LESSON 1

Physical Properties

Vocabulary

matter, E6
mass, E6
volume, E6
weight, E7
density, E8
conduct, E14
insulate, E14

Get Ready

When you say something is "bigger" than something else, what does "bigger" mean? What is bigger than a hot air balloon? How can the balloon float in the air?

If the balloon is empty and folded up, is it smaller? Will it float now?

Bigger or smaller. More or less. How could you test different ways that things can be "more" or "less" than other things?

Inquiry Skill

You experiment when you perform a test to support or disprove a hypothesis.

Explore Activity

Which Is More?

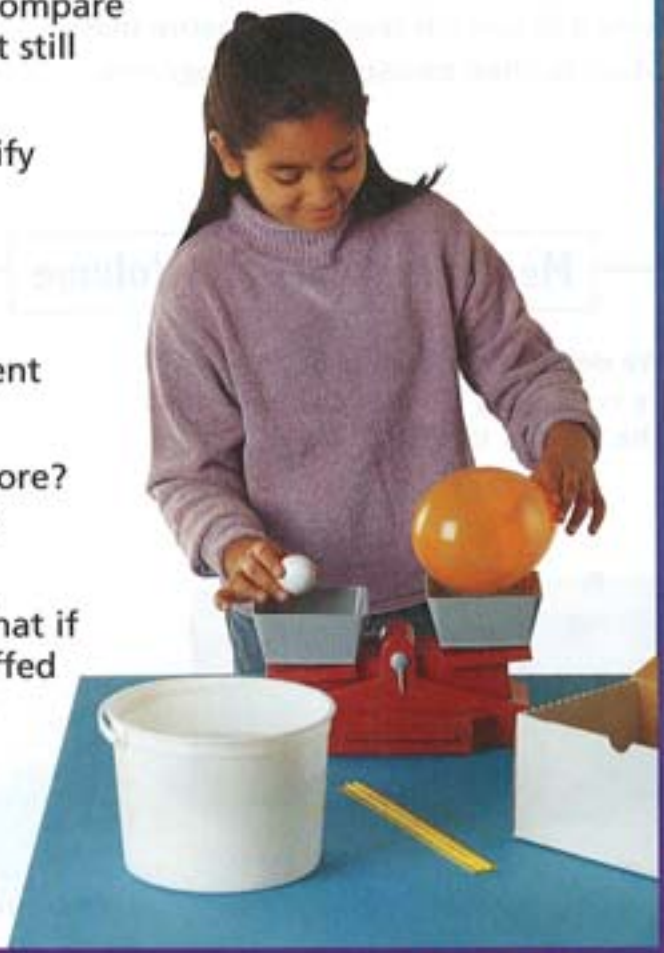
Materials

- golf ball or wooden block
- blown-up balloon
- equal-pan balance
- ruler
- string
- box, such as a shoe box
- pail of water

Procedure: Design Your Own

1. **Observe** Look at the golf ball (or wooden block) and blown-up balloon. Which is "more"? Think of how one object could be "more":
   - more when you use a balance
   - more when you put it in water and see how much the water level goes up, and so on

   Record your observations.
2. Use the equipment to verify one way that one object is more than another. Decide which of the two objects is "more" and which one is "less."
3. Repeat your measurements to verify your answer.
4. Now use different equipment to compare the two objects. Is the same object still "more"? Explain.
5. Repeat your measurements to verify your answer.



Drawing Conclusions

1. **Communicate** Identify the equipment you used. Report your results.
2. For each test, which object was more? In what way was it more than the other object?
3. FURTHER INQUIRY **Experiment** What if you were given a large box of puffed oats and a small box of oatmeal? Which do you think would be more? Design an experiment to test your hypothesis. Tell what equipment you would use.

Read to Learn

Main Idea **Matter is anything that has mass and occupies space.**

What Is Matter?

All of the gases, liquids, and solids in the world around you—the air you breathe, the water you drink, and the chair you sit on—are made of **matter**. Testing to see whether a golf ball or a balloon is "more" measures *properties* of the matter in these objects.

A golf ball has more **mass** because it tips the balance more. However, a balloon has more **volume** because it fills up a greater amount of space.

Mass is a measure of the amount of matter in an object. The photo shows how a balance is used to measure mass. Mass is often measured in kilograms.

Volume describes how much space a sample of matter takes up. Volumes are often measured in milliliters (mL). As the photo shows, the volume of a liquid may be measured using a graduated cylinder, a beaker, or a measuring cup. The volume of a solid may be measured by multiplying its height times its length times its width. Solids don't always have regular shapes, however. We can also measure the volume of a solid by seeing how much water it displaces from a container. A solid with a volume of 1 cm^3 will make the water rise 1 mL, for example. A volume of 1 cm^3 equals 1 mL.

Matter is defined using the properties of mass and volume. Matter is anything that has mass and takes up space.

Measuring Mass and Volume

We determine the mass of an object by comparing it with known masses. The mass of this block is 25 g.

