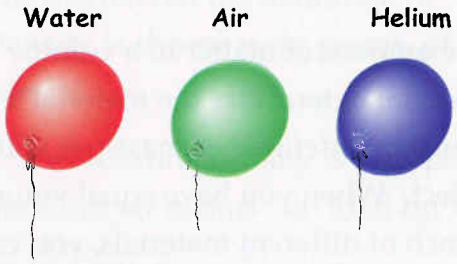
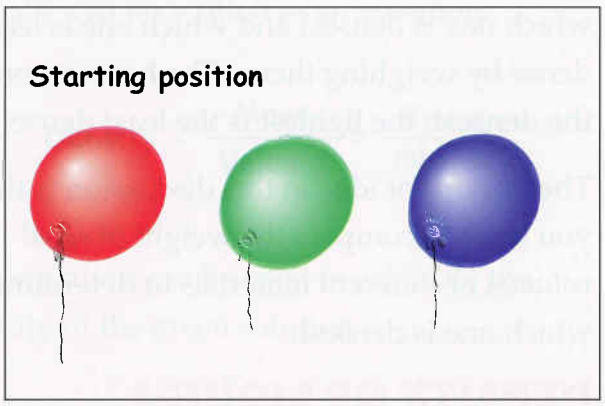
DENSITY

Make believe you have a package of regular rubber balloons. Fill one with water, tie it off, and give it to a friend. Fill a second, identical balloon with air until it is the same size as the water balloon. Tie it off and give it to a second friend to hold. Fill a third balloon with helium, same size as the other two, and tie it off.

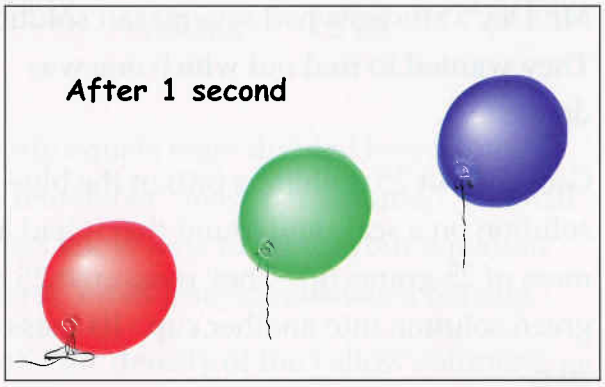


Review the balloons—three identical balloons, all filled to exactly the same volume, each tied off so nothing can get in or out. What's different? The kind of material in the three balloons. Ready to try a little experiment?

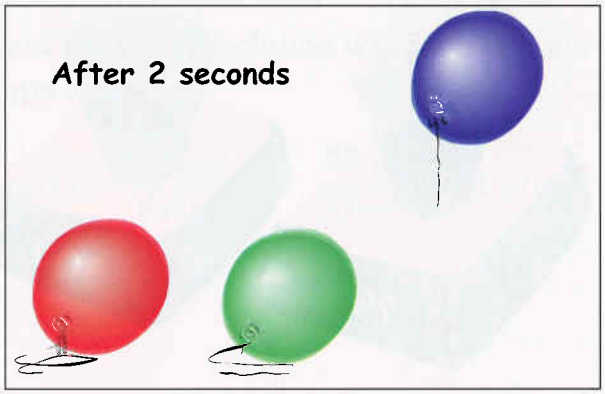


You and your friends hold the balloons at the same height above the floor. On the count of three, you will all release your balloons and observe what happens.

The water balloon will plunge to the floor, the air balloon will drift slowly to the floor, and the helium balloon will float up to the ceiling. Why?



It comes down to how much stuff there is in each balloon. The scientific word for stuff is **matter.** The amount of matter in an object is its **mass.** Matter is made out of atoms. So the mass of an object depends on *how many* atoms there are in the object and *how big* the atoms are.



The atoms in solids (glass, steel) and liquids (water, alcohol) are packed together as close as they can get. This means there are lots of atoms in a volume of water. That makes water pretty heavy.

In gases, the atoms are not packed as close together as they can get. There is a lot of space between atoms. Air and helium are gases, so they are pretty light.

Air atoms (mostly nitrogen and oxygen) are fairly large, but helium atoms are small. Generally speaking, small atoms weigh less than large atoms. So helium is much lighter than air.

DENSITY

The amount of matter in a volume of material determines the material's density. **Density** is defined as mass per volume of an object. When you have equal volumes of a bunch of different materials, you can find out which one is densest and which one is least dense by weighing them. The heaviest one is the densest; the lightest is the least dense.

The important idea in this discussion is that you need to compare the weight of *equal volumes* of different materials to determine which one is densest.

DENSITY OF LIQUIDS

Mr. Dey's students had several salt solutions. They wanted to find out which one was densest.

Group 1 put 25 milliliters (ml) of the blue solution on a scale and found that it had a mass of 25 grams (g). They measured 25 ml of green solution into another cup. Its mass was 30 g.

The students announced, "We weighed equal volumes of two solutions. The green solution is heavier, so it is denser. It has more mass per volume than the blue solution."

Group 2 put 25 ml of blue solution on a scale and found that it had a mass of 25 g. But then they made a little mistake. They put 50 ml of yellow solution in a cup and found that it had a mass of 55 g.

When they realized what they had done, Reggie said, "Oh-oh, we didn't measure equal volumes. We have to start over."

"Maybe not," said Yolanda. "We weighed twice as much yellow solution as we should have. If we had used half as much, it would have weighed half as much. All we have to do is divide the mass by two to find out the mass of 25 ml of yellow solution."

They did the math and found that 25 ml of yellow solution had a mass of 27.5 g.

The two groups put their data together in a table.

