molecules, or compounds.

Molecules Activity

Give each student a "Molecules" activity sheet. Guide the students through the activity according to the steps. When finished, compare the gumdrop models to pictures of molecules (Appendix D), or to models from a molecule kit made ahead of time.

Step 1: Color in the Molecule Color Key with colored pencils as indicated.

Step 2: Determine the number and type of elements in each molecule and write it down on the activity sheet.

Step 3: Draw and color the molecule models using the colored pencils.

Step 4: Make at least one of the molecule models using appropriately colored gumdrops and toothpicks.

Conclusion

Everything in the world is made up of atoms.

Q: What determines how atoms and molecules are structured?
A: The arrangement of the sub-atomic particles in the atom; the electrons, protons and neutrons.

The arrangement of sub-atomic particles within each atom determines not only what type of element it is, but how it combines to form molecules and how it reacts in the physical world. The makeup of the entire world is dependent on the configuration of individual atoms. Understanding the chemistry and physics of the atom helps us understand our world.
Elements Activity

This activity is best suited as an extension to the Atoms & Molecules activities.

Divide the students into groups of 4 or 5, and distribute the "Periodic Table" cards - Appendix E evenly to each group. Give each student a "Periodic Table" activity sheet - Appendix F. Write the color key and the card pattern (given below) on the board. Students will need a Periodic Table - Appendix I to do this activity.

Step 1: The card has an element box with a chemical symbol on it. Complete the information in the Element box by filling in the atomic number, element name & atomic mass.

Step 2: Determine the number of protons, neutrons and electrons for each element. Write it in the appropriate place on the card.

Step 3: Color the element box on the card according to the key:

<table>
<thead>
<tr>
<th>White</th>
<th>Green</th>
<th>Pink</th>
<th>Blue</th>
<th>Purple</th>
<th>Orange</th>
<th>Red</th>
<th>Tan</th>
<th>Yellow</th>
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</thead>
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<td>F</td>
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<tr>
<td>Na</td>
<td>S</td>
<td>Mg</td>
<td>Cl</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>Ne</td>
<td>Ar</td>
</tr>
</tbody>
</table>

Step 4: Arrange the cards in whatever pattern makes the most sense.

Discuss with the students their reasons for choosing the pattern they did. Then have them rearrange their cards in the following pattern and glue them on the construction paper. Have them notice how this is similar (or different from) the pattern on the Periodic Table.

Step 5: Answer the questions on the activity sheet using the information on your Periodic Table that you made.

Discuss the answers to the questions with the students, asking each member of the group to explain a different question.
Elements Upper Level Extension

The following information involves a more in-depth explanation of Elements and the Periodic Table. Individual lesson objectives will determine if the following material is appropriate. Slides 11 - 14 are appropriate for this extension.

The rows of the Periodic Table are called periods, and correspond to how the electrons are grouped for the elements in that row. **Point out the periods on the Periodic Table.**

**Slide 12 - Orbital Shells & Periods**

The electrons are arranged in orbital shells around the nucleus, with specific patterns of electrons in each shell. This arrangement helps determine how different atoms and elements bond together to become molecules and compounds.

Elements in any one period are only similar because they have the same number of orbitals. They do not typically have other similar characteristics. The number of the period is the same as the number of orbitals for those elements.

<table>
<thead>
<tr>
<th>Period 1 elements fill electrons in the 1st orbital shell.</th>
<th>1st orbital shell</th>
<th>Nucleus</th>
<th>He</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 2 elements fill electrons in the 2nd orbital shell. The 1st shell is full.</td>
<td>2nd orbital shell</td>
<td>Electron</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Electron &quot;placeholder&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 3 elements fill electrons in the 3rd orbital shell. The 1st &amp; 2nd shells are full.</td>
<td>3rd orbital shell</td>
<td></td>
<td>Si</td>
</tr>
</tbody>
</table>

Refer to the Periodic Table, pointing out lithium, carbon and oxygen.

Q: What Period are these elements in, and how many orbital shells would each atom have? A: Each element in this group is in Period 2, and so each atom has two orbital shells.

Gold has the chemical symbol of Au. Have the students find Au on the Periodic Table.

Q: How many orbital shells does it have and why? A: It has six orbital shells because it is in Period 6.
Slide 13 - Groups
The columns of the Periodic Table are called groups. Point out the groups on the Periodic Table.

Elements in the same group typically have similar chemical properties, which has to do with the similar configuration of the electrons for those elements. Each element in a group has the same number of electrons in its outermost orbital, which makes them have similar bonding characteristics.

Some Periodic Tables have elements in different colors.
Q: Is there a pattern to the color arrangements of the elements on the Periodic Table?
A: Yes, in most cases the elements that are the same color are adjacent to each other. The most notable patterns are the two columns on the far right of the Periodic Table.
Q: What do you think this represents?
A: Elements in the same group have the most similar properties. The elements in the last two groups have very similar properties to each other, but properties that are very different than the rest of the elements.

Slide 14 - Valence Electrons
The electrons in the outermost orbital are called valence electrons. The group number tells you how many valence electrons an element has. Each shell can only hold a certain number of electrons. The first shell only holds two electrons, and the next shells hold eight.

Refer to the Periodic Table.
Look at carbon and silicon on the Periodic Table.
Q: What group number are they in? A: They are in group IV, or 4.

Q: How many valence electrons would each element have, since they are in group IV? A: There are four valence electrons in the outermost orbital shell of those elements, and all other elements in that Group.

Atoms are in their most stable state when they have a full outer shell. In order to maintain a full outer shell, atoms will gain or lose electrons. Since most of the outer shells hold eight electrons, this is called the octet rule, because the atom wants to have a full octet (eight) of electrons. This rule, or the potential to gain or lose an electron to maintain a full shell, is what governs how elements combine with one another.
Orbitals Activity:

Materials for this activity include "Orbitals" activity sheets - Appendix G and small round stickers divided by colors (or different colored markers), one color per group. You will need to refer to the Periodic Table for this activity.

Give each student an activity sheet and a sheet of sticker dots (all one color) or a colored marker. Assign each student one of the elements listed below.
Elements: Li, B, N, F, Mg, Si, S, Ar
If there are more than 8 students in the group, also assign He, Na, P, Cl.

Step 1: Write down the name of the element you were assigned.

Step 2: Determine the Atomic number, Atomic mass (rounded), and the number of protons, neutrons and electrons for the element. Record it on your activity sheet.

Step 3: Fill in the period number of the element. This is how many orbitals it has.

Step 4: Fill in the group number of the element. This is how many electrons are in the outermost orbital.

Step 5: Starting at the innermost orbital, put stickers on (or color in) the spaces corresponding to the total number of electrons. You must fill up one orbital before moving to the next one.
Appendix A - Atoms and Molecules

Atom Models

<table>
<thead>
<tr>
<th>Bohr model of the atom</th>
<th>3-D model of the atom</th>
</tr>
</thead>
</table>

http://www.mbe.doe.gov/me70/manhattan/images/AtomLabeledLarge.gif
Refer to a Periodic Table and the Key below to fill out this table for each element. Start with helium as your first atom to make.

1. Fill out the table below with the correct values.
2. Assemble the nucleus using the proper number of large colored and white marshmallows. Stick them together with toothpicks.
3. Select the proper number of small colored marshmallows (all one color) as your electrons. Attach them one at a time to the nucleus with toothpicks.

<table>
<thead>
<tr>
<th>ATOM</th>
<th>ATOMIC SYMBOL</th>
<th>ATOMIC NUMBER</th>
<th>NUMBER OF PROTONS (Rounded)</th>
<th>ATOMIC MASS (Mass - Atomic Number)</th>
<th>NUMBER OF NEUTRONS</th>
<th>NUMBER OF ELECTRONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1.00</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Helium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beryllium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY**

- **Number of Protons** = Atomic Number
  (Use the large colored marshmallows for protons)
- **Number of Neutrons** = Atomic Mass - Atomic Number
  (Use the large white marshmallows for neutrons)
- **Number of Electrons** = Number of Protons
  (Use the small colored marshmallows for electrons)
## ATOMS: Ions & Isotopes

Refer to a Periodic Table and the Key below to fill out this table for each element.

1. Assemble the nucleus using the proper number of large colored and white marshmallows. Stick them together with toothpicks.
2. Select the proper number of small colored marshmallows (all one color) as your electrons. Attach them one at a time to the nucleus with toothpicks.
3. Turn the lithium atom into an ion, and note the information.
4. Turn either the lithium atom or the beryllium atom into an isotope. Record what you did.

<table>
<thead>
<tr>
<th>ATOM</th>
<th>ATOMIC SYMBOL</th>
<th>ATOMIC NUMBER</th>
<th># PROTONS</th>
<th>ATOMIC MASS</th>
<th># NEUTRONS</th>
<th># ELECTRONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beryllium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isotope:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Key

- **Number of Protons** = Atomic Number
- **Number of Neutrons** = Atomic Mass - Atomic Number
- **Number of Electrons** = Number of Protons

**Ions:** Add or subtract an electron from the element

**Isotope:** Add or subtract a neutron from the element
# Molecules

1. Color in the Molecule Color Key molecules with colored pencils as indicated.
2. Determine the number of elements in each molecule, and write it down.
3. Draw and color the molecule with the correct number of elements.
4. Make each molecule model using appropriately colored gumdrops and toothpicks.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Elements</th>
<th>Draw It!</th>
</tr>
</thead>
</table>
| Water          | H = _____  
                 O = _____  
                 N = _____  
                 C = _____  |
| CO₂            | H = _____  
                 O = _____  
                 N = _____  
                 C = _____  |
| Ammonia        | H = _____  
                 O = _____  
                 N = _____  
                 C = _____  |
| Methane        | H = _____  
                 O = _____  
                 N = _____  
                 C = _____  |

**Molecule Color Key**

- Hydrogen (yellow)
- Oxygen (red)
- Nitrogen (green)
- Carbon (black)
# Molecule Pictures

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H₂ (Hydrogen)</strong></td>
<td><strong>O₂ (Oxygen)</strong></td>
<td><strong>N₂ (Nitrogen)</strong></td>
<td><strong>NaCl (Salt)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H₂O (Water)</strong></td>
<td><strong>CO₂ (Carbon Dioxide)</strong></td>
<td><strong>NH₃ (Ammonia)</strong></td>
<td><strong>CH₄ (Methane)</strong></td>
</tr>
</tbody>
</table>
# Periodic Table Cards

**Sample Card**

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Symbol</th>
<th>Period</th>
<th>Electrons</th>
<th>Protons</th>
<th>Neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>1</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>He</td>
<td>2</td>
<td>He</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Li</td>
<td>3</td>
<td>Li</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Be</td>
<td>4</td>
<td>Be</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>B</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>C</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>N</td>
<td>7</td>
<td>N</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>O</td>
<td>8</td>
<td>O</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>9</td>
<td>F</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

**Notes:**
- **P** stands for Protons
- **N** stands for Neutrons
- **E** stands for Electrons
Appendix G - Atoms & Molecules

Name ________________________________

Periodic Table Activity sheet
Use the periodic table you made to answer each question

1. How are the atomic numbers and the atomic masses of the elements related to how the elements are arranged on the Periodic Table?

2. How does the number of electrons relate to the arrangement? What is the difference in the number of electrons in a 3rd period element and the 2nd period element above it?

3. Do some elements next to each other have the same number of neutrons? How is that possible?

4. How are the colors arranged, and what conclusions can be drawn from this arrangement?

Referring to the table below, write the name and number of the group above each color group on the periodic table you made.

<table>
<thead>
<tr>
<th>Green</th>
<th>Blue</th>
<th>Orange</th>
<th>Red</th>
<th>Tan</th>
<th>Pink</th>
<th>Purple</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Group II</td>
<td>Group III</td>
<td>Group IV</td>
<td>Group V</td>
<td>Group VI</td>
<td>Group VII</td>
<td>Group VIII</td>
</tr>
<tr>
<td>Alkali Metals</td>
<td>Alkaline Earth Metals</td>
<td>Boron Family</td>
<td>Carbon Family</td>
<td>Nitrogen Family</td>
<td>Oxygen Family</td>
<td>Halides</td>
<td>Noble Gases</td>
</tr>
</tbody>
</table>

5. Compare the location of the Metals groups in relation to the Noble Gases group. What is the significance of their locations on the Periodic Table?

6. Which groups have names that help you to remember where certain elements are located?
Appendix G - Atoms & Molecules

Name: _________________________

Element = ______

Atomic Number = ______
Number of Protons = Atomic Number = ______
Atomic Mass (rounded to nearest whole number) = ______
Number of Neutrons = Atomic Mass - Atomic Number = ______
Number of Electrons = Number of Protons = ______
Period = ______ = Number of Orbitals
Group = ______ = Number of electrons in outermost orbital
(These are called valence electrons)
Music

Refer to a Periodic Table and the Key below to fill out this table for each element. Start with helium as your first atom to make.

1. Fill out the table below with the correct values.
2. Assemble the nucleus using the proper number of large colored and white marshmallows. Stick them together with toothpicks.
3. Select the proper number of small colored marshmallows (all one color) as your electrons. Attach them one at a time to the nucleus with toothpicks.

<table>
<thead>
<tr>
<th>ATOM</th>
<th>ATOMIC SYMBOL</th>
<th>ATOMIC NUMBER</th>
<th>NUMBER OF PROTONS (ROUNDED)</th>
<th>ATOMIC MASS (MASS - ATOMIC NUMBER)</th>
<th>NUMBER OF NEUTRONS</th>
<th>NUMBER OF ELECTRONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1.00</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>2</td>
<td>2</td>
<td>4.00</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lithium</td>
<td>Li</td>
<td>3</td>
<td>3</td>
<td>7.00</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>4</td>
<td>4</td>
<td>9.00</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

**KEY**

- **Number of Protons** = Atomic Number (Use the large colored marshmallows for protons)
- **Number of Neutrons** = Atomic Mass - Atomic Number (Use the large white marshmallows for neutrons)
- **Number of Electrons** = Number of Protons 25 (Use the small colored marshmallows for electrons)
**ATOMS: Ions & Isotopes - Answer Key**

Refer to a Periodic Table and the Key below to fill out this table for each element.

1. Assemble the nucleus using the proper number of large colored and white marshmallows. Stick them together with toothpicks.
2. Select the proper number of small colored marshmallows (all one color) as your electrons. Attach them one at a time to the nucleus with toothpicks.
3. Turn the lithium atom into an ion, and note the information.
4. Turn either the lithium atom or the beryllium atom into an isotope. Record what you did.