Equal-pan balance

Measuring cup

Graduated cylinder

Beaker

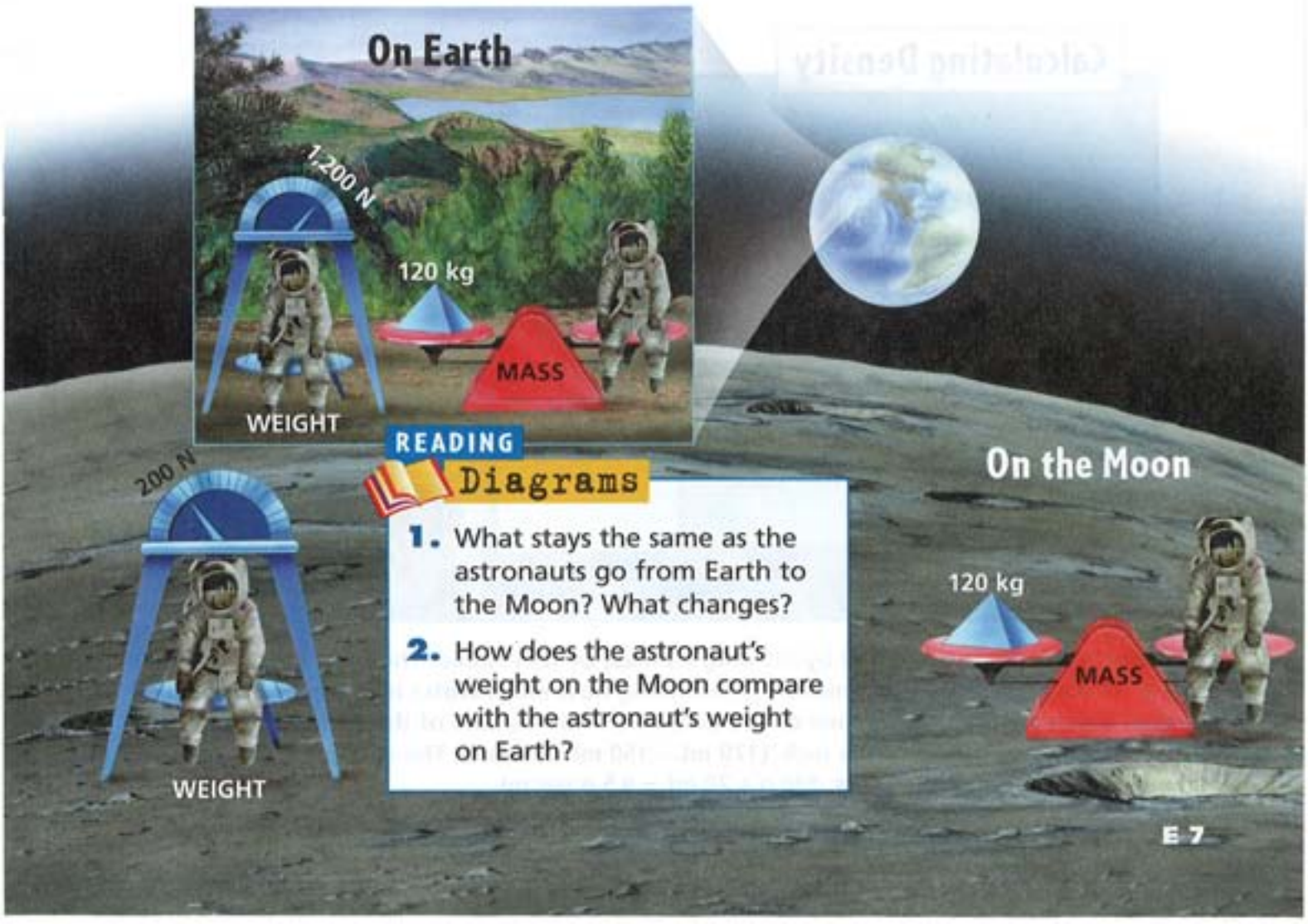
Weight

What if you find the mass of a certain book to be 1 kilogram? You might be tempted to say, "This book weighs 1 kilogram." However, this is incorrect. The book's **weight** is actually the force of gravity between Earth and the book. The book's mass, on the other hand, is a measure of the amount of matter in the book compared with known masses.

As you know, we can use kilograms to measure an object's mass. However, to measure weight, we must use a quantity that describes the force of gravity between two masses. Scientists prefer to use a quantity called the *newton* (N) to measure force. One newton is the same as 0.22 pound. (One pound is 4.45 newtons.) Newtons and pounds both describe the amount of pull or push a force produces. In this case the force is the pull of gravity.

An object's weight depends on its location in the universe. If you were to travel to the Moon, for example, you would have less weight. The Moon has less mass than Earth, so the force of gravity between your body and the Moon would be less. However, your mass would remain unchanged, as shown in the diagram.

What are two properties of matter?



READING Diagrams

1. What stays the same as the astronauts go from Earth to the Moon? What changes?
2. How does the astronaut's weight on the Moon compare with the astronaut's weight on Earth?

What Is Density?

As you learned on page E6, mass and volume are two properties of matter. Can we use these properties to tell us more about matter? How can these two measurements tell us something new?

