Chapter 9: Measurement

Figure 1: A road sign in Finland, a country that uses the metric system.

You are planning a road trip from your home state to the sunny beaches of Mexico and need to prepare a budget. While in the United States, gasoline is sold in gallons and distances are measured in miles, but in almost any other country you will find that gasoline is sold in liters and distance is measured in kilometers.

Whether you're traveling, baking, watching an international sporting event, working with machine tools, or using scientific equipment, it's important to understand the **metric system**, or the International System of Units (SI). The metric system is a decimal measuring system that uses meters, liters, and grams to quantify length, capacity, and mass. It is used in all but three countries in the world, including the United States.

9.1 The Metric System

Figure 2: A scale that measures weight in both metric and customary units.

Learning Objectives

After completing this section, you should be able to:

1. Identify units of measurement in the metric system and their uses.
2. Order the six common prefixes of the metric system.
3. Convert between like unit values.

Even if you don't travel outside of the United States, many specialty grocery stores utilize the metric system. For example, if you want to make authentic tamales you might visit the nearest Hispanic grocery store. While shopping, you discover that there are two brands of masa for the same price, but one bag is marked 1,200 g and the other 1 kg. Which one is the better deal? Understanding the metric system allows you to understand that 1,200 grams is equivalent to 1.2 kg, so the 1,200 g bag is the better deal.

Units of Measurement in the Metric System

Units of measurement provide common standards so that regardless of where or when an object or substance is measured, the results are consistent. When measuring distance, the units of measure might be feet, **meters**, or miles. Weight might be expressed in terms of pounds or **grams**. Volume or capacity might be measured in gallons, or **liters**. Understanding how metric units of measure relate to each other is essential to understanding the metric system:

- The metric unit for distance is the meter (m). A person's height might be written as 1.8 meters (1.8 m). A meter slightly longer than a yard (3 feet), while a centimeter is slightly less than half an inch.
- The metric unit for area is the **square meter** (m^2). The area of a professional soccer field is 7,140 square meters (7,140 m^2).
- The metric base unit for volume is the **cubic meter** (m^3). However, the liter (L), which is a metric unit of capacity, is used to describe the volume of liquids. Soda is often sold in 2-liter (2 L) bottles.
- The gram (g) is a metric unit of mass but is commonly used to express weight. The weight of a paper clip is approximately 1 gram (1 g).
- The metric unit for temperature is **degrees Celsius** (°C). The temperature on a warm summer day might be 24 °C.

While the U.S. Customary System of Measurement uses ounces and pounds to distinguish between weight units of different sizes, in the metric system a *base unit* is combined with a prefix, such as *kilo*– in kilogram, to identify the relationship between smaller or larger units.

CHECKPOINT

When using abbreviations to represent metric measures, always separate the quantity and the units with a space, with no spaces between the letters or symbols in the units. For example, 7 millimeters is written as 7 mm, not 7mm.

TECH CHECK

It is important to be able to convert between the U.S. Customar System of Measurement and the metric system. However, in this chapter we'll focus on converting units within the metric system. Why? Typing "200 centimeters in inches" into any browser search bar will instantly convert those measures for you (Figure 9.3). You'll have an opportunity in the Projects to work between measurement systems.

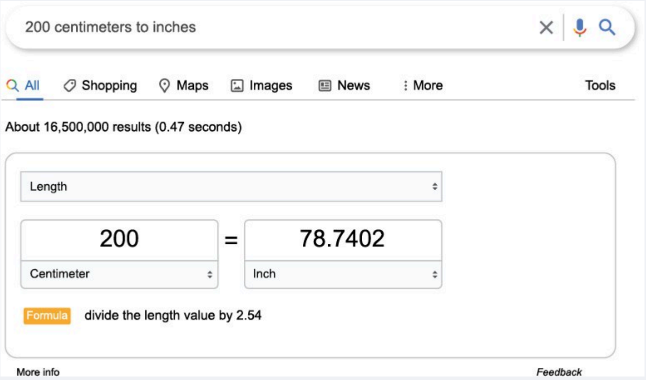


Figure 3: (credit: Screenshot/Google)

Let's be honest. Most of us use computers or smartphones to perform many of the calculations and conversions we were taught in math class. But there is value in understanding the metric system since it exists all around us, and most importantly, knowing how the different metric units relate to each other allows you to compare prices, find the right tool in a workshop, or acclimate when in another country. No matter the circumstance, you cannot avoid the metric system.

Example 1 **Determining the Correct Base Unit**

Which base unit would be used to express the following?

1. amount of water in a swimming pool
2. length of an electrical wire
3. weight of one serving of peanuts

Solution

1. Liquid volume is generally expressed in units of liters (L).
2. Length is measured in units of meters (m).
3. Weight is commonly expressed in units of grams (g).

While there are other base units in the metric system, our discussions in this chapter will be limited to units used to express length, area, volume, weight, and temperature.

Metric Prefixes

Unlike the U.S. Customary System of Measurement in which 12 inches is equal to 1 foot and 3 feet are equal to 1 yard, the metric system is structured so that the units within the system get larger or smaller by a power of 10. For example, a centimeter is 10^{-2}, or 100 times smaller than a meter, while the kilometer is 10^3, or 1,000 times larger than a meter.