<table>
<thead>
<tr>
<th>ATOM</th>
<th>ATOMIC SYMBOL</th>
<th>ATOMIC NUMBER</th>
<th># PROTONS</th>
<th>ATOMIC MASS</th>
<th># NEUTRONS</th>
<th># ELECTRONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Li</td>
<td>3</td>
<td>3</td>
<td>7.00</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>4</td>
<td>4</td>
<td>9.00</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Lithium Ion</td>
<td>Li+</td>
<td>3</td>
<td>3</td>
<td>7.00</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Isotope: Be</td>
<td>Be 10</td>
<td>4</td>
<td>4</td>
<td>—</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

**KEY**

- **Number of Protons** = Atomic Number
- **Number of Neutrons** = Atomic Mass - Atomic Number
- **Number of Electrons** = Number of Protons
- **Ions**: Add or subtract an electron from the element
- **Isotope**: Add or subtract a neutron from the element
### Periodic Table Cards - ANSWER KEY

#### Sample Card

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>H</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=1</td>
<td>H</td>
<td>Hydrogen</td>
<td>1.00</td>
</tr>
<tr>
<td>N=0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>He</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=2</td>
<td>He</td>
<td>Helium</td>
<td>4.00</td>
</tr>
<tr>
<td>N=2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>Li</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=3</td>
<td>Li</td>
<td>Lithium</td>
<td>7.00</td>
</tr>
<tr>
<td>N=4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>Be</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=4</td>
<td>Be</td>
<td>Beryllium</td>
<td>9.00</td>
</tr>
<tr>
<td>N=5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=4</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>B</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=5</td>
<td>B</td>
<td>Boron</td>
<td>11.00</td>
</tr>
<tr>
<td>N=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=5</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>C</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=6</td>
<td>C</td>
<td>Carbon</td>
<td>12.00</td>
</tr>
<tr>
<td>N=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>N</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=7</td>
<td>N</td>
<td>Nitrogen</td>
<td>14.00</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=7</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atomic #</th>
<th>O</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Oxygen</td>
<td>16.00</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>E=8</td>
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</tr>
</tbody>
</table>

<table>
<thead>
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<th>F</th>
<th>Element Name</th>
<th>Atomic mass</th>
</tr>
</thead>
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<td>Fluorine</td>
<td>19.00</td>
</tr>
<tr>
<td>N=10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E=9</td>
<td></td>
<td></td>
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</tbody>
</table>
### Periodic Table Cards - ANSWER KEY

**Pg. 2 of 2**

<p>| | | | | | |</p>
<table>
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<tr>
<th></th>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
<tr>
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<tr>
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<td>Sodium</td>
<td>Magnesium</td>
<td>Aluminum</td>
<td>Silicon</td>
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<tr>
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<td>24.00</td>
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<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Sulfur</td>
<td>Chlorine</td>
<td>Argon</td>
<td>Hydrogen</td>
<td></td>
</tr>
<tr>
<td>31.00</td>
<td>32.00</td>
<td>35.00</td>
<td>40.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

**P = 10, N = 10, E = 10**

**P = 11, N = 12, E = 11**

**P = 12, N = 12, E = 12**

**P = 13, N = 14, E = 13**

**P = 14, N = 14, E = 14**

**P = 15, N = 16, E = 15**

**P = 16, N = 16, E = 16**

**P = 17, N = 18, E = 17**

**P = 18, N = 22, E = 18**

**P = 1, N = 0, E = 1**
1. How are the atomic numbers and the atomic masses of the elements related to how the elements are arranged on the Periodic Table?
The elements are arranged in increasing atomic number, which also corresponds to increasing atomic mass.

2. How does the number of electrons relate to the arrangement? What is the difference in the number of electrons in a 3rd period element and the 2nd period element above it?
The elements are arranged in increasing number of electrons. Each element in the 3rd row has eight more electrons than the element above it in the 2nd row.

3. Do some elements next to each other have the same number of neutrons? How is that possible?
Yes, some of the elements next to each other have the same number of neutrons, but they are different elements because they have a different number of protons.

4. How are the colors arranged, and what conclusions can be drawn from this arrangement?
The colors line up in columns. The elements in each column have similar properties. Elements are organized into families (groups) according to their physical and chemical properties. Notice that the elements that are the same color fall into the same group.

5. Compare the location of the Metals groups in relation to the Noble Gases group. What is the significance of their locations on the Periodic Table?
The Metals groups are on the far left of the Table, and the Noble Gases are on the far right. There is a very big difference in the structure of the elements from one side of the Table to the other.

6. Which groups have names that help you to remember where certain elements are located?
Groups III, IV, V and VI are all named after the element at the top of the group. Knowing the names of these groups helps to locate where those elements are on the Periodic Table.
Element = Li (Lithium)
Atomic Number = 3
Atomic Mass = 6.9
Number of Protons = 3
Number of Neutrons = 7
Number of Electrons = 3
Period = 2
Group = I

Element = Mg (Magnesium)
Atomic Number = 12
Atomic Mass = 24.3
Number of Protons = 12
Number of Neutrons = 12
Number of Electrons = 12
Period = 3
Group = II

Element = B (Boron)
Atomic Number = 5
Atomic Mass = 10.8
Number of Protons = 5
Number of Neutrons = 6
Number of Electrons = 5
Period = 2
Group = III

Element = Si (Silicon)
Atomic Number = 14
Atomic Mass = 28.1
Number of Protons = 14
Number of Neutrons = 14
Number of Electrons = 14
Period = 3
Group = IV

Element = N (Nitrogen)
Atomic Number = 7
Atomic Mass = 14.4
Number of Protons = 7
Number of Neutrons = 7
Number of Electrons = 7
Period = 2
Group = V

Element = F (Fluorine)
Atomic Number = 9
Atomic Mass = 18.99
Number of Protons = 9
Number of Neutrons = 10
Number of Electrons = 9
Period = 2
Group = VII

Element = S (Sulfur)
Atomic Number = 16
Atomic Mass = 32.1
Number of Protons = 16
Number of Neutrons = 16
Number of Electrons = 16
Period = 3
Group = VI

Element = Ar (Argon)
Atomic Number = 18
Atomic Mass = 39.9
Number of Protons = 18
Number of Neutrons = 22
Number of Electrons = 18
Period = 3
Group = VIII
<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Atomic Mass</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
<th>Period</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>He (Helium)</td>
<td>2</td>
<td>4.0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>VIII</td>
</tr>
<tr>
<td>Na (Sodium)</td>
<td>11</td>
<td>22.99</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>3</td>
<td>I</td>
</tr>
<tr>
<td>P (Phosphorus)</td>
<td>15</td>
<td>30.99</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>3</td>
<td>V</td>
</tr>
<tr>
<td>Cl (Chlorine)</td>
<td>17</td>
<td>35.45</td>
<td>17</td>
<td>18</td>
<td>17</td>
<td>3</td>
<td>VII</td>
</tr>
</tbody>
</table>
# Molecules - Answer Key

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Elements</th>
<th>Draw It!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>H = 2 O = 1 N = 0 C = 0</td>
<td><img src="image" alt="Water Diagram" /></td>
</tr>
<tr>
<td>H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>H = 0 O = 2 N = 0 C = 1</td>
<td><img src="image" alt="Carbon Dioxide Diagram" /></td>
</tr>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>H = 3 O = 0 N = 1 C = 0</td>
<td><img src="image" alt="Ammonia Diagram" /></td>
</tr>
<tr>
<td>NH₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>H = 4 O = 0 N = 0 C = 1</td>
<td><img src="image" alt="Methane Diagram" /></td>
</tr>
<tr>
<td>CH₄</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# Molecule Color Key
- Hydrogen (yellow)
- Oxygen (red)
- Nitrogen (green)
- Carbon (black)
What is Matter Made of?

Objectives:

• Students will learn that MATTER is made of ATOMS.
• Students will learn how ATOMS move in different STATES of MATTER.
• Students will learn how small ATOMS are.
• Students will review the three STATES of MATTER.

Introduction:

1. Review by eliciting the THREE STATES of MATTER and examples of each. It is useful to write them on the board.
2. Explain that scientists have discovered that all MATTER is made of very, very small particles called ATOMS. Tell them the differences in the STATES of MATTER are due to the different types of ATOMS, the arrangement of the ATOMS, how they move and how closely they are packed.

DEMONSTRATION: Model of Atomic Motion

Materials:

• A clear plastic container with a lid (clear plastic cups work well)
• Enough marbles (super balls, gum balls or beads) to fill the container.

Procedure:

1. Explain that ATOMS are very, very small. So small that we can't see them without special microscopes, so scientists often use MODELS to represent how they look and act. Explain that spheres or balls are often used to represent ATOMS because ATOMS sometimes act like spheres. Take out a marble and explain that in this demonstration each marble represents an ATOM.
2. Take out the plastic container completely full of marbles. Explain that this is what the ATOMS in a SOLID act like. They are in a fixed arrangement so they do not move around. Shake the container to show that none of the ATOMS change their position, they just vibrate in the same place. Explain that this arrangement of ATOMS is why SOLIDS are hard and keep their shape.
3. Tell them you are going to turn up the temperature. Take out a bunch of the marbles (about 1/3 - 1/2) so that the others can move around as you move the container. Explain this is how the ATOMS in a LIQUID behave. They are still close to each other but don't stay in one place. Tilt the container to one side and show how a liquid flows and takes the shape of the container. Take off the lid and pour all of the marbles into a cup to emphasize how they flow.
4. Tell them you are now really going to turn up the heat. Put a few of the marbles back into the container. Explain that there is a lot of space between the ATOMS of a GAS and that they are moving very fast. Ask why they are moving so fast. Emphasize, that an increase in temperature is an increase in energy, which increases the speed that the atoms move. Shake the container so that the marbles bounce around hitting the sides and each other. Explain that
this is what the ATOMS in a GAS are doing, moving around very fast filling the entire container and colliding with each other.

5. Remind them ATOMS are so small that we can't see them. Gases are a good example of this.

6. Take out the diagrams (see Appendix) and have the class identify which state each diagram represents. As they do, hang them on the board under the name of each state.

**ACTIVITY:** *Act like ATOMS*

1. Tell the kids that they are going to have a chance to act like ATOMS as they change through the different STATES OF MATTER. Review the differences. ATOMS in SOLIDS have a fixed pattern and don't change position. ATOMS in LIQUIDS move around a bit and change their location. There is a lot of space between ATOMS in a GAS and they move around very fast, changing their position and filling the entire container.

2. Have every one stand up. Begin by having everyone get lined up in rows, close together and facing the same direction (this may be the way their desks are already arranged.) Tell them they are all ATOMS. Ask them what STATE they are in.

3. Now tell them to start to move around in the same general area. As they do they will break the rows and continue to change their locations. Ask them what STATE they are now in.

4. Ask them what is the other STATE of MATTER. When they answer GAS, ask them how the ATOMS in a GAS behave. Tell them to act like a GAS. Encourage them to run all over the room and bounce off the walls. After you have had enough, call everyone back over for an introduction.

**Introduction:** *Allow me to introduce* Oxy

Tell them that you would like to introduce them to one of the most important ATOMS in the UNIVERSE. Explain that you are going to get some help teaching the class about ATOMS by introducing them to some ATOMS from an exciting new animation called *Molecularium*. You can explain that they are imaginary characters and unlike real ATOMS, they can talk and sing.

Take out the picture of OXY and introduce her. "This is Oxy. She is an OXYGEN ATOM." Ask if anyone has ever heard of OXYGEN. (Many students will be familiar with the word and may know that we breathe it.) Discuss how OXYGEN is very important to human life. We need to breathe OXYGEN to stay alive! Oxygen is also an important element of water. Explain that they will learn a lot about Oxy in the coming lessons. Remind them that atoms are very, very small. Tell them Oxy wants to show them how small but she needs their help making a life size model.
**ACTIVITY: HOW SMALL ARE ATOMS?**

**Materials:**
- Strips of paper 28 cm (11 inches)
- Scissors

**Procedure:**
1. Give everyone a strip of paper and scissors.
2. Tell students that if they can cut the strip in half 31 times, they will be able to see how small ATOMS are.
3. Have them fold their piece of paper in half and cut it into equal halves. Have them say "ONE". Encourage them to keep track of the number of cuts by counting them out-loud or writing it down as they go. Have them cut one of these pieces in half and say "TWO".
4. Have them continue this process, cutting each new piece in half, until they give up. The chart below gives some comparisons for them to think about.

<table>
<thead>
<tr>
<th>Cut</th>
<th>Length</th>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.0 cm</td>
<td>5.5&quot;</td>
<td>Child's hand, pockets</td>
</tr>
<tr>
<td>2</td>
<td>7.0 cm</td>
<td>2.75&quot;</td>
<td>Fingers, ears, toes</td>
</tr>
<tr>
<td>3</td>
<td>3.5 cm</td>
<td>1.38&quot;</td>
<td>Watch, mushroom, eye</td>
</tr>
<tr>
<td>4</td>
<td>1.75 cm</td>
<td>0.69&quot;</td>
<td>Keyboard keys, rings, insects</td>
</tr>
<tr>
<td>6</td>
<td>0.44 cm</td>
<td>0.17&quot;</td>
<td>Poppy seeds</td>
</tr>
<tr>
<td>8</td>
<td>1 mm</td>
<td>0.04&quot;</td>
<td>Thread. Congratulations if you still in!</td>
</tr>
<tr>
<td>10</td>
<td>0.25 mm</td>
<td>0.01&quot;</td>
<td>Still cutting? Most have quit by now</td>
</tr>
<tr>
<td>12</td>
<td>0.06 mm</td>
<td>0.002&quot;</td>
<td>Microscopic range, human hair</td>
</tr>
<tr>
<td>14</td>
<td>0.015 mm</td>
<td>0.006&quot;</td>
<td>Width of paper, microchip components</td>
</tr>
<tr>
<td>18</td>
<td>1 micron</td>
<td>0.0004&quot;</td>
<td>Water purification openings, bacteria</td>
</tr>
<tr>
<td>19</td>
<td>500 nanometers</td>
<td>0.000018&quot;</td>
<td>Visible light waves</td>
</tr>
<tr>
<td>24</td>
<td>15 nanometers</td>
<td>0.000006&quot;</td>
<td>Electron microscope range, membranes</td>
</tr>
<tr>
<td>31</td>
<td>0.1 nanometers</td>
<td>0.000000045&quot;</td>
<td>The size of an ATOM!</td>
</tr>
</tbody>
</table>

Note: 1 micron is 1/1,000,000 of a meter. 1 nanometer is 1/1,000,000,000.
Source: This activity as been adapted from a lesson by the Miami Museum of Science [http://www.miamisci.org/af/shn/phantom/papercutting.html](http://www.miamisci.org/af/shn/phantom/papercutting.html)

**Expand:**
It should be clear to everyone that ATOMS are very, very small, but it may still be difficult to imagine just how small. Here are some other comparisons for them.
- If a hydrogen ATOM was the size of a soccer ball, then a soccer ball would be 6450 kilometers (4008 miles) in diameter. That is much bigger than the United States. [http://library.thinkquest.org/17940/texts/ATOM/ATOM.html](http://library.thinkquest.org/17940/texts/ATOM/ATOM.html)
- Now take a baseball and blow it up to the size of the earth... the ATOMS inside the baseball are now the size of grapes [http://static.stii.dost.gov.ph/INFOSCIENCE/jun2001/jun01_6.htm](http://static.stii.dost.gov.ph/INFOSCIENCE/jun2001/jun01_6.htm)
- A very fine pencil line's width is 3,000,000 ATOMS across.
- The smallest speck of dust contains about 10,000,000,000,000,000 ATOMS! [http://scienceteacher2.info/ATOMS1.htm](http://scienceteacher2.info/ATOMS1.htm)
GAME: Mel Says
Tell them they are going to play a game called "Mel Says". Explain that Mel is the name of the computer of the Molecularium, the most fantastic ship in the Universe. It is the most fantastic ship because it can go anywhere and travel through the nanoscale world of atoms. The game is played just like Simon Says, except in this case Mel says "Act like a Gas" "Act like a Liquid" or "Act like a Solid." The point of the activity is to reinforce the lesson, but since most of the kids like games and will be familiar with Simon Says, you can throw them off by throwing in some commands like "Touch your toes."