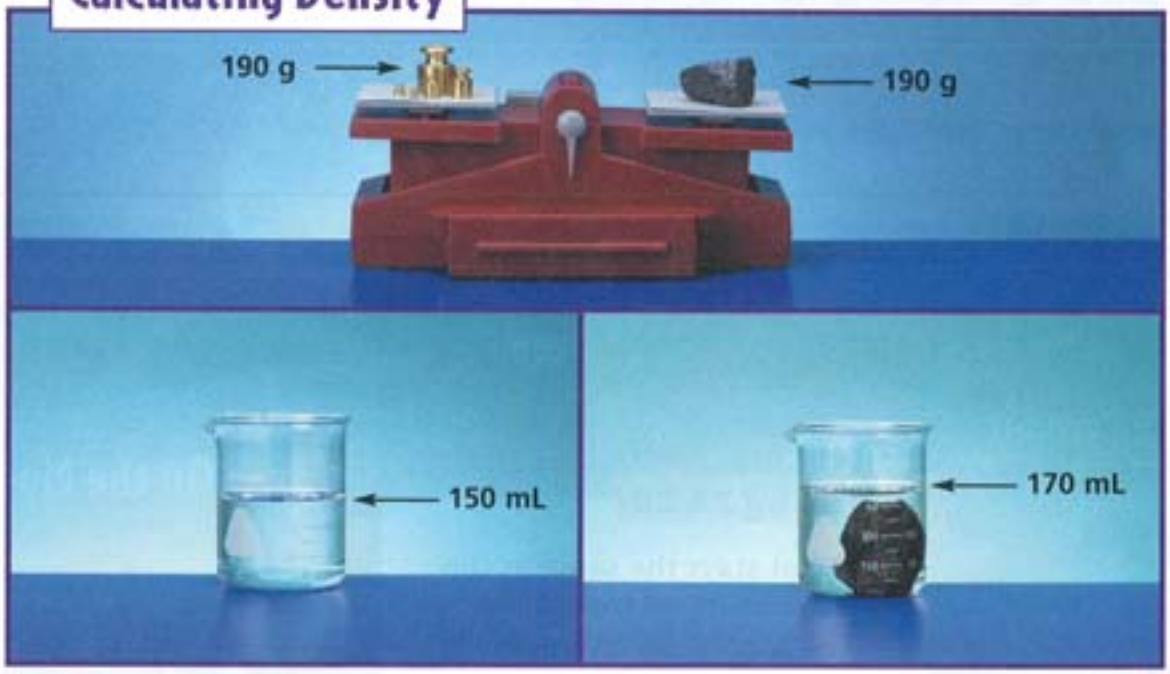
If we divide the mass of a sample by its volume, we get a new measurement of matter. This property is called **density**. The density of an object tells us how massive something is for its size. It compares an object's mass with its volume.

Let's look at an example. If 2 mL of water has a mass of 2 g, then 2 g divided by 2 mL equals 1 g per mL. The density is 1 g per mL. If we combined that water sample with another 2 mL sample, we would have 4 mL and 4 g of water. The density would still be 1 g per mL.

As long as conditions, such as temperature, do not change, the density of a substance does not change. The size of the sample does not matter. Density can be used to help identify materials because of this. If you had a piece of metal with a density of 11.3 g per mL, it would probably be lead. A similar-looking piece with a density of 2.7 g per mL, however, would probably be aluminum. Each material has its own density.

How can density be measured?

Calculating Density



An object's density is calculated by dividing its mass by its volume. The mass of this rock is 190 g. Its volume can be determined by calculating how much water it displaces from the beaker. If you subtract the volume of the water from the volume of the water plus the rock, you get the volume of the rock. (170 mL – 150 mL = 20 mL). The volume of this rock is 20 mL. The density of this rock is: 190 g ÷ 20 mL = 9.5 g per mL.

Inquiry Skill BUILDER

SKILL Make a Model

How Metal Boats Float

Think about objects that have more matter packed into the space they take up than water does. Will such objects sink or float in water? You have probably seen how a metal object like a nail or a spoon sinks in water. However, huge ships made of similar metal float even when they carry large cargoes. How is this possible? In this activity you will make different sized models of a metal boat. Scientists use models to help them understand properties of matter. Models also make experimenting easier. Try different designs to see how well the model boats can carry heavy cargo.

Materials

- aluminum foil
- large paper clips
- pan of water

Procedure

1. **Make a Model** Prepare 3 sheets of aluminum foil of different sizes. Record their lengths and widths and use them to make 3 boats. Experiment with different designs and float them on water.
2. **Predict** Write down what you think will happen when you place more and more matter in the empty space of the boat. What steps should you follow to test your prediction? Be sure to use only the materials listed above.
3. **Experiment** Carry out your procedure, keeping a written record of what you observe.

Drawing Conclusions

1. **Communicate** How well did your results agree with your prediction?
2. Compare your model with those of your classmates. Which boat held the most clips? Why?
3. **Make a Model** The aluminum foil boat is a model of a steel ship. Use the way your boat floats to explain how a steel ship floats. Why was using a model of a large ship helpful?
4. **Communicate** What changed as more and more matter was added to the empty space of the boat? What happened as a result of this change?