The metric system combines base units and unit prefixes reasonable to the size of a measured object or substance. The most used prefixes are shown. An easy way to remember the order of the prefixes, from largest to smallest, is the mnemonic *King Henry Died From Drinking Chocolate Milk*.

Prefix	kilo–	hecto–	deca–	base unit	deci–	cent–	milli–
Abbreviation	k	h	da		d	c	m
Magnitude	10^3	10^2	10^1	10^0 or 1	10^{-1}	10^{-2}	10^{-3}

Example 2 **Ordering the Magnitude of Units**

Order the measures from smallest unit to largest unit.

centimeter, millimeter, decimeter

Solution

Looking at the metric prefixes, we can see that the prefix order from smallest unit to largest unit is milli-, centi-, deci-, so the order of the units from smallest to largest is millimeter, centimeter, decimeter.

Example 3 **Determining Reasonable Values for Length**

What is a reasonable value for the length of a person's thumb: 5 meters, 5 centimeters, or 5 millimeters?

Solution

Given that a meter is slightly longer than a yard, 5 meters is not a reasonable value for the length of a person's thumb. Since a millimeter is 10 times smaller than a centimeter, which is approximately $\frac{1}{2}$ inch, 5 millimeters is not a reasonable estimate for the length of a person's thumb. The correct answer is 5 centimeters.

Converting Metric Units of Measure

Imagine you order a textbook online and the shipping detail indicates the weight of the book is 1 kg. By attaching the letter "k" to the base unit of gram (g), the unit used to express the measure is 10^3or 1,000 times greater than a gram. One kilogram is equivalent to 1,000 grams.

The tip of a highlighter measures approximately 1 cm. The letter "c" attached to the base unit of meter (m) means the unit used to express the measure is 10^{-2} or $\frac{1}{100}$ of a meter. One meter is equivalent to 100 centimeters.

A **conversion factor** is used to convert from smaller metric units to bigger metric units and vice versa. It is a number that when used with multiplication or division converts from one metric unit to another, both having the same base unit. In the metric system, these conversion factors are directly related to the powers of 10. The most common used conversion factors are shown.

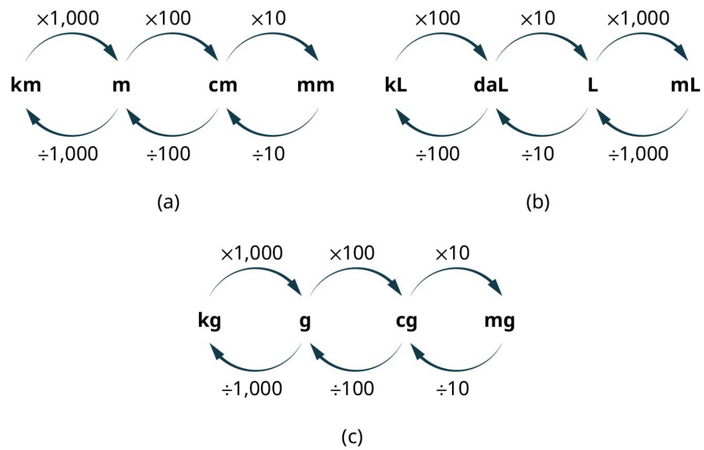


Figure 4: Common Metric Conversion Factors for (a) Meters, (b) Liters, and (c) Grams

Example 4 **Converting Metric Distances Using Multiplication**

The firehouse is 13.45 km from the library. How many meters is it from the firehouse to the library?

Solution

When converting from a larger unit to a smaller unit, use multiplication. The conversion factor from kilometer to the base unit of meters is 1,000.

$$13.45 \times 1,000 = 13,450$$

So, the firehouse is 13,450 meters away from the firehouse.

Example 5 **Converting Metric Capacity Using Division**

How many liters is 3,565 milliliters?

Solution

When converting from a smaller unit to a larger unit, use division. The conversion factor from milliliter to the base unit of liters is 1,000.

$$3,565 \div 1,000 = 3.565$$

So, 3,565 milliliters is 3.565 liters.

Example 6 **Converting Metric Units of Mass to Solve Problems**

Caroline and Aiyana are working on a chemistry experiment together and must perform calculations using measurements taken during the experiment. Due to miscommunication, Caroline took measurements in centigrams and Aiyana used milligrams. Convert Caroline's measurement of 125 centigrams to milligrams.

Solution

When converting from a larger unit to a smaller unit, use multiplication. The conversion factor from centigrams to the milligrams is 10.

$$125 \times 10 = 1,250$$

So, the 125 centigrams are 1,250 milligrams.

Example 7 **Converting Metric Units of Volume to Solve Problems**

A bottle contains 500 mL of juice. If the juice is packaged in 24-bottle cases, how many liters of juice does the case contain?

Solution

Step 1: Multiply the amount of juice in each bottle by the number of bottles.

$$500 \text{ mL} \times 24 = 12,000 \text{ mL}$$

Step 2: Divide by 1,000 to convert from milliliters to liters.

$$\frac{12{,}000 \text{ mL}}{1{,}000} = 12 \text{ L}$$

So, there are 12 liters of juice in each case.