Song: So Small
A great way to reinforce how small atoms are is with Oxy's solo number "I'm so small."
Atoms Make Molecules

Background: In this lesson, you will get some help teaching your class about ATOMS and MOLECULES by introducing them to the characters of Molecularium. The goal is to excite them by bringing them into the world of ATOMS and MOLECULES.

Objectives:
- Student will learn that ATOMS bond together to make MOLECULES.
- Students will be introduced to ELEMENTS and the PERIODIC TABLE.
- Students will learn that ATOMS have ELECTRONS
- Students will learn about OXYGEN, HYDROGEN and H₂O
- Students will observe the motion of MOLECULES in a LIQUID
- Students will be introduced to the characters of the Molecularium

Introduction: *Let me introduce you to some amazing Atoms!*

1. Review by asking what everything is made of. Ask what MATTER is made of.

2. Explain that there are many different kinds of ATOMS. Anything made of just one kind of ATOM is called an ELEMENT. Scientists have identified 116 different ELEMENTS. Some of the ELEMENTS (like GOLD, SILVER and COPPER), have been known to people for thousands of years, but most have only been discovered by scientists in the last 250 years. Scientists have organized them into a chart called the Periodic Table of Elements. Show them a copy of the Periodic Table. Point out that all of the ELEMENTS are symbolized by one or two letters. Point out OXYGEN on the Periodic Table.

3. Tell them that you would like to introduce them to some of Oxy's best friends and some of the most important ATOMS in the UNIVERSE.

Take out the picture of HYDRA and HYDRO and introduce them. Tell them they are HYDROGEN ATOMS. Explain that HYDROGEN is the most common ELEMENT in the UNIVERSE (90%). It is also the smallest and most basic. Point it out on the periodic table. Notice that it is alone at the top of the chart and that its ATOMIC NUMBER is one. At room temperature, it is a GAS. Explain that HYDRA and HYDRO are great friends because HYDROGEN loves to join (BOND) with other HYDROGENS to make H₂.
4. Explain that all ATOMS have ELECTRONS. Point out that HYDROGEN has only one ELECTRON. Explain that when HYDRO and HYDRA BOND they share electrons and stay stuck to each other. It is like they are holding hands.

5. Point out OXYGEN on the Periodic Table. Note that OXYGEN is bigger than HYDROGEN. OXYGEN is also a GAS at room temperature and also likes to BOND with other OXYGEN ATOMS to make $O_2$. $O_2$ makes up 23% of the air in the Earth's Atmosphere. Point out that OXYGEN'S ATOMIC NUMBER is 8.

6. Explain that OXYGEN has eight ELECTRONS but that usually only two of them are free to BOND. Therefore, OXYGEN often bonds with two different ATOMS. When it makes $O_2$, it is like holding both hands. It is useful to have two kids come up to the front of the class to demonstrate this.

7. There are only 114 other elements and only 92 of them occur naturally. Talk about how that really isn't that many. Talk about how many different things there are in the UNIVERSE.

8. Explain when ATOMS BOND to other ATOMS they make totally new things called MOLECULES. MOLECULES are made of two or more ATOMS. They can be the same kind of ATOMS, like H$_2$ and O$_2$, but they don't have to be. Most MOLECULES are made of different kinds of ATOMS. Explain that MOLECULES made of more than one element are called COMPOUNDS. Most of the things in the universe are made of MOLECULES that are made up of different combinations of ATOMS. Tell them that OXYGEN and HYDROGEN are an excellent example.

9. Tell them that OXY is very good friends with HYDRO and HYDRA. Since OXYGEN ATOMS have two open ELECTRONS, it often BONDS with two HYDROGEN ATOMS to make a very important MOLECULE. Show them the picture of H$_2$O and ask if anyone knows what it is called. If no one does, ask if anyone has ever heard of H$_2$O. Since this is a familiar term, someone in the class may know what it is. If not, give them the following clues and have them guess:
   1. 70% of the human body is made of it.
   2. 70% of the Earth's surface is covered with it.
   3. Most people drink it everyday.

10. Explain that MOLECULES, just like ATOMS, go through the three STATES of MATTER. Review the different states by recalling the ice melting demo from Lesson one. Discuss how in each state the MOLECULES remain H$_2$O, the only difference is how they are arranged and move. Review the ways ATOMS behave in the different STATES of MATTER.

11. Remind everyone that H$_2$O MOLECULES are incredibly small. You can reinforce this idea with the following:
   - There are approximately 1.67 sextillion ($1.67 \times 10^{21}$) MOLECULES of H$_2$O in a single drop of water. [http://www.madsci.org/posts/archives/oct2000/971190308.Ch.r.html](http://www.madsci.org/posts/archives/oct2000/971190308.Ch.r.html)
   - This is a huge number. Write it out on the board. (Discuss scientific notation by explaining that 21 is the number of places to move the decimal point, so you need to add 19 zeros.) Here are some other numbers for comparison. Write them on the board. [Note: All of these
numbers are rough estimates based on various calculations. The point is to emphasize the vast number of MOLECULES. Sources have been included.

• There are about 6.5 billion (6.5 x 10^9) people on Earth now.
• (Some) Scientists have estimated there are 7.5 quintillion (7.5 x 10^18) grains of sand on all of the world's beaches. http://www.miamisci.org/tripod/whysand.html

**ACTIVITY: Let's Make Models of MOLECULES!**

Making models of MOLECULES is an excellent way to connect kids to the concepts. You should experiment with a variety of materials and make a variety of models. The suggestions listed are some possibilities, but you are encouraged to come up with your own. One of the main considerations is size. Ideally, the oxygen ATOMS will be larger than the hydrogen ATOMS.

**Materials:**

<table>
<thead>
<tr>
<th></th>
<th>Marshmallows</th>
<th>Gumdrops</th>
<th>Balloons</th>
<th>Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Regular size</td>
<td>Large</td>
<td>Inflate more</td>
<td>Grapefruit</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Mini size</td>
<td>Small</td>
<td>Inflate less</td>
<td>Tangerines</td>
</tr>
<tr>
<td>Bond</td>
<td>toothpicks</td>
<td>toothpicks</td>
<td>double sided tape</td>
<td>toothpicks</td>
</tr>
</tbody>
</table>

**Procedure:**

1. Set up a number of MOLECULE building stations. At each, have containers holding the different kinds of ATOMS and bonding materials. You can label each container, so it is clear what kind of ATOM is in each. Make sure everyone understands that oxygen is larger than hydrogen.
2. Tell everyone that they are going to make models of water MOLECULES. Ask if anyone remembers the chemical formula of water.
3. Explain that scientists often draw models using letters and lines. Draw a picture of H\_2O on the board:

```
  O
 /\|
/  \|
```

4. Show them the picture of H\_2O from Moleculararium and point out the bond angle of the hydrogen ATOMS (104.5° in liquid).
5. Allow them to build models out of the materials supplied. Demonstrate how to do it if necessary.

**Discussion:**

After the students have made models of H\_2O, discuss that MOLECULES go through the three STATES of MATTER, just like ATOMS. Review the three STATES of MATTER and the motion and arrangement of ATOMS in each. Explain that MOLECULES also behave like this. Have them demonstrate the different states of H\_2O with their models: Solid - close together in a fixed pattern and not changing position; Liquid - moving around but still close to each other; Gas - moving all around the room quickly.
**ACTIVITY: The Motion of MOLECULES in a Liquid**

**Materials:**

- 3 clear containers (beakers, glasses or clear plastic cups)
- Red or blue food coloring
- Water at three different temperatures (hot, room, cold)

**Procedure:**

1. Fill the three containers with different temperature water. (Note: The hotter and colder, the better)
2. Allow them to sit for a little while so the water stops moving. Be sure the containers are on a stable, unmoving surface. Be careful not to bump or move them.
3. Put a couple of drops of food coloring in each of the containers.
4. Observe carefully the movement of the coloring and how long it takes for the coloring to become completely mixed in the water.

**Discussion:**

Have students discuss what they observed. Which was moving fastest? Slowest? Ask for ideas about what was causing it to move. What STATE is the water in? Discuss how this experiment shows how MOLECULES are always moving in a liquid. Their movement is related to temperature. As they just demonstrated, the hotter the water is, the faster the MOLECULES are moving.

**ACTIVITY: Let's Become MOLECULES!**

**Materials:**

- Character pictures for the whole class (1/3 Oxy, 1/3 Hydro, 1/3 Hydra)
- Tape

**Procedure:**

1. Tell everyone to "Prepare to get really small." Tell them that they are going to become ATOMS and make MOLECULES.
2. Give everyone a character picture and have them tape it on the front of their shirt. Ask everyone what kind of ATOM they are.
3. Start by having everyone BOND with other ATOMS like them and make H₂ and O₂. They should BOND by holding hands. Ask everyone what they are now, and be sure that they understand that when they are bonded together they make MOLECULES.
4. Now have them UNBOND and tell them to make H₂O MOLECULES.
5. Repeat this process a number of times, each time they should move around and BOND with different ATOMS.
6. Have everyone take a break to review the motion of ATOMS in the different STATES. (Recall how they acted as ATOMS in Lesson 2.) Explain that MOLECULES act just like the ATOMS in the different STATES. Make clear that the MOLECULES stay bonded to each other even as the temperature increases or decreases. Have everyone bond again into water MOLECULES. Tell them that they are part of a snowflake. Ask what STATE they are in. Explain the MOLECULES in an ice crystal are in a special arrangement. Show them the diagram and help them get arranged into staggered rows. Be sure to point out that they are a very, very small part of a snowflake.
7. Tell them that it is a warm day in the winter and the snowflake lands on a warm sidewalk. Ask what they think happens to the snowflake. Ask what STATE it changes into. Have them become LIQUID. Be sure they stay bonded as they start to move around.
8. Tell them that the sun is very strong that day and dries the sidewalk. Ask what happens to the water MOLECULES. (Recall the ice cube melting exercise from Lesson 1.) Ask them what state they become. Have them act like a GAS. Again, be sure they stay bonded.

**Song:** $H_2O$

This song reinforces that atoms make molecules, that HYDROGEN and OXYGEN make water and that there are three states of matter. You can divide the class into the different roles and sing along with the characters.
Teacher Guide: Density

Learning Objectives

Students will:

- State the SI units used for mass and volume.
- Measure the volumes of irregular objects using water displacement.
- Discover that density can be measured.
- Predict whether an object will float or sink by measuring its mass and volume.
- Define the relationship among mass, volume, and density.
- Calculate the densities of irregular objects.
- Compare the densities of liquids.

Vocabulary

density, mass, matter, volume

Lesson Overview

The Density Gizmo™ allows students to explore and compare the densities of both liquids and solids.

Students measure the mass and volume of an object and then see whether it floats or sinks in specific liquids.

The Student Exploration contains three activities.

- Activity A – Students determine how mass and volume affect whether an object sinks or floats.
- Activity B – Students calculate density and find the relationship between density and sinking/floatation.
- Activity C – Students find how a given object behaves in different liquids. This information is used to compare the densities of the liquids.
Suggested Lesson Sequence

1. **Pre-Gizmo activity**  (10 – 15 minutes)
   Ask the students to give examples of objects that either sink or float in water. Why do objects sink or float in water? On a chart, list vocabulary words that students use. Next, show students two equally-sized containers, one filled with bottle caps or pop tabs, the other with sand. Ask, “Which of these materials do you think is denser?” Have students explain their thinking. Allow students to hold and compare the two containers. Why is it easier to compare objects in the same size container?
2. **Prior to using the Gizmo**
   (10 – 15 minutes)
   Before students are at the computers, pass out the Student Explorations and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers yet. Afterwards, if possible, use a projector to introduce the Gizmo and to demonstrate its basic operations. You may wish to point out that a pin holds floating objects below the water’s surface in the graduated cylinder.

3. **Gizmo activities**
   (10 – 15 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the Student Exploration with the help of the Gizmo. Walk around to check student progress and answer questions as students work. Alternatively, you can use a projector and do the Exploration as a teacher-led activity. Calculators are recommended for Activity B. If you do the hands-on activities also, you will probably need to spread the Gizmo activities over multiple days.

4. **Discussion questions**
   (10 – 20 minutes)
   As students work or just after they have finished, discuss some of the following:
   - In the first activity what did you notice when you made the chart and tested the objects in water?
   - Did you have the same results when you dropped the objects in other liquids? Why or why not?
   - Do all heavy objects sink? Do all light objects float?
   - Why do some objects float higher than others?
   - Why do some objects sink faster than others?
   - Which is more dense, a small amount of a substance or a large amount of the same substance? (Students can compare the density of the gold nugget and the gold crown for an answer.)

5. **Follow-up activity: Create a density column**
   (15 – 20 minutes)
   Ask students to guess the densities of water, saltwater, corn syrup, and cooking oil. Students can make a “density column” by slowly pouring each liquid into a tilted graduated cylinder. For best results, add food coloring to the water and corn syrup for visibility. (Pick different colors so you can tell all the liquids apart.) Observe the results. Were the hypotheses correct?
Alternate activity: Have each student bring in an object from home to test. Take a class vote on whether it will sink or float, then drop it into a bucket of water. What surprises the class? What conclusions can be made? Are there new questions to explore?

**Scientific Background**

Density refers to the mass found in a given volume of a substance. It is calculated by dividing the mass of a substance by its volume: \( D = \frac{m}{V} \). A density of 2 g/mL means that a single milliliter of a substance has a mass of 2 grams. (Note: the volume unit milliliters (mL) is equivalent to the unit cubic centimeters (cm\(^3\)). Milliliters are generally used to describe the volume of liquids, while cubic centimeters are used for solids.)

