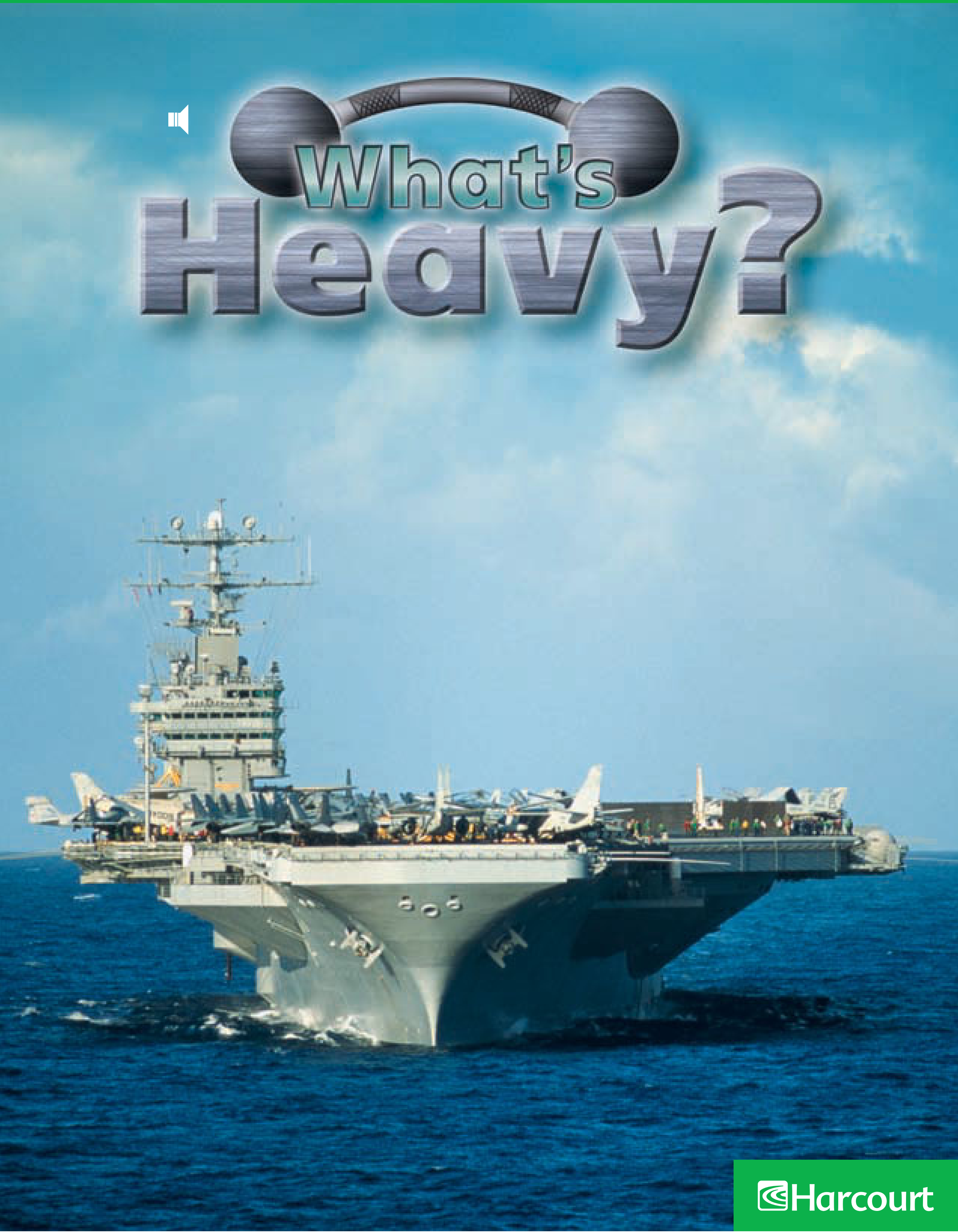
What's Heavy?