How Dense Are Solids, Liquids, and Gases?

Think of cutting a piece of aluminum foil into smaller and smaller pieces until the pieces are tinier than specks of dust. All matter—solids, liquids, and gases—is made of similar tiny particles. An object's mass is related to the number and type of particles it has.

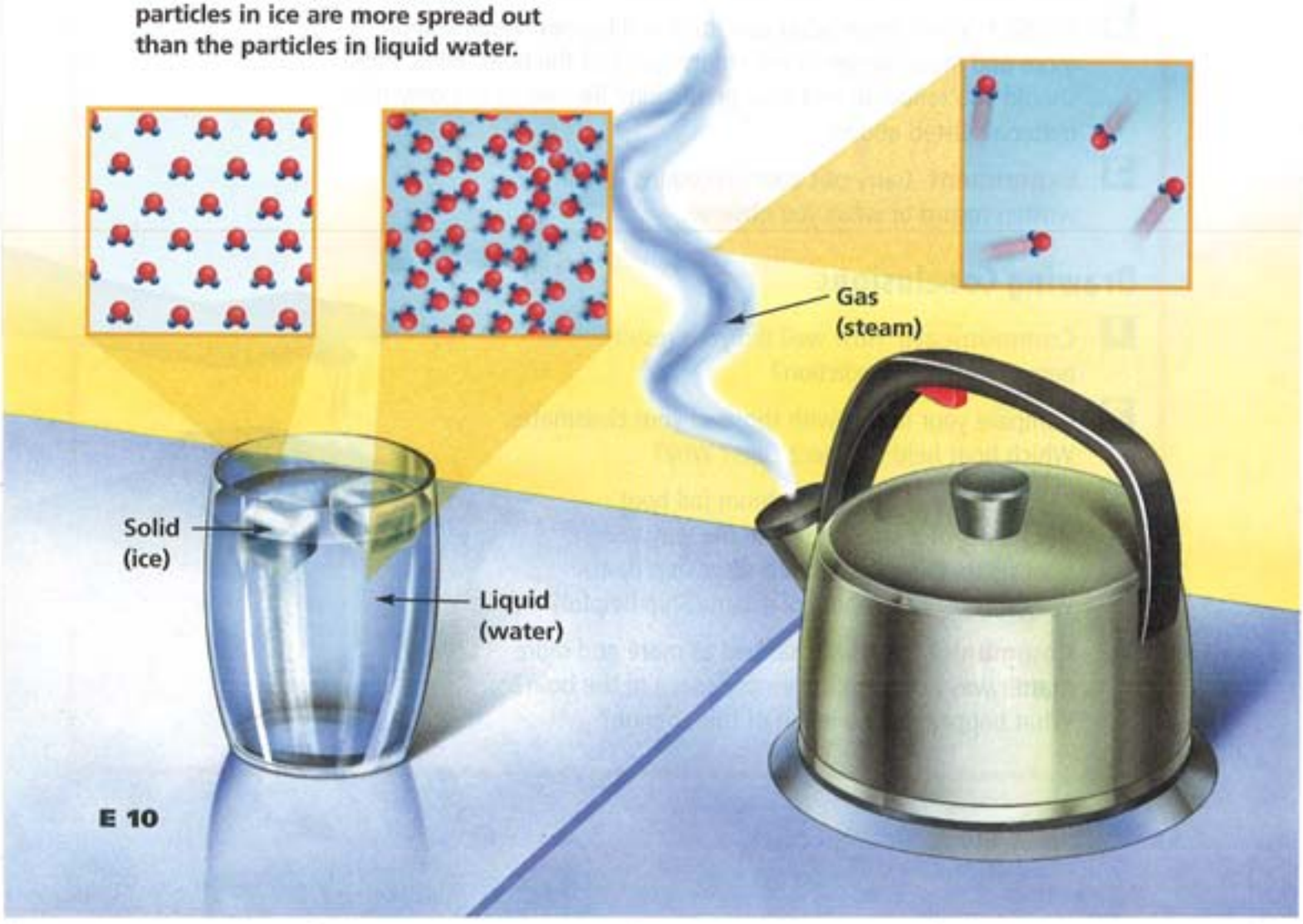
Density describes how tightly these particles are packed together. A high density means that many particles are packed tightly into a given space. A low density means that only a few particles fill the same amount of space.

The particles of a solid tend to be packed tightly together. They don't have a lot of room to move around. However, the particles of a gas usually spread out. In general, matter in the solid state is more dense than in the liquid state. Likewise, matter in the liquid state tends to be more dense than in the gaseous state.

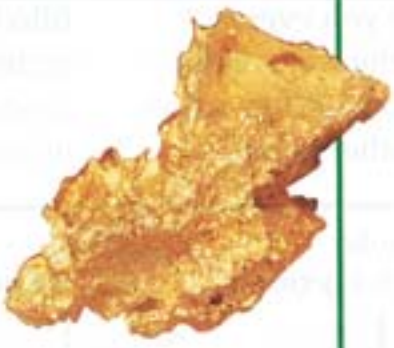
READING Main Idea

How do the densities of solids, liquids, and gases compare?