In general, dense objects can be thought of as being more tightly packed than objects with low densities. As an example, students will understand that sand in a jar is more tightly packed, or dense, than pop tabs in the same size jar.

Because density does not depend on the amount of substance, it can be used to identify substances. Each milliliter of water has a mass of one gram, so water has a density of 1.0 g/mL. Gold has a density of 19.3 g/cm\(^3\), and silver has a density of 10.5 g/cm\(^3\).

Surprise your students with this experiment. Place a can of soda and diet soda of the same brand in a tank of water. The diet soda will float while the regular soda will sink. Ask the students to explore what the differences could be. (The regular soda has approximately 10 tablespoons more sugar, giving it more mass and making it denser than diet soda.)

**Historical Connection**

There is a legend about Archimedes, an ancient philosopher and mathematician, which takes place in the third century B.C. The king of Syracuse, Hiero, had given a jeweler a brick of pure
gold to make into a crown. When the crown was completed, the king was suspicious that the jeweler had substituted a less precious metal for the gold, so he asked Archimedes to demonstrate whether the crown was pure gold or not.

At that time, there were no tools to measure irregular shapes, so it became quite a perplexing problem for Archimedes. He knew the crown was the same mass as the original bar of gold. Archimedes determined that if the crown had more volume than the original bar, it would be less dense and therefore not made of pure gold.

The problem was that Archimedes did not know how to find the volume of the crown. One day he accidentally filled his bathtub to the top. As he stepped into the tub, the water overflowed. He realized that if he collected the water that had overflowed, he would know the volume of his body. Archimedes was so excited by his discovery he jumped out of the tub and ran naked down the street, all the while yelling, “Eureka! I have found it!”

Archimedes used a balance to measure a block of gold with a mass equal to the crown. He placed the block of gold and the crown into a tank of water. Sure enough, the crown displaced more water than the gold, proving the crown was less dense than pure gold (and was therefore a fake!).

**Selected Web Resources**


Student Exploration: Density

Vocabulary: density, mass, matter, volume

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. List three objects that you think would sink in water, and three objects you think would float.
   Sink: ____________________________________________________
   Float: ____________________________________________________________________

2. Why do you think some things float and some things sink?
   __________________________________________________________________________
   __________________________________________________________________________

Gizmo Warm-up

1. In the Gizmo™ select an object and drag it onto the scale. Mass is the amount of matter, or “stuff,” in an object.
   A. Which object did you choose? _________________________________
   B. What unit of measurement is used for mass? _________________
   C. What is the object’s mass? _________________________________

2. Drag the object into the graduated cylinder. The number above the cylinder gives the volume, or the amount of space the object takes up. The unit milliliter (mL) is used for liquids, while the unit cubic centimeters (cm³) is used for solids. One milliliter is the same volume as one cubic centimeter.
   A. Which object did you choose? _________________________________
B. What is your object’s volume, in cm³? ________ (This is equal to the volume in mL.)

C. Drop the object into the beaker of water. Does it sink or float? ____________________
Activity A: Sink or float?

Get the Gizmo ready:
- Replace all objects on the shelf.
- Be sure the liquid in the beaker is Water.

Question: How do mass and volume affect sinking and floating?

1. Predict: Which objects will float in water? Which will sink? Record your predictions below.

<table>
<thead>
<tr>
<th>Object</th>
<th>Prediction (sink or float?)</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Result (sink or float?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ping pong ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chess piece</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penny</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Experiment: Use the Gizmo to find the mass and volume of each object and whether it floats or sinks. Record your results in the table.

3. Analyze results: Look at the data in your table.
   A. Can you use mass alone to predict whether an object will sink or float? Explain.

   _______________________________________________________________________

   B. Can you use volume alone to predict whether an object will sink or float? Explain.

   _______________________________________________________________________

4. Draw conclusion: Can you use mass and volume to predict whether an object will sink or float in water? Explain your thinking.

   _______________________________________________________________________

   _______________________________________________________________________

   _______________________________________________________________________
5. **Apply**: Measure the mass and volume of the toy soldier: Mass ________ Volume ________

   Will it float or sink? ________________ Use the Gizmo to test your prediction.
Activity B: Calculating density

Get the Gizmo ready:
- Replace the objects on the shelves.
- Be sure the liquid in the beaker is Water.

Question: How does density tell you whether an object will sink or float?

1. **Calculate**: Density is the amount of mass contained in a given volume. To find the density of an object, divide its mass by its volume. Density is recorded in units of grams per cubic centimeter (g/cm$^3$).

What is the density of an object with a mass of 100 g and a volume of 50 cm$^3$? __________

2. **Record data**: In the Gizmo, find mass and volume of the objects listed below. Then calculate each object’s density and record it. Finally, test whether each one sinks or floats in water.

<table>
<thead>
<tr>
<th>Object</th>
<th>Density</th>
<th>Sink or Float?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chess piece</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toy soldier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Draw conclusion**: The density of water is 1.0 g/mL, or 1.0 g/cm$^3$. Look at the data in your table. How can you use the density of an object to predict whether it will sink or float?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

4. **Apply**: In the Gizmo, either Crown 1 or Crown 2 is solid gold (but not both). Find the density of the gold nugget and of each crown. (Hint: You will probably need a calculator to do this.)

A. Density of the gold nugget: _____________________________________________

B. Density of Crown 1: _________________________________________________
C. Density of Crown 2: ___________________________________________________

D. Which crown is pure gold? ____________________________________________
Activity C: Egg-speriment

Get the Gizmo ready:
- Replace all the objects on the shelf.

Question: How does an object behave in different liquids?

1. Observe: Use the Gizmo to explore whether the egg sinks or floats in different liquids. Record what you find in the table below.

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Water</th>
<th>Oil</th>
<th>Gasoline</th>
<th>Seawater</th>
<th>Corn Syrup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink or Float?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Draw conclusion: Which liquids are denser than the egg? Which are less dense? Explain your reasoning.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3. Extend your thinking: Observe the egg in each liquid again.

A. In which liquid does the egg float the highest? _____________________________

B. In which liquid does the egg sink the fastest? _____________________________

C. Which liquid do you think is the densest? Least dense? Explain. ______________

________________________________________________________________________
________________________________________________________________________

4. Challenge yourself: Using the objects in the Gizmo to help you, list the liquids from densest to least dense. Discuss your answer with your teacher and classmates. (Hint: Compare where objects float within each liquid.)

________________________________________________________________________
________________________________________________________________________
Density

Vocabulary: density, mass, matter, volume

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

3. List three objects that you think would sink in water, and three objects you think would float.

   Sink: Answers will vary. Float: Answers will vary.

4. Why do you think some things float and some things sink? Answers will vary.

Gizmo Warm-up

3. In the Gizmo™ select an object and drag it onto the scale. Mass is the amount of matter, or “stuff,” in an object.

   A. Which object did you choose? Answers will vary.
B. What unit of measurement is used for mass? Grams (g)

C. What is the object's mass? [Check mass in table below.]

4. Drag the object into the graduated cylinder. The number above the cylinder gives the volume, or the amount of space the object takes up. The unit milliliter (mL) is used for liquids, while the unit cubic centimeters (cm³) is used for solids. One milliliter is the same volume as one cubic centimeter.

D. Which object did you choose? Answers will vary.

E. What is your object's volume, in cm³? [Check table below.] (This is equal to the volume in mL.)

F. Drop the object into the beaker of water. Does it sink or float? [Check answer below.]

<table>
<thead>
<tr>
<th>Object</th>
<th>Ping Pong</th>
<th>Golf Ball</th>
<th>Toy Soldier</th>
<th>Apple</th>
<th>Chess</th>
<th>Penny</th>
<th>Egg</th>
<th>Rock</th>
<th>Gold</th>
<th>Crown 1</th>
<th>Crown 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (g)</td>
<td>3.0</td>
<td>45.0</td>
<td>120.0</td>
<td>33.0</td>
<td>40.0</td>
<td>3.0</td>
<td>65.0</td>
<td>200</td>
<td>579</td>
<td>840.0</td>
<td>1930</td>
</tr>
<tr>
<td>Volume (cm³)</td>
<td>36.0</td>
<td>36.0</td>
<td>80.0</td>
<td>44.0</td>
<td>80.0</td>
<td>0.4</td>
<td>64.0</td>
<td>50.0</td>
<td>30.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Float or Sink?</td>
<td>Float</td>
<td>Sink</td>
<td>Sink</td>
<td>Float</td>
<td>Float</td>
<td>Sink</td>
<td>Sink</td>
<td>Sink</td>
<td>Sink</td>
<td>Sink</td>
<td>Sink</td>
</tr>
</tbody>
</table>

Activity A: Get the Gizmo ready:

- Sink or float?
  - Replace all objects on the shelf.
  - Be sure the liquid in the beaker is Water.

Question: How do mass and volume affect sinking and floating?

6. Predict: Which objects will float in water? Which will sink? Record your predictions below.
<table>
<thead>
<tr>
<th>Object</th>
<th>Prediction (sink or float?)</th>
<th>Mass (g)</th>
<th>Volume (cm$^3$)</th>
<th>Result (sink or float?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ping pong ball</td>
<td>Answers will vary</td>
<td>3 g</td>
<td>36 cm$^3$</td>
<td>float</td>
</tr>
<tr>
<td>Golf ball</td>
<td>Answers will vary</td>
<td>45 g</td>
<td>36 cm$^3$</td>
<td>sink</td>
</tr>
<tr>
<td>Apple</td>
<td>Answers will vary</td>
<td>33 g</td>
<td>44 cm$^3$</td>
<td>float</td>
</tr>
<tr>
<td>Chess piece</td>
<td>Answers will vary</td>
<td>40 g</td>
<td>80 cm$^3$</td>
<td>float</td>
</tr>
<tr>
<td>Penny</td>
<td>Answers will vary</td>
<td>3 g</td>
<td>0.4 cm$^3$</td>
<td>sink</td>
</tr>
<tr>
<td>Rock</td>
<td>Answers will vary</td>
<td>200 g</td>
<td>50 cm$^3$</td>
<td>sink</td>
</tr>
</tbody>
</table>

7. **Experiment**: Use the Gizmo to find the mass and volume of each object and whether it floats or sinks. Record your results in the table.

8. **Analyze results**: Look at the data in your table.

   C. Can you use mass alone to predict whether an object will sink or float? Explain.
   
   *No, there isn’t a pattern in the numbers. For example, the ping pong ball and the penny have the same mass, but one floats and one sinks.*

   D. Can you use volume alone to predict whether an object will sink or float? Explain.
   
   *No, there isn’t a pattern in these numbers either. For example, the ping pong ball and the golf ball have the same volume, but one floats and one sinks.*

9. **Draw conclusion**: Can you use mass and volume to predict whether an object will sink or float in water? Explain your thinking.

   *Yes, there is a pattern. If the mass [in grams] is less than the volume [in cm$^3$], the object floats. If the mass [in grams] is greater than the volume [in cm$^3$], the object sinks.*

10. **Apply**: Measure the mass and volume of the toy soldier: Mass 120 g Volume 80 cm$^3$  
    Will it float or sink? **Sink**  
    Use the Gizmo to test your prediction. *[It sinks.]*

**Activity B:**

**Calculating density**

- Get the Gizmo ready:
  - Replace the objects on the shelves.
  - Be sure the liquid in the beaker is **Water**.

**Question**: How does density tell you whether an object will sink or float?
5. **Calculate:** Density is the amount of mass contained in a given volume. To find the density of an object, divide its mass by its volume. Density is recorded in units of grams per cubic centimeter (g/cm³).

What is the density of an object with a mass of 100 g and a volume of 50 cm³? 2 g/cm³

6. **Record data:** In the Gizmo, find mass and volume of the objects listed below. Then calculate each object’s density and record it. Finally, test whether each one sinks or floats in water.

<table>
<thead>
<tr>
<th>Object</th>
<th>Density</th>
<th>Sink or Float?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chess piece</td>
<td>0.5 g/cm³</td>
<td>float</td>
</tr>
<tr>
<td>Rock</td>
<td>4.0 g/cm³</td>
<td>sink</td>
</tr>
<tr>
<td>Toy soldier</td>
<td>1.5 g/cm³</td>
<td>sink</td>
</tr>
<tr>
<td>Apple</td>
<td>0.75 g/cm³</td>
<td>float</td>
</tr>
</tbody>
</table>

7. **Draw conclusion:** The density of water is 1.0 g/mL, or 1.0 g/cm³. Look at the data in your table. How can you use the density of an object to predict whether it will sink or float?

   *An object will sink in water if it has a density greater than 1.0 g/cm³ (equal to the density of water). It will float if it has a density less than 1.0 g/cm³.*

8. **Apply:** In the Gizmo, either **Crown 1** or **Crown 2** is solid gold (but not both). Find the density of the gold nugget and of each crown. (Hint: You will probably need a calculator to do this.)

   A. Density of the gold nugget: \( \frac{579 \text{ g}}{30 \text{ cm}^3} = 19.3 \text{ g/cm}^3 \)

   B. Density of Crown 1: \( \frac{840 \text{ g}}{100 \text{ cm}^3} = 8.4 \text{ g/cm}^3 \)

   C. Density of Crown 2: \( \frac{1930 \text{ g}}{100 \text{ cm}^3} = 19.3 \text{ g/cm}^3 \)

   D. Which crown is pure gold?

   *Crown 2 has the same density as the gold nugget, so it must be the one that is pure gold. Crown 1 is not nearly as dense as pure gold.*

---

**Activity C:**

**Egg-speriment**

**Get the Gizmo ready:**

- Replace all the objects on the shelf.
Question: How does an object behave in different liquids

5. **Observe**: Use the Gizmo to explore whether the egg sinks or floats in different liquids. Record what you find in the table below.

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Water</th>
<th>Oil</th>
<th>Gasoline</th>
<th>Seawater</th>
<th>Corn Syrup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink or Float?</td>
<td>Sinks (very slowly)</td>
<td>Sinks (slowly)</td>
<td>Sinks (quickly)</td>
<td>Floats</td>
<td>Floats</td>
</tr>
</tbody>
</table>

6. **Draw conclusion**: Which liquids are denser than the egg? Which are less dense? Explain your reasoning.

When the liquid is less dense than the egg, the egg sinks. When the liquid is denser than the egg, the egg floats. Seawater and corn syrup allow the egg to float, so you know they are denser than the egg. The egg sinks in water, oil, and gasoline, so you know they are less dense than the egg.

7. **Extend your thinking**: Observe the egg in each liquid again.