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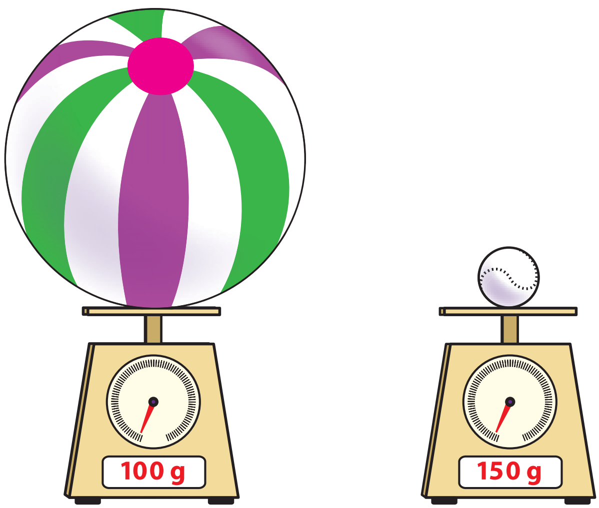
Does Big Mean Heavy?

If an object is big, is it also heavy? Not necessarily. How heavy an object is might have very little to do with its size. Look at the beach ball in the picture. The beach ball has a great deal of volume because it takes up a great deal of space. For a ball that big, it is very light. The beach ball has a mass of only 100 g!

Now, look at the baseball. The baseball takes up much less space than the beach ball, but the baseball is heavier. It has a mass of about 150 g. How can the baseball be heavier than the beach ball? This is possible because the baseball and the beach ball are made of different types of matter. The baseball has a larger mass than the beach ball does.

Size is not necessarily related to mass.

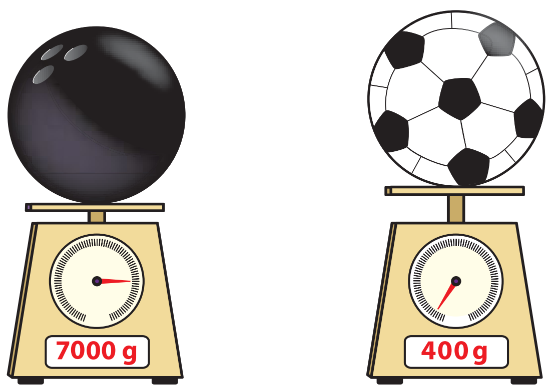


Mass: A Measurement of Matter

The property that makes an object heavy is mass. Mass is the amount of matter something has. The matter contained in the beach ball is a gas. Gases usually have less mass than solids. The baseball is solid inside. The baseball, even though it's smaller, has more mass than the beach ball.

Look at the bowling ball and the soccer ball in the picture. These two balls are almost the same size. What is the difference between them? You can see by reading the scale. The bowling ball has a greater mass than the soccer ball.

Mass is a measurement of the amount of matter in an object.

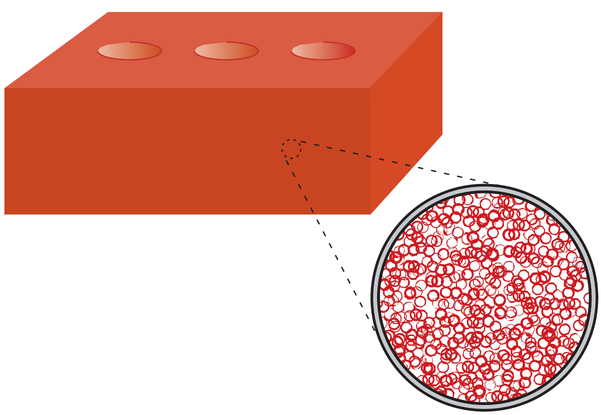


Mass, Volume, and Density

Density is the amount of mass something has in relation to its volume. The volumes of the bowling ball and the soccer ball are about the same. However, the bowling ball has a larger mass. Taking the volume and mass into account, we can say that the bowling ball has a greater density than the soccer ball. Density is often given in units of grams per cubic centimeter (g/cm^3). A cubic centimeter contains the same volume as a milliliter (mL).

