1.4: Matter, Mass, and Volume

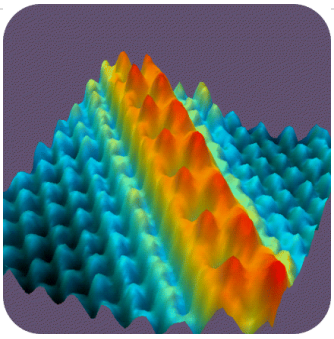

Figure 1.4.1 (Credit: Courtesy of L.J. Whitman, J.A. Stroscio, R.A. Dragoset, R.J. Celotta, and the National Institute of Standards and Technology; Source: NIST, Physical Measurement Laboratory, Scanning Tunneling Microscope(opens in new window) [www.nist.gov]; License: Public Domain)

Can you guess what this colorful image shows?

Believe it or not, it actually depicts individual atoms of cesium (reddish-orange) on a surface of gallium arsenide molecules (blue). The image was created with an extremely powerful microscope, called a scanning tunneling microscope. This is one of a few types of microscope that can make images of atoms, the basic building blocks of matter.

What's the Matter?

Matter is all the "stuff" that exists in the universe. Everything you can see and touch is made of matter, including you! The only things that aren't matter are forms of energy, such as light and sound. In science, **matter** is defined as anything that has mass and volume. Mass and volume measure different aspects of matter.

Mass

Mass is a measure of the amount of matter in a substance or an object. The basic SI unit for mass is the kilogram (kg), but smaller masses may be measured in grams (g). To measure mass, you would use a balance. In the lab, mass may be measured with a triple beam balance or an electronic balance, but the old-fashioned balance pictured below may give you a better idea of what mass is. If both sides of this balance were at the same level, it would mean that the fruit in the left pan has the same mass as the iron object in the right pan. In that case, the fruit would have a mass of 1 kg, the same as the iron. As you can see, however, the fruit is at a higher level than the iron. This means that the fruit has less mass than the iron, that is, the fruit's mass is less than 1 kg.

Figure 1.4.2 (Credit: CK-12 Foundation; Source: CK-12 Foundation; License: CK-12 Curriculum Materials License(opens in new window))

Q: Refer to the picture above. If the fruit were at a lower level than the iron object, what would be the mass of the fruit?

A: The mass of the fruit would be greater than 1 kg.

Mass vs. Weight

Mass is commonly confused with weight. The two are closely related, but they measure different things. Whereas mass measures the amount of matter in an object, weight measures the force of gravity acting on an object. The force of gravity on an object depends on its mass but also on the strength of gravity. If the strength of gravity is held constant (as it is all over Earth), then an object mass is directly proportional to the objects weight, so a greater mass also has a greater weight.

Q: With Earth's gravity, an object with a mass of 1 kg has a weight of 2.2 lb. How much does a 10 kg object weigh on Earth?

A: A 10 kg object weighs ten times as much as a 1 kg object: 10 × 2.2 lb = **22 lb**

Volume

Volume is a measure of the amount of space that a substance or an object takes up. The basic SI unit for volume is the cubic meter (m^3), but smaller volumes may be measured in cm^3, and liquids may be measured in liters (L) or milliliters (mL). How the volume of matter is measured depends on its state.

- The volume of a liquid is measured with a measuring container, such as a measuring cup or graduated cylinder.
- The volume of a gas depends on the volume of its container: gases expand to fill whatever space is available to them.
- The volume of a regularly shaped solid can be calculated from its dimensions. For example, the volume of a rectangular solid is the product of its length, width, and height.
- The volume of an irregularly shaped solid can be measured by the displacement method. You can read below how this method works.

Calculating Volume from Dimensions

Q: How could you find the volume of air in an otherwise empty room?

A: If the room has a regular shape, you could calculate its volume from its dimensions. For example, the volume of a rectangular room can be calculated with the formula:

Volume = length × width × height

If the length of the room is 5.0 meters, the width is 3.0 meters, and the height is 2.5 meters, then the volume of the room is:

Volume = 5.0 m × 3.0 m × 2.5 m = 37.5 m3

Measuring Volume Using the Displacement Method

The following video shows how the volume of an irregular shaped object, like your science teacher can be measured by the displacement method.

Q: What is the volume of the dinosaur in the diagram below?

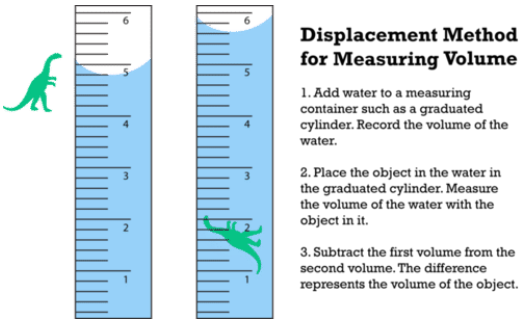

Figure 1.4.3 (Credit: Christopher AuYeung; Source: CK-12 Foundation; License: CK-12 Curriculum Materials License(opens in new window))

A: The volume of the water alone is 4.8 mL. The volume of the water and dinosaur together is 5.6 mL. Therefore, the volume of the dinosaur alone is 5.6 mL – 4.8 mL = 0.8 mL.

Summary

- Matter is all the "stuff" that exists in the universe. It has both mass and volume.
- Mass measures the amount of matter in a substance or an object. The basic SI unit for mass is the kilogram (kg).
- Volume measures the amount of space that a substance or an object takes up. The basic SI unit for volume is the cubic meter (m^3).

Review

1. How do scientists define matter?
2. What is mass? What is the basic SI unit of mass?
3. What does volume measure? Name two different units that might be used to measure volume.
4. Explain how to use the displacement method to find the volume of an irregularly shaped object.