D. In which liquid does the egg float the highest? *Corn syrup*

E. In which liquid does the egg sink the fastest? *Gasoline*

F. Which liquid do you think is the densest? Least dense? Explain.

*The egg floats highest in the corn syrup, which shows that it is the densest liquid. The least dense is gasoline; the egg sinks the fastest in that liquid.*

8. **Challenge yourself**: Using the objects in the Gizmo to help you, list the liquids from densest to least dense. Discuss your answer with your teacher and classmates. (Hint: Compare where objects float within each liquid.)

*Corn syrup (densest), seawater, water, oil, gasoline (least dense)*

*There are several ways to determine this. A golf ball floats in corn syrup but does not float in seawater, so corn syrup must be denser than seawater. An egg floats in seawater but sinks in water, so seawater is denser than plain water. The egg sinks more quickly in oil than in water, so water must be denser than oil. (The chess piece and apple also float lower in oil than in water.) Finally, the apple floats in oil but sinks in gasoline, so oil must be denser than gasoline.*
Teacher Guide: Density via Comparison

Learning Objectives

Students will …

- Understand that a floating object is less dense than the liquid it is in.
- Understand that a sinking object is denser than the liquid it is in.
- Estimate the density of an object by observing its behavior in liquids of various known densities.
- Compare the densities of objects by observing how high they float or how quickly they sink in a liquid.

Vocabulary

density, mass, volume

Lesson Overview

Whether an object floats or sinks in a liquid depends on the density of the object and the density of the liquid. If the object is less dense than the liquid, it will float. If the object is denser than the liquid, it will sink. With the Density via Comparison Gizmo™, students can use this principle to estimate the densities of a variety of objects by placing them in liquids of various known densities.

The Student Exploration sheet contains one activity. In this activity, students estimate the densities of objects by placing them in liquids of known densities.

Suggested Lesson Sequence

1. Pre-Gizmo activity: Floating egg
   Ask each student or group of students to add water to two beakers or cups. Students should mix five to six teaspoons of salt into one beaker to create a saltwater solution. Students can then place an egg into the freshwater and saltwater beakers. Students will observe that the egg sinks in the fresh water and floats in the saltwater solution.
Ask students to explain their observations. Why did the egg sink in one beaker and float in the other? One clue can be gained by finding the mass of equal volumes of fresh water and salt water. Students can add 100 mL of each liquid to a graduated cylinder and find the mass of each. After subtracting the mass of the graduated cylinder, students will find that 100 mL of fresh water has a mass of 100 g and that 100 mL of salt water has a mass of 102–104 g.

2. Prior to using the Gizmo

*Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations.

3. Gizmo activities

Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. Discussion questions

As students are working or just after they are done, discuss the following questions:

- If an object floats in a liquid, what can you say about its density?
- If an object sinks in a liquid, what can you say about its density?
- How can you compare the densities of two objects that both float in a liquid?
- How can you compare the densities of two objects that both sink in a liquid?
- Why do swimmers float so easily in the Dead Sea?

5. Follow-up activities

Bring in a variety of liquids of varying densities (see the table at right), and pass out a beaker of a liquid to each group of students. Students should first measure the mass of an empty graduated cylinder. Next, have them add a specified amount of liquid to the cylinder, measure the mass, and subtract the mass of the cylinder to find the mass of the liquid. Students then can divide the mass by the volume to obtain the density of the liquid.

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubbing alcohol</td>
<td>0.87 g/mL</td>
</tr>
<tr>
<td>Vegetable oil</td>
<td>0.91 g/mL</td>
</tr>
<tr>
<td>Water</td>
<td>1.00 g/mL</td>
</tr>
<tr>
<td>Dish soap</td>
<td>1.03 g/mL</td>
</tr>
<tr>
<td>Glycerine</td>
<td>1.26 g/mL</td>
</tr>
<tr>
<td>Corn syrup</td>
<td>1.36 g/mL</td>
</tr>
</tbody>
</table>
After the density of each liquid has been determined, set up a row of liquids in the front of the classroom. Label each liquid with its density. Students then can drop a variety of objects into the liquids to estimate each object’s density, just as they did with the Gizmo. Objects could include wood, plastic, eggs, apple slices, potato chunks, ice cubes, etc.

Finally, create a density column by adding the liquids, one at a time, to a large graduated cylinder. Add the liquids in order from the densest to the least dense. You can add food coloring to some of the liquids (corn syrup, water, and alcohol) to help them stand out within the density column. When the column is complete, each liquid will form a distinct layer. Small objects can be dropped into the density column and their density estimated based on where they come to rest.

**Scientific Background**

Density is a measure of the mass in a given volume of a substance. To calculate the density of an object, divide its mass by its volume:

\[ D = \frac{m}{V} \]

or, more formally:

\[ \rho = \frac{m}{V} \]

When an object is placed in a liquid, gravity pulls the object down with a force equal to the weight of the object. At the same time, the liquid pushes the object up with a force known as the *buoyant force*. The magnitude of the buoyant force is given by *Archimedes’ principle*; it is equal to the weight of the liquid that is displaced by the object.

If an object is denser than the liquid, the weight of the object will be greater than the weight of displaced liquid. The result is a net downward force, and the object sinks. The greater the density of the object, the faster it will sink through the liquid.

If the object is less dense than the liquid, it will sink into the liquid until the weight of displaced liquid is equal to the weight of the object. At this point the downward force of gravity is equal to the buoyant force, and the object floats. An object with less mass will displace less liquid than an object with greater mass. Therefore, the lower the density of the object, the higher it will float in the liquid. In fact, the density of the object can be measured by estimating the proportion of the object that is below the surface of the liquid. For example, if 60% of the object is below the surface of the liquid, the object’s density is 60% of the liquid’s density.
Technology Connection: Galileo thermometer

Galileo Galilei (1564–1642) is famous for his numerous contributions to physics and astronomy. Galileo was also an avid inventor who helped develop the telescope, microscope, pendulum clock, and one of the earliest thermometers.

During the 1590s, while teaching at the University of Padua near Venice, Galileo discovered that the density of water varies very slightly with temperature. Liquid water has a maximum density of 1.00 g/mL (grams per milliliter) at 4 °C (39 °F) and a minimum density of 0.96 g/mL at 99 °C (210 °F).

A Galileo thermometer is a large cylinder of water that is filled with several glass bulbs. Each glass bulb has a density between 1.00 and 0.96 g/mL and is labeled with the corresponding temperature. At 4 °C (39 °F), the water density is at a maximum and all of the bulbs will float. As the water temperature increases, its density decreases and more of the bulbs sink to the bottom. The water temperature is between the minimum temperature marked on the floating bulbs and the maximum temperature marked on the sunken bulbs.

Selected Web Resources

Floating egg experiment: http://www.reekoscientific.com/Experiments/FloatEggInSaltwater.aspx

Buoyancy: http://hyperphysics.phy-astr.gsu.edu/Hbase/pbuoy.html


Archimedes’ principle: http://physics.weber.edu/carroll/Archimedes/principle.htm

Density column: http://www.stevespanglerscience.com/experiment/seven-layer-density-column

Galileo thermometer: http://en.wikipedia.org/wiki/Galileo_thermometer
Related Gizmos:

Density: http://www.explorelearning.com/gizmo/id?629
Density Laboratory: http://www.explorelearning.com/gizmo/id?362
Determining Density via Water Displacement: http://www.explorelearning.com/gizmo/id?400
Density Experiment: Slice and Dice: http://www.explorelearning.com/gizmo/id?434
Archimedes’ Principle: http://www.explorelearning.com/gizmo/id?603
**Student Exploration: Density via Comparison**

**Vocabulary:** density, mass, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

The image at right shows a man floating in the Dead Sea, an extremely salty lake that lies between Israel and Jordan.

1. Why do you think the man is floating so high in the water? __________________________________________

2. What might happen if this man tried to read the newspaper while floating in a normal pool?

**Gizmo Warm-up**

Whether an object floats or sinks in a fluid depends on the density—or mass per unit of volume—of the object as well as the density of the fluid. The *Density via Comparison* Gizmo™ allows you to compare objects by placing them in fluids of differing densities.

1. Place object A into Beaker 2, which contains a liquid with a density of 1 g/mL, equal to the density of water.

   A. What happens? ____________________________________________________________

   B. Is object A more or less dense than water? Explain how you know. ______________

   ____________________________________________________________
2. Now drop object B into Beaker 2. Describe what happens and explain what that tells you about the density of object B.

__________________________________________________________________________

__________________________________________________________________________
Activity: Estimating density

Get the Gizmo ready:
- Double-click on the shelf to return all objects to the shelf.

Question: How do you estimate the density of an object without measuring its mass or volume?

1. **Observe**: Drag object A into **Beaker 1**. If it sinks, move it into beakers 2, 3, and so on until it floats.
   - A. What is the highest-density fluid in which object A sinks? _________________
   - B. What is the lowest-density fluid in which object A floats? _________________
   - C. Based on the previous two answers, what can you say about the density of object A? (Note: The density of a solid is measured in g/cm³, which are equivalent to g/mL.)
     _____________________________________________________________________

2. **Gather data**: Drag each object into all of the beakers. Write “floats” or “sinks” in each space in the table below. In the last column, estimate the density of each object.

<table>
<thead>
<tr>
<th>Object</th>
<th>Beaker 1 (0.5 g/mL)</th>
<th>Beaker 2 (1 g/mL)</th>
<th>Beaker 3 (1.5 g/mL)</th>
<th>Beaker 4 (2.5 g/mL)</th>
<th>Estimated density</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Analyze**: Drag objects B and E into **Beaker 2**. Which object is denser? ________________

   Explain how you know: __________________________________________________________________

4. **Challenge yourself**: Describe how you know which object is denser in each situation.
   - A. Objects A and B are placed in **Beaker 1**: ________________
Density via Comparison

**Vocabulary:** density, mass, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

*Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.*

The image at right shows a man floating in the Dead Sea, an extremely salty lake that lies between Israel and Jordan.

3. Why do you think the man is floating so high in the water?  
   *Answers will vary.*  
   *The man is floating so high in the water because the salty water in the Dead Sea has a much greater density than freshwater in a pool or even seawater.*

4. What might happen if this man tried to read the newspaper while floating in a normal pool?  
   *Answers will vary.*  
   *The man will probably sink into the water and would not be able to read his newspaper.*

**Gizmo Warm-up**

Whether an object floats or sinks in a fluid depends on the **density**—or **mass** per unit of **volume**—of the object as well as the density of the fluid. The *Density via Comparison* Gizmo™ allows you to compare objects by placing them in fluids of differing densities.

3. Place object **A** into **Beaker 2**, which contains a liquid with a density of 1 g/mL, equal to the density of water.  
   C. *What happens? Object A sinks to the bottom of beaker 2.*

---

B. Objects **A** and **B** are placed in **Beaker 4**: ________________________________
D. Is object A more or less dense than water? Explain how you know.

*Object A is denser than water because it sinks in a liquid with a density of 1 g/mL.*

4. Now drop object B into Beaker 2. Describe what happens and explain what that tells you about the density of object B.

*Object B floats, so the density of object B must be less than 1 g/mL.*
Activity: Estimating density

Get the Gizmo ready:

- Double-click on the shelf to return all objects to the shelf.

Question: How do you estimate the density of an object without measuring its mass or volume?

5. **Observe**: Drag object A into Beaker 1. If it sinks, move it into beakers 2, 3, and so on until it floats.
   
   A. What is the highest-density fluid in which object A sinks? 1.5 g/mL
   B. What is the lowest-density fluid in which object A floats? 2.5 g/mL
   
   C. Based on the previous two answers, what can you say about the density of object A? (Note: The density of a solid is measured in g/cm³, which are equivalent to g/mL.)
   
   The density of object A is between 1.5 g/cm³ and 2.5 g/cm³.

6. **Gather data**: Drag each object into all of the beakers. Write “floats” or “sinks” in each space in the table below. In the last column, estimate the density of each object.

   Accept all reasonable estimates of density.

<table>
<thead>
<tr>
<th>Object</th>
<th>Beaker 1 (0.5 g/mL)</th>
<th>Beaker 2 (1 g/mL)</th>
<th>Beaker 3 (1.5 g/mL)</th>
<th>Beaker 4 (2.5 g/mL)</th>
<th>Estimated density</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Sinks</td>
<td>Floats</td>
<td>Floats</td>
<td>Floats</td>
<td>0.6 g/cm³</td>
</tr>
<tr>
<td>C</td>
<td>Sinks</td>
<td>Sinks</td>
<td>Floats</td>
<td>Floats</td>
<td>1.25 g/cm³</td>
</tr>
<tr>
<td>D</td>
<td>Sinks</td>
<td>Sinks</td>
<td>Sinks*</td>
<td>Floats</td>
<td>1.5 g/cm³*</td>
</tr>
<tr>
<td>E</td>
<td>Sinks</td>
<td>Floats</td>
<td>Floats</td>
<td>Floats</td>
<td>0.7 g/cm³</td>
</tr>
<tr>
<td>F</td>
<td>Floats</td>
<td>Floats</td>
<td>Floats</td>
<td>Floats</td>
<td>0.25 g/cm³</td>
</tr>
</tbody>
</table>

   *Object D sinks when “dropped” in beaker 3, but does not move when placed in beaker 3. Therefore, object D has a density equal to the density of the liquid in beaker 3.

7. **Analyze**: Drag objects B and E into Beaker 2. Which object is denser? **Object E**
   
   Explain how you know: I know object E is denser because it floats a bit lower in the liquid.

8. **Challenge yourself**: Describe how you know which object is denser in each situation.

9. A. Objects A and B are placed in Beaker 1: **Object A is denser because it sinks more quickly than object B.**
B. Objects A and B are placed in Beaker 4: Object A is denser because it floats much lower than object B.
Teacher Guide: Density Laboratory

Learning Objectives

Students will…

- Measure the mass of objects with a scale.
- Measure the volume of objects by water displacement in a graduated cylinder.
- Calculate the density of objects.
- Understand how density is related to the tendency to float or sink.
- Based on the density of an object and the liquid it is placed in, predict whether the object will sink or float.

Vocabulary

buoyancy, density, graduated cylinder, mass, matter, scale, volume

Lesson Overview

Density is an extremely important concept, but one that students often find confusing. The Density Laboratory Gizmo™ shows how mass, volume, and the tendency to float are related. If the Gizmo is combined with classroom investigations, students will acquire a deeper understanding of density. (Note: The related Density Gizmo lessons cover similar topics at a more basic level.)

The Student Exploration sheet contains two activities and an Extension:

- Activity A – Students measure the mass, volume, and density of irregular objects. Students relate density to the tendency to float or sink.
- Activity B – Students predict whether objects will sink or float in liquids of various densities.
- Extension – Students find the density of three crowns to see which is made of pure gold.