Here is an example of how volume and mass relate to density. Suppose that you have two boxes that are exactly the same size: Their volumes are equal. You fill one with golf balls and the other with table-tennis balls. You use a balance to measure the mass of each box, and you find that the box filled with golf balls has more mass than the box filled with table-tennis balls. Because the volumes of the

Dense objects have more particles of matter per unit of volume than less dense objects do.



Volume = 1,000 cc^3

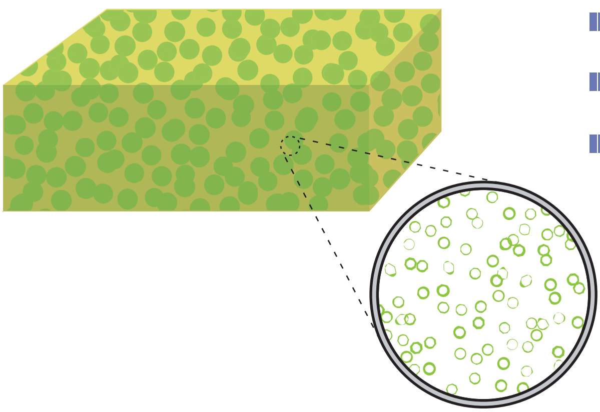
Mass = 3,000 g

Density = 3 g/cc^3

boxes are equal, you may conclude that golf balls are denser than table-tennis balls.

Let's consider another example. Look at the brick and sponge shown in the picture. They have equal volumes, but the mass of the brick is greater than the mass of the sponge. The brick is denser than the sponge because it contains more mass per unit of volume than the sponge does.

Different types of matter have different densities. So, density can be used to identify a substance. For example, gold has a density of about 20 g/cc^3. Silver has a density of about 10 g/cc^3. Gold is about twice as dense as silver. The densest substance known is a bluish-white metal known as osmium. A piece of osmium the size of a football would be too heavy to lift.



Volume = 1,000 cc^3

Mass = 10 g

Density = 0.01 g/cc^3

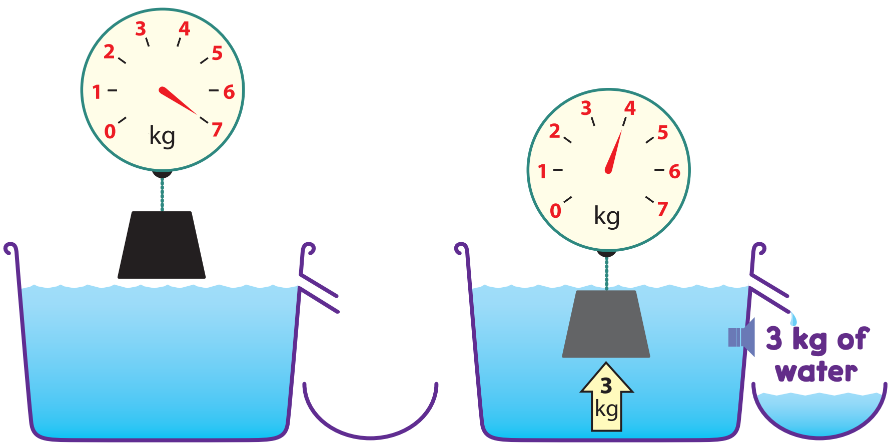
Eureka!

More than 2,000 years ago, a Greek king had a problem. He paid a goldsmith to make a pure gold crown. When the goldsmith had finished, the king thought that the goldsmith might have tricked him. Was the crown made out of a mix of gold and silver instead of pure gold? The king suspected that this was the case, but he didn't know how to prove it. He asked a scientist named Archimedes to find out.

Archimedes wanted to compare the density of the crown to the density of gold. If the crown were made of gold, then the densities would be the same.