PEOPLE IN MATHEMATICS

Valerie Antoine

In the 1970s, people were told that they must learn the metric system because the United States was soon going to convert to using metric measurements. Children and young adults probably watched educational cartoons about the metric system on Saturday mornings.

In 1975, President Gerald Ford signed the Metric Conversion Act and created a board of 17 people commissioned to coordinate the voluntary switch to the metric system in the United States. Among those 17 people was Valerie Antoine, an engineer who made it her life's work to push for this change. Despite President Ronald Reagan dissolving the board in 1982, effectively killing the move to the metric system at the time, Antoine continued the movement out of her own home as the executive director of the U.S. Metric Association. Reagan's decision followed intensive lobbying by American businesses whose factories used machinery designed to use customary measurements by workers trained in customary measurements. There was also intense public pressure from American citizens who didn't want to go through the time consuming and expensive process of changing the country's entire infrastructure. Fueled by a Congressional mandate in 1992 that required all federal agencies make the switch to the metric system, Antoine never gave up hope that the metric system would trickle down from the government and find its way into American schools, homes, and everyday life.

VIDEO

U.S. Office of Education: Metric Education

Example 8 **Converting Grams to Solve Problems**

The nutrition label on a jar of spaghetti sauce indicates that one serving contains 410 mg of sodium. You have poured two servings over your favorite pasta before recalling your doctor's advice about keeping your sodium consumption below 1 g per meal. Have you followed your doctor's recommendation?

Solution

Step 1: Multiply the number of servings by the amount of sodium in each serving.

$$410 \text{ mg} \times 2 = 820 \text{ mg}$$

Step 2: Divide by 1,000 to convert from milligrams to grams.

$$\frac{820 \text{ mg}}{1{,}000} = 0.82\text{g}$$

You have followed doctor's recommendation because 0.82 g is less than 1 gram.

Example 9 **Comparing Different Units**

A student carefully measured 0.52 cg of copper for a science experiment, but their lab partner said they need 6 mg of copper total. How many more centigrams of copper does the student need to add?

Solution

Step 1: Convert these two measurements into a common unit. Since the question asks for the number of centigrams, convert 6 mg to centigrams, which is 0.6 cg.

Step 2: Find the difference by subtracting $0.6 - 0.52$ which is 0.08 cg. This means the student must add another 0.08 cg of copper.

WHO KNEW?

The United States and the Metric System

Did you know that the metric system pervades daily life in the United States already? While Americans still may purchase gallons of milk and measure house sizes in square feet, there are many instances of the metric system. Photographers buy 35 mm film and use 50 mm lenses. When you have a headache, you might take 600 mg of ibuprofen. And if you are eating a low-carb diet you probably restrict your carb intake to fewer than 20 g of carbs daily. Did you know even the dollar is metric? In the video, Neil DeGrasse Tyson and comedian co-host Chuck Nice provide an amusing perspective on the metric system.

The International System of Units (SI) is the current international standard metric system and is the most widely used system around the world. In most English-speaking countries SI units such as meter, liter, and metric ton are spelled metre, litre, and tonne.

VIDEO

Neil deGrasse Tyson Explains the Metric System

WORK IT OUT

Get to Know the Metric System

Just how much is the metric system a part of your life now? Probably more than you think. For the next 24 hours, take notice as you move through your daily activities. When you are shopping, are the package sizes provided in metric units? Change the weather app on your phone to display the temperature in degrees Celsius. Are you able to tell what kind of day it will be now? While the United States is not officially using the metric system, you will still find the metric system all around you.

Key Terms

- metric system
- meter (m)
- gram (g)
- liter (L)
- square meter (m^2)
- cubic meter (m^3)
- degrees Celsius (°C)
- conversion factor

Key Concepts

- The metric system is decimal system of weights and measures based on base units of meter, liter, and gram. The system was first proposed in 1670 and has since been adopted as the International System of Units and used in nearly every country in the world.
- Each successive unit on the metric scale is 10 times larger than the previous one. To convert between units with the same base unit, you must either multiply or divide by a power of 10.
- The most used prefixes are listed in . An easy way to remember the order of the prefixes, from largest to smallest, is the mnemonic *King Henry Died from Drinking Chocolate Milk.*

Videos

- U.S. Office of Education: Metric Education
- Neil deGrasse Tyson Explains the Metric System

Formulas

You can convert between unit sizes with the same base unit using the conversion factors shown.

9.2 Measuring Area

Figure 5: A painter uses an extension roller to paint a wall.

Learning Objectives

After completing this section, you should be able to:

1. Identify reasonable values for area applications.
2. Convert units of measures of area.
3. Solve application problems involving area.

Area is the size of a surface. It could be a piece of land, a rug, a wall, or any other two-dimensional surface with attributes that can be measured in the metric unit for distance-meters. Determining the area of a surface is important to many everyday activities. For example, when purchasing paint, you'll need to know how many **square units** of surface area need to be painted to determine how much paint to buy.