Suggested Lesson Sequence

6. **Pre-Gizmo activity: Sink or float?** (20 – 40 minutes)
   Ask each student to bring in an object from home that will not be damaged if it gets wet. In addition to the students’ objects, provide a paper clip, a deflated balloon, an inflated balloon, and a good-sized chunk of wood. Place all of the objects on a table at the front of the classroom, and allow the students to pick up each object and vote on whether the object will sink or float. List the voting results on the board.
Next, fill a large plastic tub with water. Drop each object into the water to see what happens, and record the results. Discuss with your class what causes objects to float or sink. If necessary, point out that mass alone cannot be the only explanation—after all, the wood is much heavier than the paper clip, but the wood floats and the paper clip sinks! Ask students why the inflated balloon floats while the deflated balloon sinks. (Note: Be sure that no air is trapped in the deflated balloon!)
7. **Prior to using the Gizmo**

   *Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. If possible, use a projector to introduce the Gizmo and demonstrate its basic operations. You may wish to point out that a pin holds floating objects below the water’s surface in the graduated cylinder.

8. **Gizmo activities**

   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

9. **Discussion questions**

   As students are working or just after they are done, discuss the following questions:

   - If you know the mass and volume of an object, how can you immediately predict whether it sinks or floats without calculating density? [If an object’s mass is less than its volume, it will float. If the mass is greater than the volume, it will sink.]
   - What are some ways you can compare the density of floating objects without measuring their mass and volume? [Denser objects will float lower in the liquid.]
   - What are some ways you can compare the density of sinking objects without measuring their mass and volume? [Denser objects will sink faster.]
   - In the Gizmo, how could you estimate the density of an object without using the scale or graduated cylinder? [You can use the Liquid Density slider.]

10. **Follow-up activity: Measuring density**

    You can practice the same experiments shown in the *Density Laboratory* Gizmo in the classroom. You will need an electronic scale or triple-beam balance to measure mass, and a graduated cylinder to measure volume. Provide a variety of objects to measure. (Note: the objects must be small enough to fit into the graduated cylinder.) When measuring the volume of the object, remind students to subtract the original volume of water in the cylinder. For example, if a cylinder initially contains 50 mL of water and the water level rises to 64 mL when the object is added, the volume of the object is 14 cm³.

    For objects that are too big to fit into a graduated cylinder, use an overflow cup. (These are available in many science catalogs, or you can make your own—see the **Selected Web Resources**.) Fill the overflow cup until water starts to spill. Place a beaker under the spigot of the cup. Carefully lower (or push) the object into the overflow cup, and collect the displaced water in the beaker. Finally, use a graduated cylinder to measure the volume of the water in the beaker.
Another great follow-up activity is creating a density column. You can make a four-layer column using corn syrup, blue dish soap, water, and vegetable oil. Dye the water green and the corn syrup red for effect. First, add the corn syrup to a graduated cylinder to form the bottom layer. Next, add the dish soap, then the water, and finally the vegetable oil. Tilt the cylinder to the side and carefully dribble each liquid into the cylinder so the liquids don’t mix. See the Selected Web Resources for more details.

**Scientific Background**

Density is a measure of the mass in a given volume of a substance. To calculate the density of an object, divide the mass by the volume:

\[ D = \frac{m}{V} \quad \text{or, more formally:} \quad \rho = \frac{m}{V} \]

The units of density are units of mass per volume. For small objects, density can be expressed in grams per cubic centimeter (g/cm\(^3\)) or grams per milliliter (g/mL). The former unit is used for solids, while the latter is used for liquids. A cubic centimeter is equivalent to a milliliter, so an object with a density of 2.5 g/cm\(^3\) also has a density of 2.5 g/mL. For larger objects, kilograms per cubic meter (kg/m\(^3\)) are the preferred units. To convert from g/cm\(^3\) to kg/m\(^3\), divide by 1,000.

The mass of an object can be measured on a balance or a properly calibrated scale. The volumes of regular objects such as rectangular prisms and spheres can be found by measuring their dimensions and applying the appropriate volume formula. To find the volume of an irregular object, it is necessary to submerge the object in liquid. As the object moves into the water, it displaces a volume of water equal to the volume of the object. For example, if a pebble with a volume of 7 cm\(^3\) is added to a graduated cylinder, the water level will rise 7 mL.

**Earth science connection: Convection and density**

When a fluid is heated, the molecules within the fluid move more quickly. The volume of the fluid increases, which causes the density of the fluid to decrease. If you put a pot of water on the stove, the water at the bottom of the pot will be heated, decrease in density, and rise to the top. Once exposed to the cool air above the pot, the water will cool.
down and sink again. The result is a circular motion called a convection current.

Convection currents are found in many places on Earth. If a mass of air is heated, it will tend to rise as cooler air moves in. The result is anything from a cool ocean breeze to hurricane. Convection also drives the motion of tectonic plates. Below the oceans, hot magma rises into mid-ocean ridges, adding new crust to the ocean floor. Older, denser ocean crust sinks back into the mantle in regions called subduction zones.

Selected Web Resources

Water displacement experiment: [http://www.iit.edu/~smile/ph9504.html](http://www.iit.edu/~smile/ph9504.html)


Density bottles: [http://www.thinkingfountain.org/d/density/density.html](http://www.thinkingfountain.org/d/density/density.html)


Related Gizmos:


Student Exploration: Density Laboratory

**Vocabulary:** buoyancy, density, graduated cylinder, mass, matter, scale, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. Of the objects below, circle the ones you think would float in water.

   ![Objects](image)

   - Rock
   - Cruise ship
   - Quarter
   - Saturn
   - Beach ball

2. Why do some objects float, while others sink? ____________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________
   ___________________________________________________________________________

**Gizmo Warm-up**

The *Density Laboratory* Gizmo™ allows you to measure a variety of objects, then drop them in water (or other liquid) to see if they sink or float.

1. An object’s **mass** is the amount of **matter** it contains. The mass of an object can be measured with a calibrated **scale** like the one shown in the Gizmo. Drag the first object onto the **Scale**. (This is object 1.)

   What is the mass of object 1? ____________________________________

2. An object’s **volume** is the amount of space it takes up. The volume of an irregular object can be measured by how much water it displaces in a **graduated cylinder**. Place object 1 into the **Graduated cylinder**.

   What is the volume of object 1? ____________________________________

Note: While milliliters (mL) are used to measure liquid volumes, the equivalent unit cubic centimeters (cm³) are used for solids. Therefore, write the volume of object 1 in cm³.
3. Drag object 1 into the **Beaker of liquid**. Does it sink or float? ________________________
Activity A:

Float or sink?

Get the Gizmo ready:
- Drag object 1 back to the shelf.
- Check that Liquid density is set to 1.0 g/mL.

**Question:** How can you predict whether an object will float or sink?

10. **Observe:** Experiment with the different objects in the Gizmo. Try to determine what the floating objects have in common and what the sinking objects have in common.

11. **Form hypothesis:** Compare the floating objects, then do the same for the sinking objects.
   - **A.** What do the floating objects have in common? ______________________________
   - **B.** What do the sinking objects have in common? ______________________________

12. **Collect data:** Measure the mass and volume of objects 1 through 12, and record whether they float or sink in the table below. Leave the last column blank for now.

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Float or sink?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<td>3</td>
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<td>9</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(Activity A continued on next page)
Activity A (continued from previous page)

13. **Analyze:** Look carefully for patterns in your data.
   
   A. Does mass alone determine whether an object will float or sink? ________________
   
   Explain: ________________________________________________________________________

   B. Does volume alone determine whether an object will float or sink? ________________
   
   Explain: ________________________________________________________________________

   C. Compare the mass and volume of each object. What is true of the mass and volume of all the floating objects? ________________
   
   ______________________________________________________________________________

   D. What is true of the mass and volume of all the sinking objects? ________________
   
   ______________________________________________________________________________

14. **Calculate:** The **density** of an object is its mass per unit of volume. Dense objects feel very heavy for their size, while objects with low density feel very light for their size.

   To calculate an object’s density, divide its mass by its volume. If mass is measured in grams and volume in cubic centimeters, the unit of density is grams per cubic centimeter (g/cm$^3$).

   Calculate the density of each object, and record the answers in the last column of your data table. Label this column “Density (g/cm$^3$).”

15. **Analyze:** Compare the density of each object to the density of the liquid, 1.0 g/mL. This is the density of water.

   A. What do you notice about the density of the floating objects? ________________
   
   ______________________________________________________________________________

   B. What do you notice about the density of the sinking objects? ________________
   
   ______________________________________________________________________________

16. **Draw conclusions:** If you know the mass and volume of an object, how can you predict whether it will float or sink in water?

   ______________________________________________________________________________
Activity B: Get the Gizmo ready:

Liquid density

- Drag all the objects back onto the shelf.
- Check that the Liquid density is still 1.0 g/mL.

Question: How does liquid density affect whether objects float or sink?

1. **Observe**: Place object 1 into the Beaker of liquid. Slowly move the Liquid density slider back and forth. What do you notice? ____________________
   _________________________________________________________________________

2. **Form a hypothesis**: Buoyancy is the tendency to float. How do you think the liquid density affects the buoyancy of objects placed in the liquid? ____________________
   _________________________________________________________________________

3. **Predict**: In the table below, write the density of each object. Then predict whether the object will float or sink in each of the fluids. Write “Float” or “Sink” in each empty box of the table.

<table>
<thead>
<tr>
<th>Object</th>
<th>Object density</th>
<th>Liquid density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5 g/mL</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **Test**: Test your predictions using the Gizmo. Place a checkmark (✓) next to each correct prediction, and an “X” next to each incorrect prediction.

5. **Draw conclusions**: What is the relationship between the object density, the liquid density, and the tendency of the object to float? ____________________
### Extension:

**King Hieron's crown**

**Get the Gizmo ready:**
- Drag all the objects back onto the shelf.
- Set the **Liquid density** to 1.0 g/mL.

---

### Introduction:

In the third century B.C., King Hieron of Syracuse asked the famous mathematician Archimedes to determine if his crown was made of pure gold. This was a puzzling problem for Archimedes—he knew how to measure the weight of the crown, but how could he measure the volume?

Archimedes solved the problem when he got into his bath and noticed the water spilling over the sides of the tub. He realized that the volume of the displaced water must be equal to the volume of the object placed into the water. Archimedes was so excited by his discovery that he jumped out of the bath and ran through the streets shouting “Eureka!”

### Question: How can you tell if a crown is made of solid gold?

1. **Think about it:** Gold is one of the densest substances known, with a density of 19.3 g/cm³. If the gold in the crown was mixed with a less-valuable metal like bronze or copper, how would that affect its density?

   ____________________________________________________________

   ____________________________________________________________

2. **Observe:** Drag each of the crowns into the liquid. Based on what you see, which crown do you think is densest? Explain why you think so.

   ____________________________________________________________

   ____________________________________________________________

3. **Measure:** Find the mass, volume, and density of each of the three crowns.

<table>
<thead>
<tr>
<th>Crown</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **Draw conclusions:** Which of the three crowns was made of gold? ____________________
Explain: ________________________________________________________________

________________________________________________________________________
Density Laboratory

Vocabulary: buoyancy, density, graduated cylinder, mass, matter, scale, volume

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

3. Of the objects below, circle the ones you think would float in water. Predictions will vary. Correct answers are shown:

   ![Objects](image)
   - Rock
   - Cruise ship
   - Quarter
   - Saturn
   - Beach ball

4. Why do some objects float, while others sink?

   Answers will vary. [An object floats when the weight of the liquid it displaces is equal to the weight of the object. Objects sink when they are heavier than the equivalent volume of liquid. In other words, objects sink when they are denser than the liquid.]

Gizmo Warm-up

The *Density Laboratory* Gizmo™ allows you to measure a variety of objects, then drop them in water (or other liquid) to see if they sink or float.

4. An object’s **mass** is the amount of **matter** it contains. The mass of an object can be measured with a calibrated **scale** like the one shown in the Gizmo. Drag the first object onto the **Scale**. (This is object 1.) What is the mass of object 1? **19.5 grams (19.5 g)**

5. An object’s **volume** is the amount of space it takes up. The volume of an irregular object can be measured by how much water it displaces in a **graduated cylinder**. Place object 1 into the **Graduated cylinder**. What is the volume of object 1? **14.0 cm³ (equivalent to 14.0 mL)**

Note: While milliliters (mL) are used to measure liquid volumes, the equivalent unit cubic centimeters (cm³) are used for solids. Therefore, write the volume of object 1 in cm³.
6. Drag object 1 into the **Beaker of liquid**. Does it sink or float? *It sinks.*
Activity A: Get the Gizmo ready:

- Drag object 1 back to the shelf.
- Check that Liquid density is set to 1.0 g/mL.

Float or sink?

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Float or sink?</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.5 g</td>
<td>14.0 cm³</td>
<td>Sink</td>
<td>1.39 g/cm³</td>
</tr>
<tr>
<td>2</td>
<td>11.0 g</td>
<td>9.0 cm³</td>
<td>Sink</td>
<td>1.22 g/cm³</td>
</tr>
<tr>
<td>3</td>
<td>4.0 g</td>
<td>5.0 cm³</td>
<td>Float</td>
<td>0.80 g/cm³</td>
</tr>
<tr>
<td>4</td>
<td>135.0 g</td>
<td>7.0 cm³</td>
<td>Sink</td>
<td>19.29 g/cm³</td>
</tr>
<tr>
<td>5</td>
<td>4.0 g</td>
<td>3.5 cm³</td>
<td>Sink</td>
<td>1.14 g/cm³</td>
</tr>
<tr>
<td>6</td>
<td>78.0 g</td>
<td>29.0 cm³</td>
<td>Sink</td>
<td>2.69 g/cm³</td>
</tr>
<tr>
<td>7</td>
<td>2.0 g</td>
<td>21.0 cm³</td>
<td>Float</td>
<td>0.10 g/cm³</td>
</tr>
<tr>
<td>8</td>
<td>24.0 g</td>
<td>26.0 cm³</td>
<td>Float</td>
<td>0.92 g/cm³</td>
</tr>
<tr>
<td>9</td>
<td>99.0 g</td>
<td>44.0 cm³</td>
<td>Sink</td>
<td>2.25 g/cm³</td>
</tr>
<tr>
<td>10</td>
<td>42.0 g</td>
<td>61.0 cm³</td>
<td>Float</td>
<td>0.69 g/cm³</td>
</tr>
<tr>
<td>11</td>
<td>65.0 g</td>
<td>40.0 cm³</td>
<td>Sink</td>
<td>1.63 g/cm³</td>
</tr>
<tr>
<td>12</td>
<td>104.0 g</td>
<td>114.0 cm³</td>
<td>Float</td>
<td>0.91 g/cm³</td>
</tr>
</tbody>
</table>

(Activity A continued on next page)
Activity A (continued from previous page)

20. **Analyze**: Look carefully for patterns in your data.
   