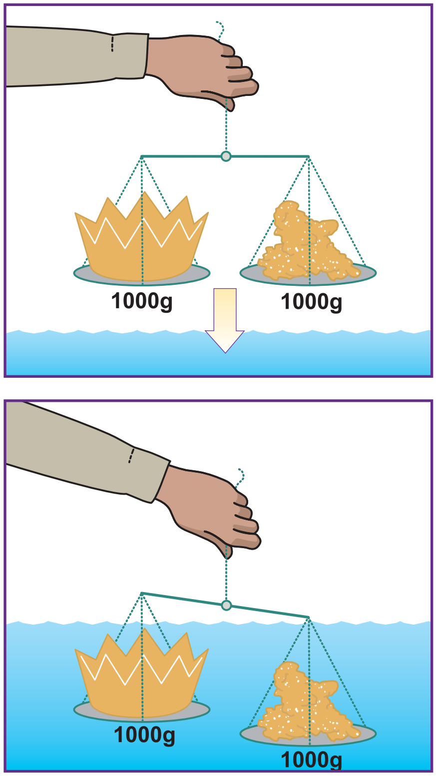
To find the density of the crown, he needed to know the crown's mass and volume. Mass was no problem: He could put the crown on a scale. But there was no easy way to find its volume. The crown was not a simple solid figure, such as a brick. The crown had an intricate shape.

Archimedes' principle states that buoyant force is equal to the weight of the displaced water.



Sometimes a solution arises when you least expect it. In Archimedes' case, it happened when he was taking a bath. As he sat down in the water, he noticed that the water rose and poured over the edge of the tub. The volume of his submerged body had displaced the same amount of water. Archimedes was so excited with his discovery that he jumped out of the tub and shouted, "Eureka!"

After Archimedes found the mass of the crown, he made a chunk of gold and a chunk of silver, each having the same mass as the crown. Because silver is less dense than gold, the chunk of silver had a greater volume than the chunk of gold. If the crown were solid gold, it would displace as much water as the chunk of solid gold. But it didn't—it displaced more. The king's suspicions were correct. The crown was not made of solid gold.



The crown was less dense than the mass of gold.

Later, Archimedes experimented with buoyancy. We learn from his experiments that if an object is denser than water it sinks. If an object is less dense than water it floats. Today, this is called Archimedes' Principle.

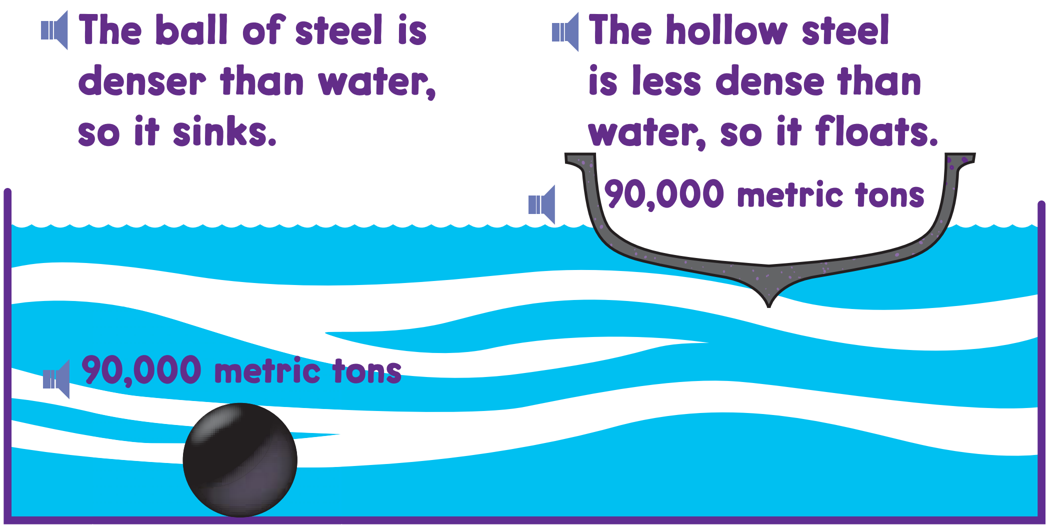
How Does an Aircraft Carrier Float?