Water is special! Solid water, ice, is less dense than liquid water. The particles in ice are more spread out than the particles in liquid water.



Densities of Common Substances

State	Substance		Density (g/cm^3)
Solid	 Aluminum	 Gold	Aluminum, 2.7 Gold, 18.9
Liquid	 Water	 Mercury	Water, 1.0 Mercury, 13.5
Gas	Helium 		Helium, 0.00018 Air at sea level, 0.0012

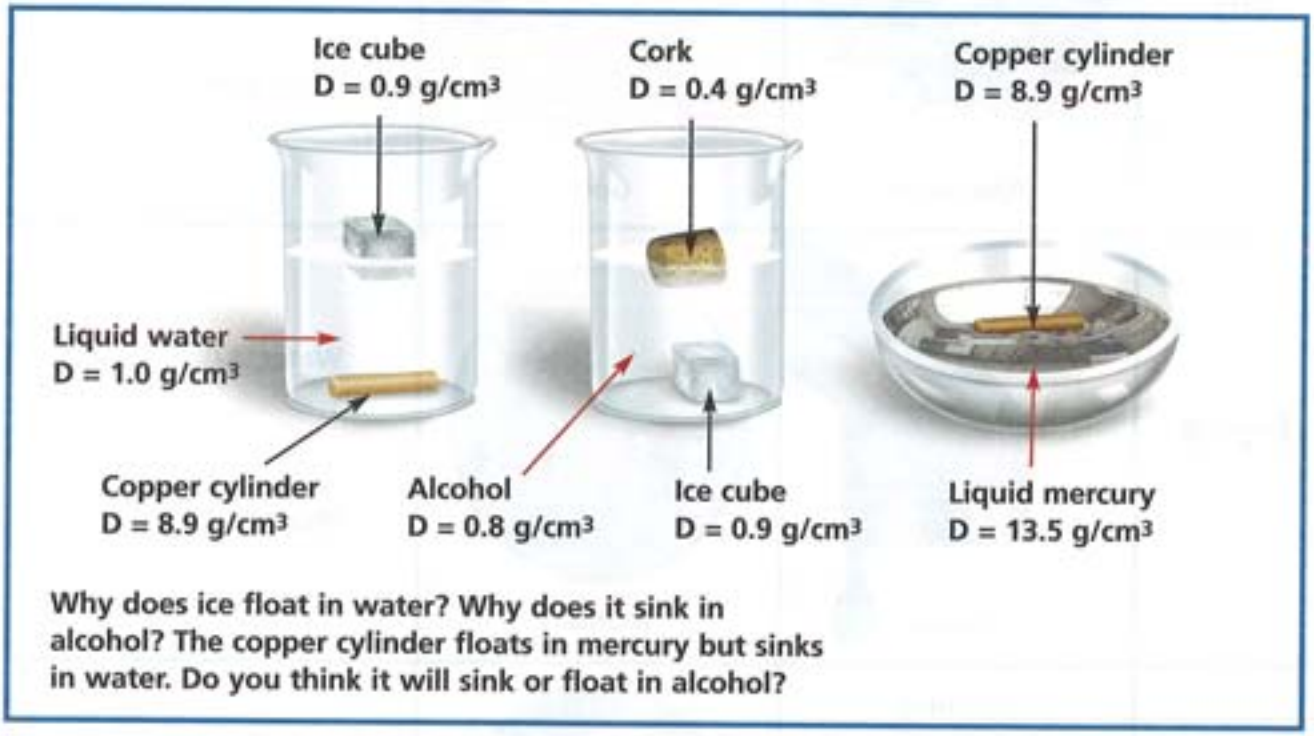
READING Charts

1. Which is denser—aluminum or gold? Mercury or gold?
2. Organize the substances in the chart from the least dense to the most dense. Make a bar graph with the densities of these substances.

How Does Density Make Things Sink or Float?