Square units indicate that two measures in the same units have been multiplied together. For example, to find the area of a rectangle, multiply the length units and the width units to determine the area in square units.

$$1 \text{ cm} \times 1 \text{ cm} = 1 \text{ cm}^2$$

Note that to accurately calculate area, each of the measures being multiplied must be of the same units. For example, to find an area in square centimeters, both length measures (length and width) must be in centimeters.

FORMULA

The formula used to determine area depends on the shape of that surface. Here we will limit our discussions to the area of rectangular-shaped objects like the one in Figure 9.6. Given this limitation, the basic formula for area is:

$$\text{Area} = \text{length } (l) \times \text{width } (w)$$

or

$$A = l \times w$$

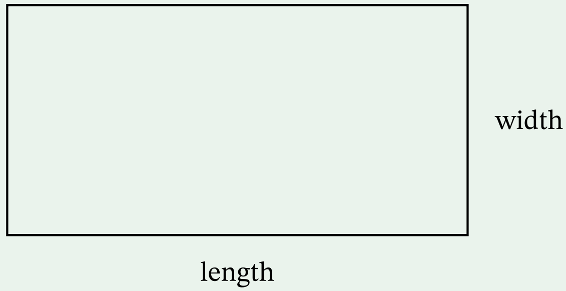


Figure 6: Rectangle with Length (l) and Width (w) Labeled

Reasonable Values for Area

Because area is determined by multiplying two lengths, the magnitude of difference between different square units is exponential. In other words, while a meter is 100 times greater in length than a centimeter, a square meter $\left(m^2\right)$ is 100×100, or $10,000$ times greater in area than a square centimeter $\left(cm^2\right)$. The relationships between benchmark metric area units are shown in the following table.

Units	Relationship	Conversion Rate
km^2 to m^2	$km \times km = km^2$ $1\ km = 1,000\ m$ $1,000\ m \times 1,000\ m = 1,000,000\ m^2$	$1km^2 = 1,000,000\ m^2$
m^2 to cm^2	$m \times m = m^2$ $1\ m = 100\ cm$ $100\ cm \times 100\ cm = 10,000 cm^2$	$1m^2 = 10,000 cm^2$
cm^2 to mm^2	$cm \times cm = cm^2$ $1\ cm = 10\ mm$ $10\ mm \times 10\ mm = 100\ mm^2$	$1\ cm^2 = 100\ mm^2$

An essential understanding of metric area is to identify reasonable values for area. When testing for reasonableness you should assess both the unit and the unit value. Only by examining both can you determine whether the given area is reasonable for the situation.

Example 1 **Determining Reasonable Units for Area**

Which unit of measure is most reasonable to describe the area of a sheet of paper: km^2, cm^2, or mm^2?

Solution

In the U.S. Customary System of Measurement, the length and width of paper is usually measured in inches. In the metric system centimeters are used for measures usually expressed in inches. Thus, the most reasonable unit of measure to describe the area of a sheet of paper is square centimeters. Square kilometers is too large a unit and square millimeters is too small a unit.

Example 2 **Determining Reasonable Values for Area**

You want to paint your bedroom walls. Which represents a reasonable value for the area of the walls: 100 cm², 100 m², or 100 km²?

Solution

An area of 100 cm² is equivalent to a surface of 10 cm × 10 cm, which is much too small for the walls of a bedroom. An area of 100 km² is equivalent to a surface of 10 km × 10 km, which is much too large for the walls of a bedroom. So, a reasonable value for the area of the walls is 100 m².

Example 3 **Explaining Reasonable Values for Area**

A landscaper is hired to resod a school's football field. After measuring the length and width of the field they determine that the area of the football field is 5,350 km². Does their calculation make sense? Explain your answer.

Solution

No, kilometers are used to determine longer distances, such as the distance between two points when driving. A football field is less than 1 kilometer long, so a more reasonable unit of value would be m². An area of 5,350 km² can be calculated using the dimensions 53.5 by 100, which are reasonable dimensions for the length and width of a football field. So, a more reasonable value for the area of the football field is 5,350 m².

Converting Units of Measures for Area

Just like converting units of measure for distance, you can convert units of measure for area. However, the conversion factor, or the number used to multiply or divide to convert from one area unit to another, is not the same as the conversion factor for metric distance units. Recall that the conversion factor for area is exponentially relative to the conversion factor for distance. The most frequently used conversion factors are shown.

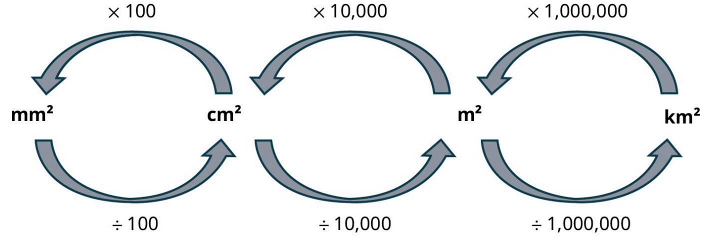


Figure 7: Common Conversion Factors for Metric Area Units

VIDEO

Converting Metric Units of Area

Example 4 **Converting Units of Measure for Area Using Division**

A plot of land has an area of 237,500,000 m^2. What is the area in square kilometers?