Solution	Volume	Mass
Blue	25 ml	25 g
Green	25 ml	30 g
Yellow	25 ml	27.5 g

Students could now easily compare equal volumes of the three solutions to see which one was heaviest and, therefore, densest. They determined that green was densest, blue least dense, and yellow in the middle.

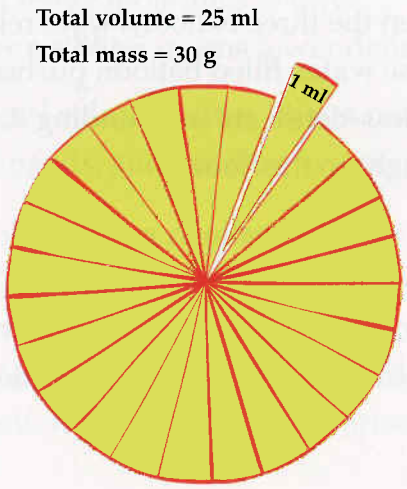
Mr. Dey had a question. "What is the mass of 1 ml of each of the solutions?"

Reggie offered, "Twenty-five milliliters of blue solution has a mass of 25 g, so 1 ml of blue has a mass of 1 g."

"And the green solution?" asked Mr. Dey.

Reggie's group thought about it this way.

- Twenty-five milliliters of green has a mass of 30 g. That's more than 1 g for each milliliter.
- They drew a pie chart to help them think about the problem. Each slice of pie represented 1 ml, or 1/25 of the total volume.



- One milliliter is 1/25 of the total volume. Each milliliter must have 1/25 of the total mass.
- They divided 30 g by 25 ml to find the mass of 1 ml of green solution.

The students discovered the definition of density. **Density is the mass, in grams, of 1 ml of material.**

The usual way of stating density is *mass per volume*. The word *per* means "divided by."

Density can be written as an equation.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{g}{ml}$$

The equation can be used to calculate the density of the green solution.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{30\ g}{25\ ml} = 1.2\ g/ml$$

Density equals mass divided by volume. If you remember "mass per volume," you will always know how to set up your equation when it comes time to calculate a density.

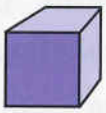
What's the density of the yellow solution? Remember, mass per volume. The original mass of the yellow solution was 55 g, and the volume was 50 ml.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{55\ g}{50\ ml} = 1.1\ g/ml$$

DENSITY INTERACTIONS

Density is a number that tells you how much matter there is in a milliliter or **cubic centimeter (cc)** of material. One milliliter is exactly the same volume as one cubic centimeter.

1 cubic centimeter = 1 milliliter →



Liquids are generally measured in milliliters, and solids and gases are measured in cubic centimeters.

If there is a lot of matter in a cubic centimeter of something, it is dense. If there is very little matter in a cubic centimeter of material, it is not dense.

Water has a density of 1 g/ml. Materials with densities greater than 1 g/ml are denser than water; materials with densities less than 1 g/ml are less dense than water.

What will happen if you put a rock with a density of 3 g/cc in a tub of water? It will sink like, well, a rock. And if you put a cork, with a density of 0.45 g/cc in the tub of water? Yes, it will float.

Materials that are denser than water sink in water. Materials that are less dense than water float in water. That's the way it always works.

When salt dissolves in water, it forms a solution. The more salt dissolved in a volume of water, the greater the solution's density.

If you carefully pour a little bit of each of the colored solutions from Mr. Dey's class into a vial, what do you think would happen? Can you describe the result?

Solution	Density
Blue	1.0 g/ml
Yellow	1.1 g/ml
Green	1.2 g/ml

DENSITY OF GASES

Back to the balloons. We know the density of water, but what about the air and the helium?

Material	Density
Water	1.0 g/ml
Air	0.0013 g/ml
Helium	0.0002 g/ml

The chart shows that air and helium are not very dense. There is very little mass in a milliliter of gas.

When the three balloons were released, the dense water-filled balloon pushed through the less-dense air surrounding it. It fell straight to the floor.

The air-filled balloon was almost the same density as the surrounding air. The rubber-balloon membrane is denser than air, and the air was compressed a little inside the balloon,

making the air-filled balloon a little denser than the surrounding air. It drifted slowly to the floor.

The helium-filled balloon was quite a bit less dense than the surrounding air. Just like a cork in water, the less-dense helium balloon floated up to the ceiling.

DENSITY OF AIR

Air is gas. The molecules in gases are not bonded to other molecules. Gas molecules move around freely in space.

When energy transfers to matter, the kinetic energy (movement) of the atoms and molecules increases. The increased motion causes most matter to expand. When matter expands, the atoms and molecules do not get bigger—they get farther apart. This is a very important point: It is the distance between molecules that increases, not the size of the molecules.

When matter expands, the molecules get farther apart. What do you think that does to the density of the material? The density gets lower. When the molecules get farther apart, each cubic centimeter (which is the same as a milliliter) has fewer molecules. Fewer molecules per milliliter means lower density.

This is a general rule of matter. When matter gets hot, it expands, and the density goes down.

Air is matter. Air expands when it gets hot. Air gets less dense when it gets hot. When energy transfers from Earth's surface to the air by conduction (contact between surface molecules and air molecules) or reradiation, the air temperature goes up and the air expands. The low-density, warm air rises, just like the helium balloon in air.

DENSITY AND WEATHER

Weather happens in the atmosphere. Energy transfers into and out of the atmosphere in the form of heat. As air heats up and cools down, its density changes. Warm air tends to go up, and cold air tends to go down. When masses of air move, things happen in the weather.

The idea of density will be an important concept in our investigation of weather and the processes that cause it.

THINK QUESTIONS

1. **What do you think the density of a person might be? Explain.**
2. **Why do you think hot-air balloons are able to rise into the air? How do hot-air-balloon pilots get their balloons back to Earth?**