Have you ever seen an aircraft carrier floating on water? An aircraft carrier weighs about 90,000 metric tons, so how can it float? You would think that the steel that is used to make an aircraft carrier would make it sink. But, because the carrier is hollow, its volume increases.

Remember that if an object's volume increases, then its density decreases. In other words, the ship's shape makes it less dense than water. This means that the carrier can float.

The Density of Water

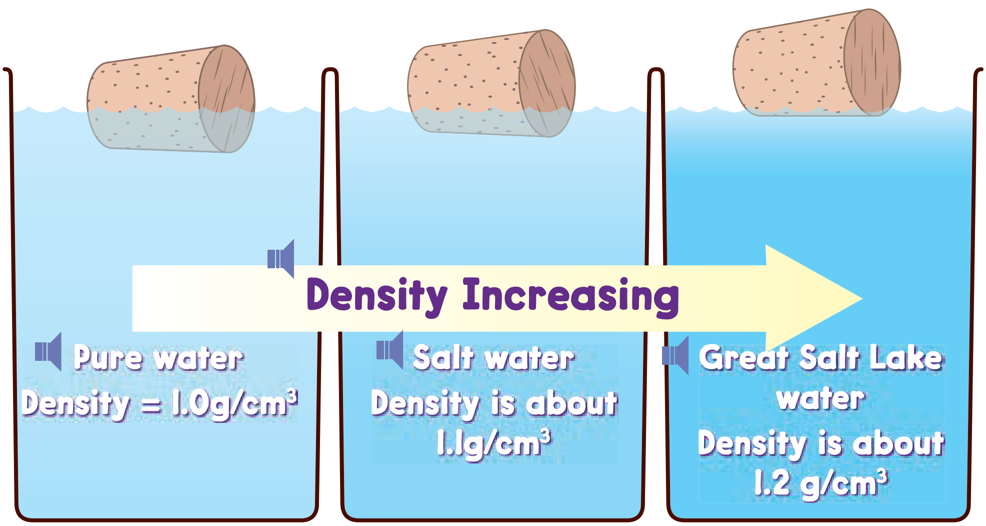
Aircraft carriers can float more easily in the salty ocean than in fresh water. Ships (and everything else) are more buoyant in water that is denser. Water with salt in it is denser than pure water. The more salt you add to water, the denser it becomes.



To understand why this happens, think of pure water as a jar of marbles. What would happen if you added sand to the jar? As you poured the sand into the jar, the sand would move into the spaces between the marbles. Soon, the sand would fill all of the gaps between the marbles. The density of the jar would increase.

The sand in the jar acts just as salt does in water. When you place an object that floats in salty ocean water, the object doesn't displace as much water as it would if the water were fresh water. Remember what we've learned from Archimedes' Principle: If an object is denser than water it sinks. If an object is less dense than water it floats.

As water's density increases, so does the buoyancy of the objects floating on it.