Solution

Use division to convert from a smaller metric area unit to a larger metric area unit. To convert from m^2 to km^2, divide the value of the area by 1,000,000.

$$\frac{237{,}500{,}000}{1{,}000{,}000} = 237.5$$

The plot of land has an area of 237.5 km^2.

Example 5 **Converting Units of Measure for Area Using Multiplication**

A plot of land has an area of 0.004046 km^2. What is the area of the land in square meters?

Solution

Use multiplication to convert from a larger metric area unit to a smaller metric area unit. To convert from km^2 to m^2, multiply the value of the area by 1,000,000.

$$0.004046 \times 1,000,000 = 4,046$$

The plot of land has an area of 4,046 m^2.

Example 6 **Determining Area by Converting Units of Measure for Length First**

A computer chip measures 10 mm by 15 mm. How many square centimeters is the computer chip?

Solution

Step 1: Convert the measures of the computer chip into centimeters

$$\begin{aligned} 10 \text{ mm} &= 1 \text{ cm} \\ 15 \text{ mm} &= 1.5 \text{ cm} \end{aligned}$$

Step 2: Use the area formula to determine the area of the chip.

$$1 \times 1.5 = 1.5$$

The computer chip has an area of 1.5 cm^2.

Solving Application Problems Involving Area

While it may seem that solving area problems is as simple as multiplying two numbers, often determining area requires more complex calculations. For example, when measuring the area of surfaces, you may need to account for portions of the surface that are not relevant to your calculation.

Example 7 **Solving for the Area of Complex Surfaces**

One side of a commercial building is 12 meters long by 9 meters high. There is a rolling door on this side of the building that is 4 meters wide by 3 meters high. You want to refinish the side of the building, but not the door, with aluminum siding. How many square meters of aluminum siding are required to cover this side of the building?

Solution

Step 1: Determine the area of the side of the building.

$$12\text{m} \times 9\text{m} = 106\text{m}^2$$

Step 2: Determine the area of the door.

$$4\text{m} \times 3\text{m} = 12\text{m}^2$$

Step 3: Subtract the area of the door from the area of the side of the building.

$$106\text{m}^2 - 12\text{m}^2 = 92\text{m}^2$$

So, you need to purchase 92m^2 of aluminum siding.

When calculating area, you must ensure that both distance measurements are expressed in terms of the same distance units. Sometimes you must convert one measurement before using the area formula.

Example 8 **Solving for Area with Distance Measurements of Different Units**

A national park has a land area in the shape of a rectangle. The park measures 2.2 kilometers long by 1,250 meters wide. What is the area of the park in square kilometers?

Solution

Step 1: Use a conversion fraction to convert the information given in meters to kilometers.

$$1,250\text{m} \times \frac{1\text{ km}}{1{,}000\text{m}} = 1.25\text{ km}$$

Step 2: Multiply to find the area.

$$2.2\text{ km} \times 1.25\text{ km} = 2.75\text{km}^2$$

The park has an area of 2.75 km^2.

When calculating area, you may need to use multiple steps, such as converting units and subtracting areas that are not relevant.

Example 9 **Solving for Area Using Multiple Steps**

A kitchen floor has an area of 15 m^2. The floor in the kitchen pantry is 100 cm by 200 cm. You want to tile the kitchen and pantry floors using the same tile. How many square meters of tile do you need to buy?

Solution

Step 1: Determine the area of the pantry floor in square centimeters.

$$100 \text{ cm} \times 200 \text{ cm} = 20,000\text{cm}^2$$

Step 2: Divide the area in cm^2 by the conversion factor to determine the area in m^2 since the other measurement for the kitchen floor is in m^2.

$$\frac{20{,}000}{10{,}000} = 2$$

The area of the kitchen pantry floor is 2 m^2.

Step 3: Add the two areas of the pantry and the kitchen floors together.

$$15\text{m}^2 + 2\text{m}^2 = 17\text{m}^2$$

So, you need to buy 17 m^2 of tile.

WHO KNEW?

The Origin of the Metric System

The metric system is the official measurement system for every country in the world except the United States, Liberia, and Myanmar. But did you know it originated in France during the French Revolution in the late 18th century? At the time there were over 250,000 different units of weights and measures in use, often determined by local customs and economies. For example, land was often measured in days, referring to the amount of land a person could work in a day.

VIDEO

Why the Metric System Matters

Key Terms

- area
- square units

Key Concepts

- Area describes the size of a two-dimensional surface. It is the amount of space contained within the lines of a two-dimensional space.
- Area is measured in square meters units; in the metric system the base unit for area is square meters (m^2).