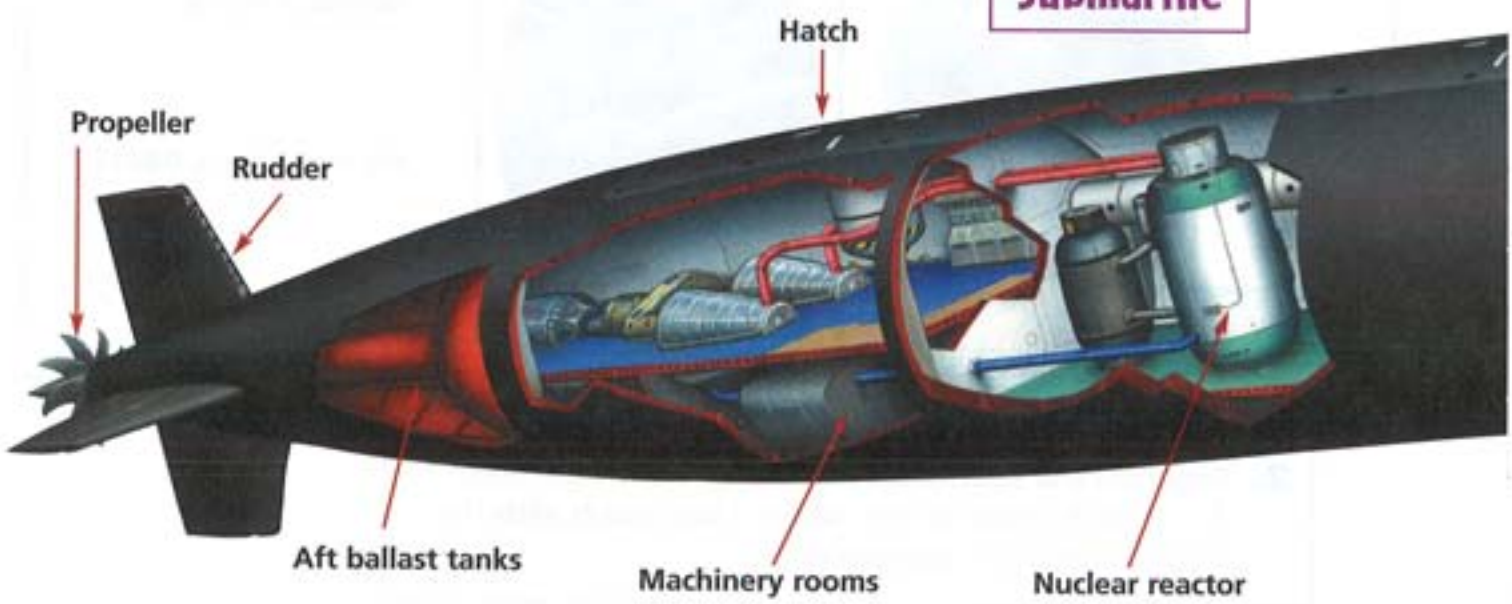
Have you ever observed a beach ball floating in a pool? Have you ever dropped your towel in the water, only to see it sink to the bottom? What makes some things float, and others sink?

Density determines an object's ability to sink or float. An object floats in a liquid when its density is less than the liquid's density. A beach ball is filled with air. Air is less dense than water, so the beach ball floats. We describe an object's ability to float as its *buoyancy* (BOY·uhn·see).



Why does ice float in water? Why does it sink in alcohol? The copper cylinder floats in mercury but sinks in water. Do you think it will sink or float in alcohol?