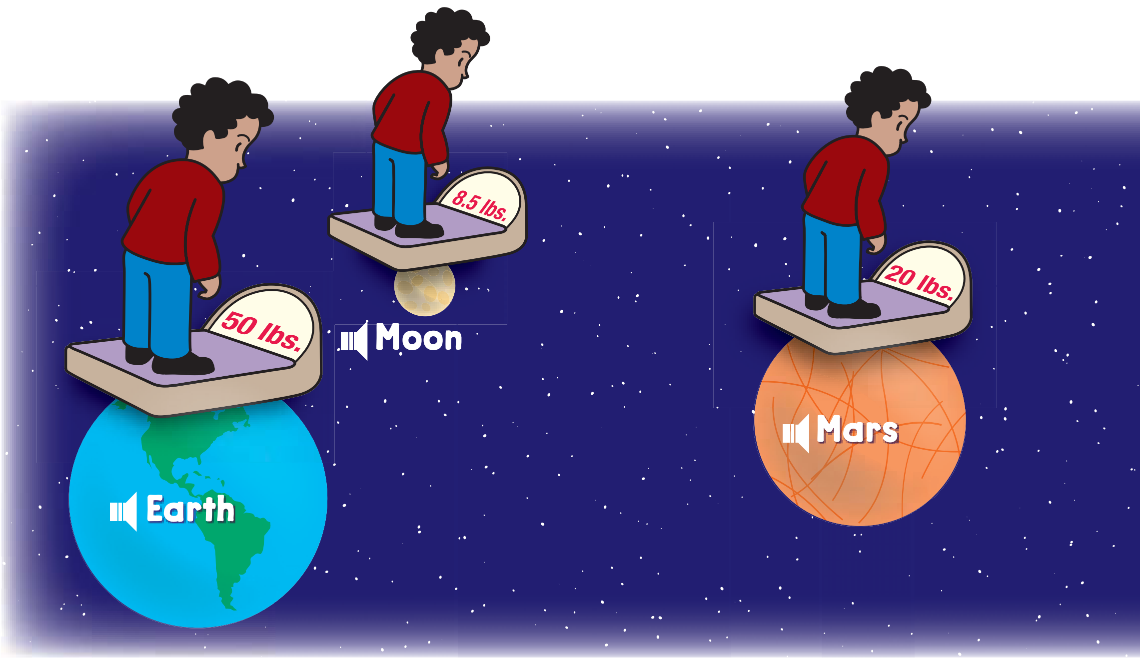


Weight

You have learned about mass and density. But what about weight? Weight is often confused with mass, but weight and mass are not the same thing. Weight is the measure of gravitational pull, or gravity, on an object. You may already know about gravity. Earth's gravity is what causes things to fall down.

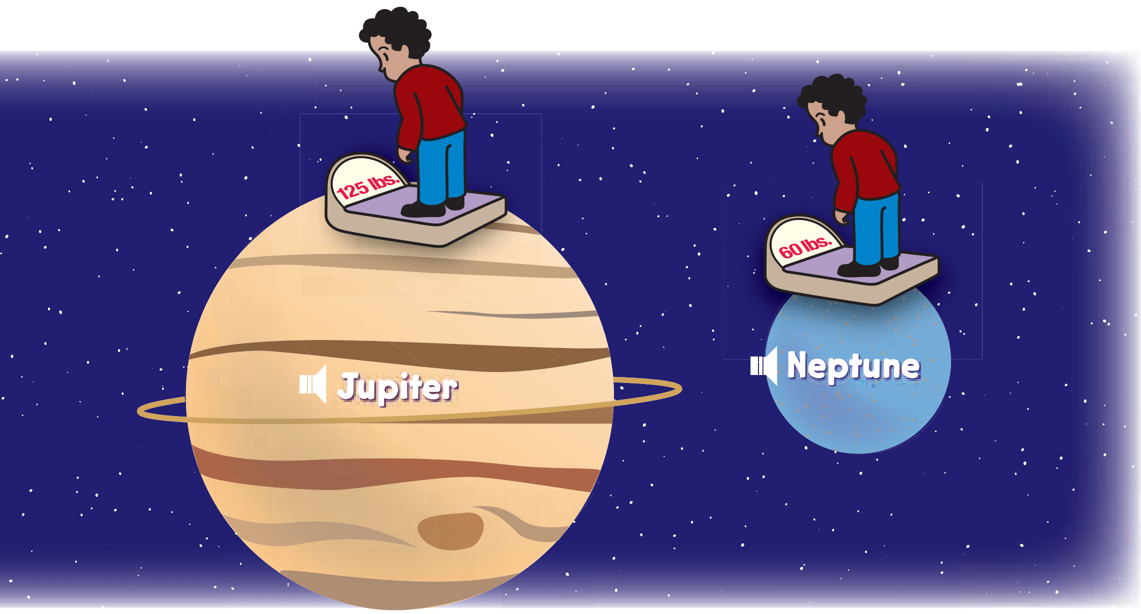
The more mass an object has, the more gravity it has. Earth has a large amount of gravity. A grain of sand has only a small amount of gravity. This is why you don't feel the pull of all the objects around you. The gravitational force of Earth is so strong that it overpowers the gravity of every other object on the planet.