Videos

- Converting Metric Units of Area
- Why the Metric System Matters

Formulas

To determine the area of rectangular-shaped objects:

$$\text{Area} = \text{length } (l) \times \text{width } (w)$$

or

$$A = l \times w$$

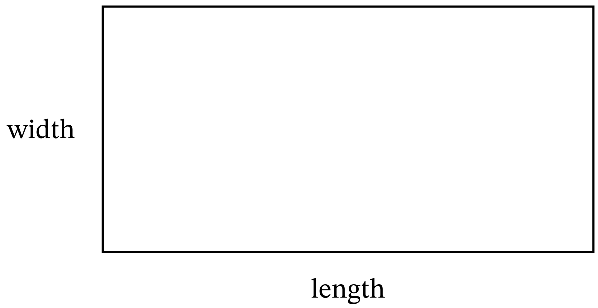


Figure 8: Rectangle with Length (l) and Width (w) Labeled

You can convert between metric area units using the conversion factors shown.

9.3 Measuring Volume

Figure 9: Packing cartons sit on a loading dock ready to be filled.

Learning Objectives

After completing this section, you should be able to:

1. Identify reasonable values for volume applications.
2. Convert between like units of measures of volume.
3. Convert between different unit values.
4. Solve application problems involving volume.

Volume is a measure of the space contained within or occupied by three-dimensional objects. It could be a box, a pool, a storage unit, or any other three-dimensional object with attributes that can be measured in the metric unit for distance–meters. For example, when purchasing an SUV, you may want to compare how many **cubic units** of cargo the SUV can hold.

Cubic units indicate that three measures in the same units have been multiplied together. For example, to find the volume of a rectangular prism, you would multiply the length units by the width units and the height units to determine the volume in square units:

$$1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ cm} = 1\text{cm}^3$$

Note that to accurately calculate volume, each of the measures being multiplied must be of the same units. For example, to find a volume in cubic centimeters, each of the measures must be in centimeters.

FORMULA

The formula used to determine volume depends on the shape of the three-dimensional object. Here we will limit our discussions to the area to rectangular prisms like the one in Given this limitation, the basic formula for volume is:

$$\text{Volume} = \text{ length } (l) \times \text{width } (w) \times \text{height } (h)$$

or

$$V = lwh$$

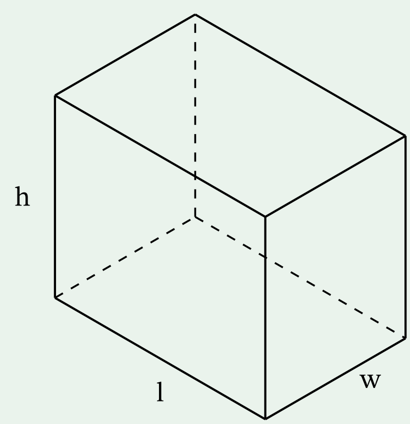


Figure 10: Rectangular Prism with Height (h), Length (l), and Width (w) Labeled.

Reasonable Values for Volume

Because volume is determined by multiplying three lengths, the magnitude of difference between different cubic units is exponential. In other words, while a meter is 100 times greater in length than a centimeter, a cubic meter, m^3, is $100 \times 100 \times 100$, or $1,000,000$ times greater in area than a cubic centimeter, cm^3. This relationship between benchmark metric volume units is shown in the following table.

Units	Relationship	Conversion Rate
km^3 to m^3	$km \times km \times km = km^3$ $1\ km = 1,000\ m$ $1,000m \times 1,000\ m \times$ $1,000\ m = 1,000,000,000\ m^3$	$1\ km^3 = 1{,}000{,}000{,}000\ m^3$
m^3 to dm^3	$m \times m \times m = m^3$ $1m = 10\ dm$ $10\ dm \times 10\ dm \times 10\ dm = 1,000dm^3$	$1\ m^3 = 1{,}000\ dm^3$
dm^3 to cm^3	$dm \times dm \times dm = dm^3$ $1\ dm = 10\ cm$ $10\ cm \times 10\ cm \times 10\ cm = 1,000,000cm^3$	$1\ cm^3 = 1{,}000\ dm^3$
cm^3 to mm^3	$cm \times cm \times cm = cm^3$ $1\ cm = 10\ mm$ $10\ mm \times 10\ mm \times 10\ mm = 1,000mm^3$	$1\ cm^3 = 1{,}000\ mm^3$

To have an essential understanding of metric volume, you must be able to identify reasonable values for volume. When testing for reasonableness you should assess both the unit and the unit value. Only by examining both can you determine whether the given volume is reasonable for the situation.

Example 1 **Determining Reasonable Values for Volume**

A grandparent wants to send cookies to their grandchild away at college. Which represents a reasonable value for the volume of a box to ship the cookies:

- 3,375 km^3,
- 3,375 m^3, or
- 3,375 cm^3?

Solution

A volume of 3,375 km^3 is equivalent to a rectangular prism with dimensions of 15 km × 15 km × 15 km, which is far too large for a shipping box. An area of 3,375 m^3 is equivalent to a surface of 15m × 15m × 15m, which is also too large. A reasonable value for the volume of the box is 3,375 cm^3.

Example 2 **Identifying Reasonable Values for Volume**

A food manufacturer is prototyping new packaging for one of its most popular products. Which represents a reasonable value for the volume of the box:

- 2 dm^3,
- 2 cm^3, or

- 2 mm³?