Submarine

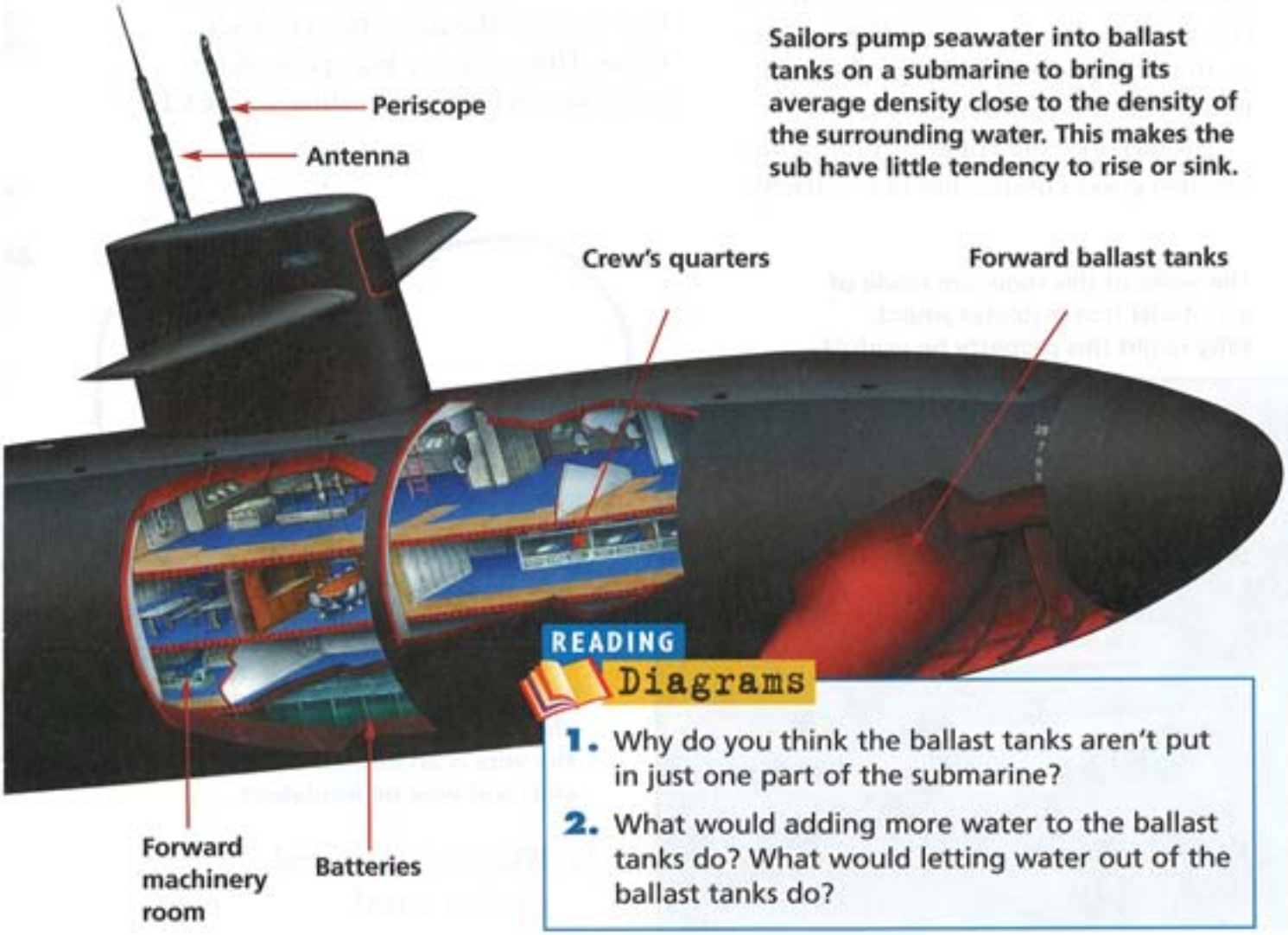


Helium balloons can float, too. However, they float in air instead of water. Helium is less dense than air, so helium balloons rise into the sky.

As you know, not all objects float. An object sinks in a liquid when it is more dense than the liquid. The copper cylinder shown in the diagram sinks in water. The ice cube sinks in alcohol.

It's easy to float in the Dead Sea because salt water is denser than fresh water. The Dead Sea has the densest saltiest water on Earth. Swimmers float higher in this sea than in ocean water.

How does density determine an object's ability to float in water?



Sailors pump seawater into ballast tanks on a submarine to bring its average density close to the density of the surrounding water. This makes the sub have little tendency to rise or sink.

READING
Diagrams

1. Why do you think the ballast tanks aren't put in just one part of the submarine?
2. What would adding more water to the ballast tanks do? What would letting water out of the ballast tanks do?

What Are Conductors and Insulators?

Matter has many important properties besides density. For example, some materials **conduct** energy very well. These materials allow energy to flow through them easily. However, other materials **insulate** against the passage of energy. They do not readily permit energy to flow. Look carefully at the photographs to learn about materials that conduct or insulate.

Cooking pots and pans are made of metal because metal conducts heat well. However, they should have wooden or ceramic handles. Such handles insulate against heat so you don't get burned when you touch the handles.

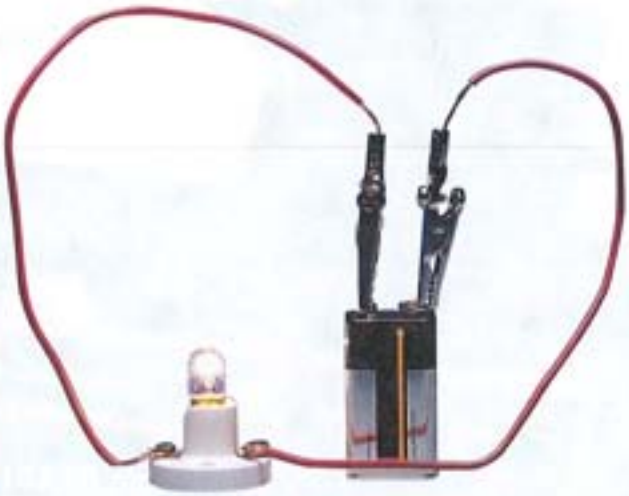
Metals, like the copper in the wire, are also good conductors of electricity.

Which material in this pan is a conductor? Which is an insulator?

The electricity flows from the battery to the light bulb through the wire, producing light and heat. The plastic that coats the wire is an insulator. Anyone who touches the plastic coating will not be shocked, because the electricity cannot pass through it.

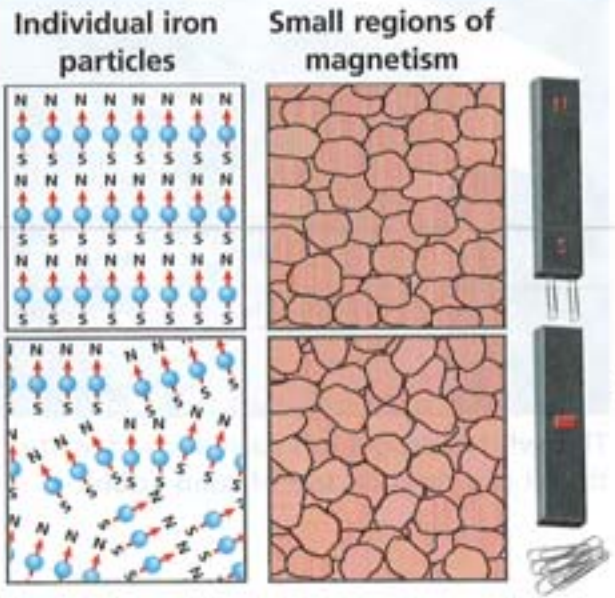
Sound booths are made of materials that insulate the room from outside noise. This property is important for musicians who are recording a new CD.