   A. Does mass alone determine whether an object will float or sink? *No*
      
      *Explain: Object 12 is relatively heavy but floats, and object 5 is fairly light but sinks.*
   
   B. Does volume alone determine whether an object will float or sink? *No*
      
      *Explain: Object 3 has a small volume but floats, and object 9 has a relatively large volume but sinks.*
   
   C. Compare the mass and volume of each object. What is true of the mass and volume of all the floating objects? *The mass is less than the volume.*
   
   D. What is true of the mass and volume of all the sinking objects? *The mass is greater than the volume.*

21. **Calculate**: The **density** of an object is its mass per unit of volume. Dense objects feel very heavy for their size, while objects with low density feel very light for their size.

   To calculate an object’s density, divide its mass by its volume. If mass is measured in grams and volume in cubic centimeters, the unit of density is grams per cubic centimeter (g/cm$^3$).

   Calculate the density of each object, and record the answers in the last column of your data table. Label this column “Density (g/cm$^3$).”

22. **Analyze**: Compare the density of each object to the density of the liquid, 1.0 g/mL. This is the density of water.

   A. What do you notice about the density of the floating objects? *The density of the floating objects is less than 1 g/cm$^3$.*

   B. What do you notice about the density of the sinking objects? *The density of the sinking objects is greater than 1 g/cm$^3$.*

23. **Draw conclusions**: If you know the mass and volume of an object, how can you predict whether it will float or sink in water?

   *To predict if the object will float or sink in water, compare the mass to the volume. If the mass is larger, the object will sink. If the volume is larger, the object will float. You could also find the density of the object by dividing mass by volume. If the density is greater than 1 g/cm$^3$, the object will sink. If the density is less than 1 g/cm$^3$, the object will float.*
Activity B: Get the Gizmo ready:

- Drag all the objects back onto the shelf.
- Check that the Liquid density is still 1.0 g/mL.

**Liquid density**

<table>
<thead>
<tr>
<th>Object</th>
<th>Object density</th>
<th>Liquid density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 g/mL</td>
<td>1.0 g/mL</td>
</tr>
<tr>
<td>1</td>
<td>1.39 g/cm³</td>
<td>Sink</td>
</tr>
<tr>
<td>2</td>
<td>1.22 g/cm³</td>
<td>Sink</td>
</tr>
<tr>
<td>3</td>
<td>0.80 g/cm³</td>
<td>Sink</td>
</tr>
<tr>
<td>4</td>
<td>19.29 g/cm³</td>
<td>Sink</td>
</tr>
<tr>
<td>5</td>
<td>1.14 g/cm³</td>
<td>Sink</td>
</tr>
</tbody>
</table>

**Question:** How does liquid density affect whether objects float or sink?

6. **Observe:** Place object 1 into the Beaker of liquid. Slowly move the Liquid density slider back and forth. What do you notice?

   *When the liquid density increases, object 1 starts to float. When the liquid density decreases, object 1 sinks again.*

7. **Form a hypothesis:** Buoyancy is the tendency to float. How do you think the liquid density affects the buoyancy of objects placed in the liquid? *Hypotheses will vary.*

8. **Predict:** In the table below, write the density of each object. Then predict whether the object will float or sink in each of the fluids. Write “Float” or “Sink” in each empty box of the table. *Predictions will vary. Correct results are shown below.*

9. **Test:** Test your predictions using the Gizmo. Place a checkmark (✓) next to each correct prediction, and an “X” next to each incorrect prediction.

10. **Draw conclusions:** What is the relationship between the object density, the liquid density, and the tendency of the object to float?

   *If an object is less dense than the surrounding liquid, it will float. If an object is denser than the liquid, it will sink.*
Extension:

King Hieron’s crown

Get the Gizmo ready:

- Drag all the objects back onto the shelf.
- Set the Liquid density to 1.0 g/mL.

Introduction: In the third century B.C., King Hieron of Syracuse asked the famous mathematician Archimedes to determine if his crown was made of pure gold. This was a puzzling problem for Archimedes—he knew how to measure the weight of the crown, but how could he measure the volume?

Archimedes solved the problem when he got into his bath and noticed the water spilling over the sides of the tub. He realized that the volume of the displaced water must be equal to the volume of the object placed into the water. Archimedes was so excited by his discovery that he jumped out of the bath and ran through the streets shouting “Eureka!”

Question: How can you tell if a crown is made of solid gold?

5. Think about it: Gold is one of the densest substances known, with a density of 19.3 g/cm³. If the gold in the crown was mixed with a less-valuable metal like bronze or copper, how would that affect its density?
   
   If the gold is mixed with other metals, the density of the crown will decrease.

6. Observe: Drag each of the crowns into the liquid. Based on what you see, which crown do you think is densest? Explain why you think so.
   
   Crown B sinks most quickly in the liquid, so crown B is probably the densest crown.

7. Measure: Find the mass, volume, and density of each of the three crowns.

<table>
<thead>
<tr>
<th>Crown</th>
<th>Mass (g)</th>
<th>Volume (cm³)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>325.0 g</td>
<td>65.0 cm³</td>
<td>5.00 g/cm³</td>
</tr>
<tr>
<td>B</td>
<td>1250.0 g</td>
<td>65.0 cm³</td>
<td>19.23 g/cm³</td>
</tr>
<tr>
<td>C</td>
<td>306.0 g</td>
<td>65.0 cm³</td>
<td>4.71 g/cm³</td>
</tr>
</tbody>
</table>

8. Draw conclusions: Which of the three crowns was made of gold? Crown 3

Explain: Only crown B had a density close to the density of pure gold, 19.3 g/cm³.
Student Exploration: Density Experiment: Slice and Dice

**Vocabulary:** density, mass, matter, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

5. What do you think would happen if you threw a block of Styrofoam™ into the water? ____________________________

6. What would happen if you broke the Styrofoam up into lots of pieces, then threw the pieces into water? ____________________________________________

7. What would happen if you threw a big rock into water? ____________________________

8. What would happen if you broke the rock into little pieces, then threw the pieces into water? ____________________________

**Gizmo Warm-up**

The *Density Experiment: Slice and Dice* Gizmo™ allows you to compare different-sized pieces of the same material.

5. Check that **Styrofoam** is selected. Drag the whole Styrofoam piece into the water.

   Does it sink or float? ____________________________

6. Click **Reset**, and then click **Slice** to cut the styrofoam into pieces. Drag each piece into the water and then back to the block.

   What happens? ____________________________

7. How do you think the amount of a material affects its tendency to sink or float? ____________________________
Activity A: Slice and dice

Get the Gizmo ready:
- Click Reset. Check that Styrofoam is selected.
- A calculator is recommended for this activity.

Introduction: The **density** of a material is the amount of **mass** per unit of **volume**. Density is calculated by dividing an object’s mass by its volume.

Question: How does density depend on the amount of material?

24. **Form hypothesis:** How do you think cutting up a material will affect its density? __________

25. **Collect data:** Click Slice. Choose a piece of Styrofoam and drag it onto the Material Investigation tray. Record the mass and volume, then calculate the density by dividing the mass by the volume. Replace the piece, and then repeat for the remaining pieces.

<table>
<thead>
<tr>
<th>Piece</th>
<th>Mass (g)</th>
<th>Volume (cm$^3$)</th>
<th>Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 (if available)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

26. **Analyze:** What do you notice about the density of the Styrofoam pieces? ______________

27. **Predict:** What do you think is the density of the whole block of Styrofoam? _____________

28. **Test:** Click Reset. Drag the whole (uncut) block of Styrofoam onto the Material Investigation tray. Record its mass and volume and calculate the density.

  Mass: _____________ Volume: _____________ Density: _____________
29. **Apply**: An archaeologist finds a golden figurine. How could she determine if the figurine is solid gold without cutting it? 

_________________________________________________________________________
Activity B:

Sink or float?

Get the Gizmo ready:
- Click Reset.

Question: The density of water is 1.0 g/mL, which is equivalent to 1 g/cm³. How does an object’s density affect whether it sinks or floats in water?

1. **Form hypothesis:** How do you think an object’s density relates to whether it sinks or floats?

2. **Collect data:** Measure the mass and volume of each known material, and calculate its density. Then drag each material into the water to see whether it sinks or floats.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
<th>Volume</th>
<th>Density</th>
<th>Sinks or floats?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrofoam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Analyze:** How does an object’s density determine if it will sink or float?

4. **Apply:** Find the density of Unknown A and Unknown B. Based on their densities, predict whether each will sink or float. Then, test your prediction using the Gizmo.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
<th>Volume</th>
<th>Density</th>
<th>Sinks or floats? (prediction)</th>
<th>Sinks or floats? (actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. **Extend your thinking:** Compare the three floating materials. How does the density of each material relate to how high it floats in the water?
Density Experiment: Slice and Dice

**Vocabulary:** density, mass, matter, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers to the Prior Knowledge Questions.]

9. What do you think would happen if you threw a block of Styrofoam™ into the water?  
   **Answers will vary.** [The block will float.]

10. What would happen if you broke the Styrofoam up into lots of pieces, then threw the pieces into water? **Answers will vary.** [Each of the pieces will float.]

11. What would happen if you threw a big rock into water? **Answers will vary.** [The rock will sink.]

12. What would happen if you broke the rock into little pieces, then threw the pieces into water?  
   **Answers will vary.** [All of the rock pieces will sink.]

**Gizmo Warm-up**

The *Density Experiment: Slice and Dice* Gizmo™ allows you to compare different-sized pieces of the same material.

8. Check that **Styrofoam** is selected. Drag the whole Styrofoam piece into the water. Does it sink or float? **The Styrofoam floats.**

9. Click **Reset**, and then click **Slice** to cut the styrofoam into pieces. Drag each piece into the water and then back to the block. What happens? **All of the pieces float.**

10. How do you think the amount of a material affects its tendency to sink or float?  
   **Answers will vary.** [The amount of a material will not affect its tendency to sink or float.]
Activity A: Get the Gizmo ready:
- Click Reset. Check that Styrofoam is selected.
- A calculator is recommended for this activity.

Introduction: The **density** of a material is the amount of **mass** per unit of **volume**. Density is calculated by dividing an object’s mass by its volume.

**Question:** How does density depend on the amount of material?

30. **Form hypothesis:** How do you think cutting up a material will affect its density?  
   *Hypotheses will vary.*

31. **Collect data:** Click **Slice**. Choose a piece of Styrofoam and drag it onto the **Material Investigation** tray. Record the mass and volume, then calculate the density by dividing the mass by the volume. Replace the piece, and then repeat for the remaining pieces.

<table>
<thead>
<tr>
<th>Piece</th>
<th>Mass (g)</th>
<th>Volume (cm$^3$)</th>
<th>Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>0.2 g/cm$^3$</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>0.2 g/cm$^3$</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>0.2 g/cm$^3$</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>0.2 g/cm$^3$</td>
</tr>
<tr>
<td>5 (if available)</td>
<td></td>
<td></td>
<td>0.2 g/cm$^3$</td>
</tr>
</tbody>
</table>

*Individual measurements will vary.*  
*However, the ratio of mass to volume will always be 0.2 g/cm$^3$.*

32. **Analyze:** What do you notice about the density of the Styrofoam pieces?  
   *The density of each piece is the same, 0.2 g/cm$^3$.*

33. **Predict:** What do you think is the density of the whole block of Styrofoam? 0.2 g/cm$^3$

34. **Test:** Click **Reset**. Drag the whole (uncut) block of Styrofoam onto the **Material Investigation** tray. Record its mass and volume and calculate the density.

   - **Mass:** 7.28 g  
   - **Volume:** 36.4 cm$^3$  
   - **Density:** 0.2 g/cm$^3$

35. **Apply:** An archaeologist finds a golden figurine. How could she determine if the figurine is solid gold without cutting it?  
   *The archaeologist should compare the density of the figurine to the density of pure gold.*
Activity B:

Sink or float?

Get the Gizmo ready:

- Click Reset.

Question: The density of water is 1.0 g/mL, which is equivalent to 1 g/cm$^3$. How does an object’s density affect whether it sinks or floats in water?

6. Form hypothesis: How do you think an object’s density relates to whether it sinks or floats? Hypotheses will vary.

7. Collect data: Measure the mass and volume of each known material, and calculate its density. Then drag each material into the water to see whether it sinks or floats.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
<th>Volume</th>
<th>Density</th>
<th>Sinks or floats?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrofoam</td>
<td>7.28 g</td>
<td>36.4 cm$^3$</td>
<td>0.2 g/cm$^3$</td>
<td>Floats</td>
</tr>
<tr>
<td>Aluminum</td>
<td>98.28 g</td>
<td>36.4 cm$^3$</td>
<td>2.7 g/cm$^3$</td>
<td>Sinks</td>
</tr>
<tr>
<td>Wood</td>
<td>25.48 g</td>
<td>36.4 cm$^3$</td>
<td>0.7 g/cm$^3$</td>
<td>Floats</td>
</tr>
<tr>
<td>Slate</td>
<td>76.44 g</td>
<td>36.4 cm$^3$</td>
<td>2.1 g/cm$^3$</td>
<td>Sinks</td>
</tr>
</tbody>
</table>

8. Analyze: How does an object’s density determine if it will sink or float?

If the density is less than the density of water (1 g/mL or 1 g/cm$^3$), the object floats. If the density is greater than 1 g/cm$^3$, the object sinks.

9. Apply: Find the density of Unknown A and Unknown B. Based on their densities, predict whether each will sink or float. Then, test your prediction using the Gizmo.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
<th>Volume</th>
<th>Density</th>
<th>Sinks or floats? (prediction)</th>
<th>Sinks or floats? (actual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown A</td>
<td>21.84 g</td>
<td>36.4 cm$^3$</td>
<td>0.6 g/cm$^3$</td>
<td>Floats</td>
<td>Floats</td>
</tr>
<tr>
<td>Unknown B</td>
<td>54.6 g</td>
<td>36.4 cm$^3$</td>
<td>1.5 g/cm$^3$</td>
<td>Sinks</td>
<td>Sinks</td>
</tr>
</tbody>
</table>

10. Extend your thinking: Compare the three floating materials. How does the density of each material relate to how high it floats in the water?

The greater the density, the lower the object floats in the water. [In fact, the ratio of the object’s density to the density of water (1 g/mL or 1 g/cm$^3$) determines what portion of the object is underwater. For example, if the object has a density of 0.2 g/cm$^3$, then 20% of the object will be below the water’s surface.]
Student Exploration: Determining Density via Water Displacement

**Vocabulary:** Archimedes’ principle, density, displacement, mass, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

A ship floats by an iceberg as shown.