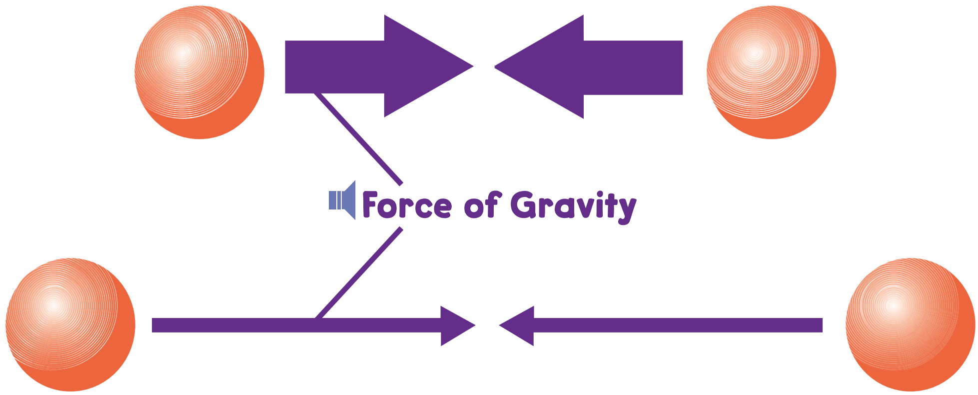
On Earth, this boy weighs 50 pounds. How much does he weigh on other planets?



Because Earth's gravity is just about the same all over the planet, you could be standing in any city or country and weigh about the same. This is why most people confuse mass and weight. When people say that something weighs a lot, they usually mean that it has a lot of mass.

However, suppose you left Earth and went to the moon. Your mass would stay the same, but you would have a different weight. This is because the moon has less mass and, therefore, less gravity than Earth. Because weight is the measure of the gravitational pull on an object, you would weigh less on the moon than on Earth. And if you were in outer space, far from any other object, you would be nearly weightless!





Gravity and Distance

No matter whether you are standing, walking, running, or jumping somewhere on Earth, you still weigh the same. The astronauts in space who orbit Earth weigh much less than if they were actually standing on the planet because the force of gravity between two objects decreases as the objects get farther apart. Astronauts in space weigh much less because they are farther from Earth. The force of gravity depends on both mass and distance.

The Relationship Between Weight and Mass

On Earth, which will weigh more—a 100-gram object or a 500-gram object? When gravity does not change, the object with more mass will have more weight. Weight depends on both gravity and an object's mass. Now take those same objects to the moon. Both of them have their same masses, but not their same weights. Both of them are lighter. However, the 500-gram object is still heavier than the 100-gram object.

Think and Write

1. How can two objects with the same volume have different masses?
2. How does a boat stay afloat on the ocean?
3. How is mass different from weight?
4. **Narrative Writing** A person would weigh about 2 $1/2$ times as much on Jupiter as on Earth. Write a story about a person who visits Jupiter. What problems might that person have? What would moving around feel like?

Hands-On Activity

Sink or Float Collect a group of small objects that can be placed in water. Use a scale to measure each object's mass. Then use a measuring cup to measure each object's volume. To do this, fill the cup halfway with water. Record the water level. Place an object under the water. Record the water level again. The difference between the water levels is the object's volume. Divide mass by volume. This is the object's density. After you measure all of the objects, place them in order of density from the densest to the least dense.

School-Home Connection

Build a Boat Work with a family member to design a toy boat that can carry 1 kg of cargo. How much water will the boat have to displace? If you have time, you can build your boat and test its buoyancy.

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