The walls of this room are made of a material that insulates sound. Why might this property be useful?



The wire is a good conductor of electricity. The plastic that coats the wire is an insulator. Why must electrical wire be insulated?

What do *insulate* and *conduct* mean?



When iron particles in small areas of the metal line up, a permanent magnet is formed.

What makes a material magnetic?

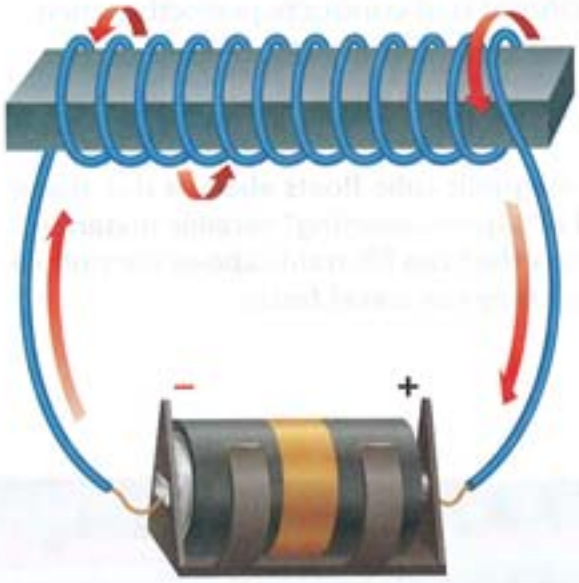
What Is Magnetism?

Certain objects push or pull on each other because they are *magnetic*. Magnetism is another property of some kinds of matter. A magnet has a north pole and a south pole. North poles and south poles of magnets attract, but two poles that are alike repel. Magnets can also attract certain materials that are made of a metal like iron.

Like density, magnetism results from the combined effect of the properties of tiny particles. In iron, for example, each tiny particle of iron is itself a magnet.

Look at the diagram above. Each particle has a north and a south pole. When the particles line up, the material is magnetic. When the particles do not line up pole to pole, however, the material is not magnetic.

Earth acts like a huge magnet. A compass needle is a magnet that points to the Earth's magnetic North pole.



The electric current flowing through the coils lines up the iron core particles pole to pole, making a strong electromagnet. Without the current, the lineup ends and the magnetism disappears.

How Do We Use Properties of Matter?

Engineers and scientists use properties of matter when they design and build new things.

Aerogels are new materials with very low density and relatively great strength. They are made of tiny pockets of air surrounded by thin walls of silica. Silica is the same material found in sand and in window glass.

Aerogels are very good insulators of heat. Insulated windows containing aerogel would be from 10 to 20 times better at holding in heat than ordinary glass windows.

Scientists have discovered that some materials become perfect conductors of electricity when they are very cold. The photo shows a ceramic, glasslike material that conducts perfectly when cooled to –196°C (–320.8°F).

This white aerogel has such a low density that it can float on top of soap bubbles.

How are properties of matter used?

A magnetic cube floats above a disk made of a "superconducting" ceramic material. This effect can lift trains above the rails so that they can travel faster.

Why It Matters

You use many different properties of matter every day. Matter that conducts electricity lets you use a reading lamp at night or listen to your favorite CDs. Density allows you to float in a boat on a lake or float through the sky in a hot air balloon. Magnets help you find your way home with a compass.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on properties and structure of matter.

Think and Write

1. List four properties of matter.
2. If a rock was taken from Earth to the Moon, how would its mass and weight be affected?
3. What if you had rubber bands, wood chips, straight pins, aluminum foil, and glass beads? Using a property of matter, classify these objects. Show your results in a table.
4. **INQUIRY SKILL** **Make a Model** Design a strong, light (up to 100 g), cardboard structure to bridge a 30-cm gap. How much weight can it support?
5. **Critical Thinking** Think of the properties of matter you use every day. In what ways are they important to you?

L·I·N·K·S

WRITING LINK

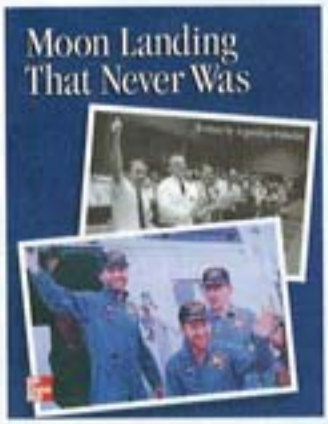
Personal Narrative Write about a typical day from the time you get up until the time you go to sleep. Tell the events in order. What properties of matter do you rely on to get to school, do your homework, and play with your friends?

MATH LINK

Calculate density. Find some small objects around your classroom or house—a seashell, a rock, or even a piece of fruit. Measure its mass and its volume. Use its mass and volume to find its density.

LITERATURE LINK

Read *Moon Landing That Never Was* to learn about the spacecraft *Apollo 13*. Try the activities at the end of the book.



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