Solution

A decimeter is equal to 10 centimeters. A box with a volume of 2 dm³ might have the dimensions 1 dm × 1 dm × 2 dm, or 10 cm × 10 cm × 20 cm, which is reasonable. A box with a volume of 2 cm³ or 2 mm³ would be too small.

Example 3 **Explaining Reasonable Values for Volume**

A farmer has a hay loft. They calculate the volume of the hayloft as 64 cm³. Does the calculation make sense? Explain your answer.

Solution

No. Centimeters are used to determine smaller distances, such as the length of a pencil. A hayloft is more than 64 centimeters long, so a more reasonable unit of value would be m². A volume of 64 m³ can be calculated using the dimensions 4 meters by 4 meters by 4 meters, which are reasonable dimensions for a hayloft. So, a more reasonable value for the volume of the hayloft is 64 m³.

Converting Like Units of Measures for Volume

Just like converting units of measure for distance, you can convert units of measure for volume. However, the conversion factor, the number used to multiply or divide to convert from one volume unit to another, is different from the conversion factor for metric distance units. Recall that the conversion factor for volume is exponentially relative to the conversion factor for distance. The most frequently used conversion factors are illustrated in .

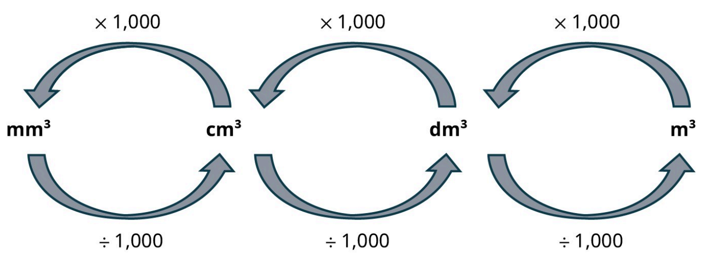


Figure 11: Common Conversion Factors for Metric Volume Units

Example 4 **Converting Like Units of Measure for Volume Using Multiplication**

A pencil case has a volume of 1,700 cm³. What is the volume in cubic millimeters?

Solution

Use multiplication to convert from a larger metric volume unit to a smaller metric volume unit. To convert from cm³ to mm³, multiply the value of the volume by 1,000.

$$1,700 \times 1,000 = 1,700,000$$

The pencil case has a volume of 1,700,000 mm³.

VIDEO
How to Convert Cubic Centimeters to Cubic Meters

Example 5 **Converting Like Units of Measure for Volume Using Multi-Step Multiplication**

A shipping container has a volume of 33.2 m^3. What is the volume in cubic centimeters?

Solution

Use multiplication to convert a larger metric volume unit to a smaller metric volume unit. To convert from m^3 to cm^3, first multiply the value of the volume by 1,000 to convert from m^3 to dm^3, and then multiply again by 1,000 to convert from dm^3 to cm^3.

$$33.2 \times 1,000 \times 1,000 = 33,200,000$$

The shipping container has a volume of 32,200,000 cm^3.

Example 6 **Converting Like Units of Measure for Volume Using Multi-Step Division**

A holding tank at the local aquarium has a volume of 22,712,000,000 cm^3. What is the volume in cubic meters?

Solution

indicates that when converting from a smaller metric volume unit to a larger metric volume unit you divide using the given conversion factor. To convert from cm^3 to m^3, divide the value of the volume by 1,000 to first convert from cm^3 to dm^3, then divide again to convert from dm^3 to m^3.

$$\text{cm}^3\text{to dm}^3 : \frac{22{,}712{,}000{,}000}{1{,}000} = 22,712,000$$

$$\text{dm}^3\text{to m}^3 : \frac{22{,}712{,}000}{1{,}000} = 22,712$$

The holding tank has a volume of 22,712 m^3.

Understanding Other Metric Units of Volume

When was the last time you purchased a bottle of soda? Was the volume of the bottle expressed in cubic centimeters or liters? The liter (L) is a metric unit of capacity often used to express the volume of liquids. A liter is equal in volume to 1 cubic decimeter. A milliliter is equal in volume to 1 cubic centimeter. So, when a doctor orders 10 cc (cubic centimeters) of saline to be administered to a patient, they are referring to 10 mL of saline.

The most frequently used factors for converting from cubic meters to liters are listed in .

m^3 to L	m^3 to mL
$1dm^3 = 1L$	$1dm^3 = 1,000$ mL
$1,000cm^3 = 1L$	$1cm^3 = 1$ mL
$1,000,000mm^3 = 1L$	$1mm^3 = 0.001$ mL

VIDEO

Converting Metric Units of Volume

Example 7 **Converting Different Units of Measure for Volume**

A holding tank at the local aquarium has a volume of 22,712,000,000 cm^3? What is the capacity of the holding tank in liters?

Solution

Use division to convert from cubic centimeters to liters. To determine the equivalent volume in liters, convert from cm^3 to L by dividing the value of the volume in cm^3 by 1,000.

$$\frac{22{,}712{,}000{,}000cm^3}{1{,}000} = 22,712,000L$$

The holding tank holds 22,712,000 L of water.