13. Based on the picture, which object is denser, the iceberg or the ship?

14. How do you know?

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**Gizmo Warm-up**

Have you ever gotten into a bath and noticed the water level rise? Have you added potatoes to a full pot of water and had water spill over the sides? If so, you have witnessed a phenomenon called **displacement**, in which water or another fluid is pushed out of the way when a solid object is submerged in the fluid.

The **Determining Density via Water Displacement** Gizmo™ allows you to calculate the **density**, or mass per unit volume, of an object using nothing but a graduated cylinder and a container of water.

11. Place object A into the water. Does it float or sink?

12. Click **Reset**. Add each object to the water, one at a time. (Click **Reset** after each trial.)

Which objects float? Which objects sink?

13. Which object do you think is densest? Least dense?

Explain:
Introduction: Over 2,000 years ago, the Greek mathematician Archimedes discovered that an object in water is pushed up by a force equal to the weight of the displaced water. This law, called **Archimedes’ principle**, has two consequences:

- If an object floats, its **mass** is equal to the mass of the displaced water.
- If an object sinks, its **volume** is equal to the volume of the displaced water.

**Question:** How do you find the density of an object without using a balance?

36. **Measure:** Drop object A into the water. Notice the water displaced into the graduated cylinder to the left of the container. The unit of volume is the milliliter (mL).

   A. How much water is displaced by object A? ____________________

   B. Water has a density of 1 gram per milliliter (1 g/mL). Based on its density, what is the mass of the displaced water? ____________________

   C. Use Archimedes’ principle to determine the mass of object A: ____________________

37. **Measure:** The volumes of solid objects are measured in cubic centimeters (cm³). One cubic centimeter is exactly the same volume as one milliliter. Click **Reset**. Notice that object F has the same volume as object A. Drag object F into the water.

   A. Does object F float or sink? ____________________

   B. How much water is displaced by object F, in mL? ____________________

   C. What is the volume of object F, in cm³? ____________________

   D. What is the volume of object A? ____________________

38. **Calculate:** The density of an object is equal to its mass divided by its volume: \( D = \frac{m}{V} \). The density of solids is measured in grams per cubic centimeter (g/cm³).

   What is the density of object A? ____________________

39. **Analyze:** Click **Reset** and drop object A back into the water. About what percentage of object A is under the water? How is this percentage related to the density of object A? ____________________

   ____________________

(.Activity continued on next page)
**Activity (continued from previous page)**

40. **Gather data:** Click **Reset**. Find how much water is displaced by objects **B**, **C**, **D**, and **E**. Record your measurements below. Include units.

<table>
<thead>
<tr>
<th>Object</th>
<th>Volume of displaced water</th>
<th>Floats or sinks?</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
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<table>
<thead>
<tr>
<th>Object</th>
<th>Volume of displaced water</th>
<th>Floats or sinks?</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
41. Calculate: Use your data to find the mass, volume, and density of the two floating objects, C and E. Recall that the mass of a floating object is equal to the mass of displaced water, and the volume of a sinking object is equal to the volume of displaced water. Assume objects B and E have the same volume, as do objects C and D.

Object C: Mass: _________  Volume: _________  Density: _________

Object E: Mass: _________  Volume: _________  Density: _________

42. Analyze: Drag objects C and E into the water. Estimate the percentage of these objects that are submerged below the waterline. List these estimates below:

Object C: ____________________  Object E: ____________________

How do these estimates relate to the densities you calculated above? ____________________

43. Think and discuss: Why can’t you use this Gizmo to measure the densities of objects B, D, and F? If possible, discuss your answer with your classmates and teacher.

________________________________________________________________________

________________________________________________________________________

44. Challenge: What can you say about the densities of objects B, D, and F? Is there a way to compare the relative densities of these three objects? Explain.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Determining Density via Water Displacement

**Vocabulary:** Archimedes’ principle, density, displacement, mass, volume

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

*Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answers.*

A ship floats by an iceberg as shown.

15. Based on the picture, which object is denser, the iceberg or the ship?  
   *Answers will vary. [The iceberg is denser.]*

16. How do you know?  
   *Answers will vary. [The iceberg floats lower in the water than the ship.]*

**Gizmo Warm-up**

Have you ever gotten into a bath and noticed the water level rise? Have you added potatoes to a full pot of water and had water spill over the sides? If so, you have witnessed a phenomenon called displacement, in which water or another fluid is pushed out of the way when a solid object is submerged in the fluid.

The **Determining Density via Water Displacement** Gizmo™ allows you to calculate the density, or mass per unit volume, of an object using nothing but a graduated cylinder and a container of water.

14. Place object A into the water. Does it float or sink?  
   *Object A floats.*

15. Click Reset. Add each object to the water, one at a time. (Click Reset after each trial.)  
   Which objects float?  
   *Objects A, C, and E*  
   Which objects sink?  
   *Objects B, D, and F*

16. Which object do you think is densest?  
   *Answers will vary.*  
   Least dense?  
   *Answers will vary.*

   Explain:  
   *Answers will vary. [Object D sinks fastest, so it is probably densest. Object E floats highest, so it is probably the least dense object.]*
**Activity:**

**Finding density**

**Get the Gizmo ready:**
- Click Reset.

**Introduction:** Over 2,000 years ago, the Greek mathematician Archimedes discovered that an object in water is pushed up by a force equal to the weight of the displaced water. This law, called **Archimedes’ principle**, has two consequences:

- If an object floats, its **mass** is equal to the mass of the displaced water.
- If an object sinks, its **volume** is equal to the volume of the displaced water.

**Question: How do you find the density of an object without using a balance?**

45. **Measure:** Drop object A into the water. Notice the water displaced into the graduated cylinder to the left of the container. The unit of volume is the milliliter (mL).
   - A. How much water is displaced by object A? 1.7 mL
   - B. Water has a density of 1 gram per milliliter (1 g/mL). Based on its density, what is the mass of the displaced water? 1.7 g
   - C. Use Archimedes’ principle to determine the mass of object A: 1.7 g

46. **Measure:** The volumes of solid objects are measured in cubic centimeters (cm³). One cubic centimeter is exactly the same volume as one milliliter. Click Reset. Notice that object F has the same volume as object A. Drag object F into the water.
   - A. Does object F float or sink? **Object F sinks.**
   - B. How much water is displaced by object F, in mL? 2 mL
   - C. What is the volume of object F, in cm³? 2 cm³
   - D. What is the volume of object A? 2 cm³

47. **Calculate:** The density of an object is equal to its mass divided by its volume: \( D = \frac{m}{V} \). The density of solids is measured in grams per cubic centimeter (g/cm³).
   - What is the density of object A? 0.85 g/cm³

48. **Analyze:** Click Reset and drop object A back into the water. About what percentage of object A is under the water? How is this percentage related to the density of object A?

   *About 85% of object A is under the water. If you convert this percentage to a decimal, it is the same as the density of object A in g/cc.*

(Activity continued on next page)
Activity (continued from previous page)

49. **Gather data**: Click **Reset**. Find how much water is displaced by objects **B**, **C**, **D**, and **E**. Record your measurements below. Include units.

<table>
<thead>
<tr>
<th>Object</th>
<th>Volume of displaced water</th>
<th>Floats or sinks?</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>4 mL</td>
<td>Sinks</td>
</tr>
<tr>
<td>E</td>
<td>0.4 mL</td>
<td>Floats</td>
</tr>
<tr>
<td>C</td>
<td>3 mL</td>
<td>Floats</td>
</tr>
<tr>
<td>D</td>
<td>5.8 mL</td>
<td>Sinks</td>
</tr>
</tbody>
</table>
50. **Calculate:** Use your data to find the mass, volume, and density of the two floating objects, **C** and **E**. Recall that the mass of a floating object is equal to the mass of displaced water, and the volume of a sinking object is equal to the volume of displaced water. Assume objects **B** and **E** have the same volume, as do objects **C** and **D**.

**Object C:**
- Mass: 3 g
- Volume: 5.8 cm$^3$
- Density: 0.52 g/cm$^3$

**Object E:**
- Mass: 0.4 g
- Volume: 4 cm$^3$
- Density: 0.1 g/cm$^3$

51. **Analyze:** Drag objects **C** and **E** into the water. Estimate the percentage of these objects that are submerged below the waterline. List these estimates below:

*Note: Estimates will vary, but should be close to the exact values given below.*

Object **C:** 52%  
Object **E:** 10%

How do these estimates relate to the densities you calculated above?

*If percentages are converted to decimals, the percentage under water is very close to the density of the object. [In fact the two values are exactly equal.]*

52. **Think and discuss:** Why can’t you use this Gizmo to measure the densities of objects **B**, **D**, and **F**? If possible, discuss your answer with your classmates and teacher.

*We can use the Gizmo to find the volume of objects **B**, **D**, and **F**, but not their mass.*

53. **Challenge:** What can you say about the densities of objects **B**, **D**, and **F**? Is there a way to compare the relative densities of these three objects? Explain.

*The denser an object, the faster it will sink. Object **D** sinks the most quickly so it is the densest object. Object **F** sinks the most slowly so it is the least dense object.*
6th Grade Science Unit: 6.PS.2

Unit Snapshot

Topic: Matter and Motion

Grade Level: 6  Duration: ~2 weeks

Summary (as stated in Ohio's New Learning Standards for Science)

Thermal energy is the total amount of kinetic energy present in a substance (the random motion of its atoms and molecules). When thermal energy increases, the total kinetic energy of the particles in the system increases. The thermal energy of a substance depends upon the mass of the substance, the nature of the material making up the substance, and the average kinetic energy of the particles of the substance. Thermal energy cannot be directly measured; however, changes in thermal energy can be inferred based on changes in temperature. The higher the temperature of a particular substance, the greater the average kinetic energy and motion of the particles. Thermal energy depends on the amount of the substance, whereas temperature does not depend on the amount of the substance.

Solids, liquids and gases vary in the motion of and the spacing and attractions between particles. Solid particles are close together and held more rigidly in a space by the attractions between the particles. However, solid particles can still vibrate back and forth within this space. Liquid particles may be slightly farther apart but move with more speed than solid particles. In liquids, particles can move from one side of the sample to another. Gas particles are much farther apart and move with greater speed than liquid or solid particles. Because of the large spaces between the particles, gases are easily compressed into smaller volumes by pushing the particles closer together. Most substances can exist as a solid, liquid or gas depending on temperature. Generally, for a specific temperature, materials that exist as solids have the greatest attraction between the particles. Substances that exist as gases generally have the weakest attraction between the particles.

During phase changes, the mass of the substance remains constant because the particles (atoms and molecules) are not created or destroyed. There is simply a change in the motion of and spacing between the particles. Experiments and investigations (3-D and virtual) must be used to demonstrate phase changes.

For substances to rearrange and form new substances, often the particles of the substances must first collide. The higher the temperature, the greater the average motion and the more likely the particles are to collide and rearrange to form new substances. In a solid, particles are rigidly held in fixed position. When the solid dissolves in water, the particles of the solid separate and move freely with the water particles. Therefore, particles in the dissolved state are more likely to collide with other particles and rearrange to form a new substance than they are as a solid.

Since moving atoms and molecules cannot be observed directly, provide the opportunity to experiment with temperature, phase changes and particle motion using virtual labs.
**Clear Learning Targets**

*"I can"…statements*

- ____ explain that thermal energy is a measure of the motion of the atoms and molecules (kinetic energy) in a substance.
- ____ describe the factors that affect thermal energy.
- ____ investigate temperature change in order to infer changes in thermal energy.
- ____ describe solids, liquids, and gases in terms of motion of and spacing and attractions between particles.
- ____ model and explain how mass is conserved when substances undergo a change of state.

**Activity Highlights and Suggested Timeframe**

<table>
<thead>
<tr>
<th>ENGAGE</th>
<th>EXPLORE</th>
<th>EXPLAIN</th>
<th>ELABORATE</th>
<th>EVALUATE</th>
<th>EXTENSION/INTERRUPTION</th>
</tr>
</thead>
</table>

Use the following website:  
[http://www.middleschoolchemistry.com/lessonplans/chapter1](http://www.middleschoolchemistry.com/lessonplans/chapter1)  
Follow the Lessons for Chapter 1 and 2 (see below)
OHIO'S NEW LEARNING STANDARDS:
6.PS.2 Changes of state are explained by a model of matter composed of atoms and/or molecules that are in motion.
- When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure.
- Thermal energy is a measure of the motion of the atoms and molecules in a substance.
- Mass is conserved when substances undergo changes of state.

Note: Thermal energy can be connected to kinetic energy at this grade level.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:
During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering) that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Framework for K-12 Science Education Scientific and Engineering Practices

STUDENT KNOWLEDGE:

Prior Concepts Related to Matter:
PreK-2: Properties can be observed and used to sort materials. Changes in materials are investigated, including solid-liquid phase changes.
Grades 3-5: Matter has mass* and volume. Properties of solids, liquids and gases, and phase changes are reversible and do not change the identity of the material. The total amount of matter remains the same when it undergoes a change. Mass* stays constant during phase changes.
*While mass is the scientifically correct term to use in this context, the NAEP 2009 Science Framework (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level. In Ohio, students will not be assessed on the differences between mass and weight until Grade 6.

Future Application of Concepts:
Grades 7-8: Acids, bases, mixtures and pure substances are investigated. Elements are classified as metals, nonmetals or nonreactive gases based on their properties and position on the periodic table. Atoms can be joined together into separate molecules or large three-dimensional networks. Changes are classified as chemical or physical, depending upon whether the atomic composition of the materials changes.
Below are links to two sets of lessons that explore the Changes of State (6.PS.2) standard from http://www.middleschoolchemistry.com.

Teachers should review the websites prior to teaching. Each link has several handouts and videos. Teachers should create a summative assessment that demonstrates an understanding of these concepts at their discretion at the end of this unit.

http://www.middleschoolchemistry.com/lessonplans/chapter1
  • http://www.middleschoolchemistry.com/lessonplans/chapter1/lesson1
  • http://www.middleschoolchemistry.com/lessonplans/chapter1/lesson2
  • http://www.middleschoolchemistry.com/lessonplans/chapter1/lesson3
  • http://www.middleschoolchemistry.com/lessonplans/chapter1/lesson4
  • http://www.middleschoolchemistry.com/lessonplans/chapter1/lesson5

http://www.middleschoolchemistry.com/lessonplans/chapter2
  • http://www.middleschoolchemistry.com/lessonplans/chapter2/lesson1
  • http://www.middleschoolchemistry.com/lessonplans/chapter2/lesson2
  • http://www.middleschoolchemistry.com/lessonplans/chapter2/lesson3
  • http://www.middleschoolchemistry.com/lessonplans/chapter2/lesson4
  • http://www.middleschoolchemistry.com/lessonplans/chapter2/lesson5