Example 8 **Converting Different Units of Measure for Volume Using Multiplication**

An airplane used 150 m^3 of fuel to fly from New York to Hawaii. How many liters of fuel did the airplane use?

Solution

Because 1 liter is equivalent to 1 cubic decimeter, use multiplication to convert from m^3 to dm^3. Multiply the value of the volume by 1,000 to convert from m^3 to dm^3. Because $1dm^3 = 1L$, the resulting value is equivalent to the number of liters used.

$$150 \times 1,000 = 150,000dm^3 = 150,000L$$

The airplane used 150,000 liters of fuel.

Example 9 **Converting Different Units of Measure for Volume Using Multi-Step Division**

How many liters can a pitcher with a volume of 8,000,000 mm^3 hold?

Solution

Use division to convert from a smaller metric volume unit to a larger metric volume unit. To convert from mm^3 to dm^3,

Step 1: Divide by 1,000 to convert from mm^3 to cm^3.

Step 2: Divide again by 1,000 to convert from cm^3 to dm^3.

Step 3: Use the unit value to express the volume in terms of liters.

$$\frac{8{,}000{,}000 \text{ mm}^3}{1{,}000} = 8{,}000 \text{ cm}^3$$

$$\frac{8{,}000 \text{ cm}^3}{1{,}000} = 8\text{dm}^3 = 8 \text{ L}$$

The pitcher can hold 8 liters of liquid.

Solving Application Problems Involving Volume

Knowing the volume of an object lets you know just how much that object can hold. When making a bowl of punch you might want to know the total amount of liquid a punch bowl can hold. Knowing how many liters of gasoline a car's tank can hold helps determine how many miles a car can drive on a full tank. Regardless of the application, understanding volume is essential to many every day and professional tasks.

Example 10 **Using Volume to Solve Problems**

A cubic shipping carton's dimensions measure 2 m × 2 m × 2 m. A company wants to fill the carton with smaller cubic boxes that measure 10 cm × 10 cm × 10 cm. How many of the smaller boxes will fit in each shipping carton?

Solution

Step 1: Determine the volume of the shipping carton.

$$2\text{m} \times 2\text{m} \times 2\text{m} = 8\text{m}^3$$

Step 2: Use the appropriate conversion factor to convert the volume of the shipping carton from m^3 to cm^3.

$$8\text{m}^3 \times 1{,}000 = 8{,}000\text{dm}^3$$

$$8{,}000\text{dm}^3 \times 1{,}000 = 8{,}000{,}000\text{cm}^3$$

Step 3: Determine the volume of the smaller boxes.

$$10 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm} = 1{,}000\text{cm}^3$$

Step 4: Divide the volume of the shipping carton, in cm^3, by the volume of the smaller box, in cm^3.

$$\frac{8{,}000{,}000\text{cm}^3}{1{,}000\text{cm}^3} = 8{,}000$$

The shipping carton will hold 8,000 smaller boxes.

Example 11 **Solving Volume Problems with Different Units**

A carton of juice measures 6 cm long, 6 cm wide and 20 cm tall. A factory produces 28,800 liters of orange juice each day. How many cartons of orange juice are produced each day?

Solution

Step 1: Find the volume of the carton in cubic centimeters.

$$6 \text{ cm} \times 6 \text{ cm} \times 20 \text{ cm} = 720\text{cm}^3$$

Step 2: Convert the volume in cm^3 to liters.

$$\begin{aligned} 1 \text{ cm}^3 &= \ \ 1 \text{ mL} \\ 720 \text{ cm}^3 &= 720 \text{ mL} \\ \frac{720 \text{ mL}}{1{,}000} &= \ \ 0.72 \text{ L} \end{aligned}$$

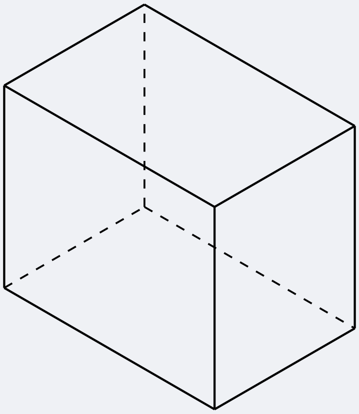
Step 3: Divide the number of liters of orange juice produced each day by the volume of each carton.

$$\frac{28{,}800\text{L}}{0.72\text{L}} = 40,000$$

The factory produces 40,000 cartons of orange juice each day.

Example 12 **Solving Complex Volume Problems**

A fish tank measures 60 cm long, 15 cm wide and 34 cm tall . The tank is 25 percent full. How many liters of water are needed to completely fill the tank?



Solution

Step 1: Determine the volume of the fish tank in cubic centimeters.

$$60 \text{ cm} \times 15 \text{ cm} \times 34 \text{ cm} = 30,600\text{cm}^3$$

Step 2: Convert the volume in cm^3 to volume in liters.

$$\begin{aligned} 1 \text{ cm}^3 &= 1 \text{ mL} \\ 30,600 \text{ cm}^3 &= 30,600 \text{ mL} \\ \frac{30{,}600 \text{ mL}}{1{,}000} &= 30.6 \text{ L} \end{aligned}$$

Step 3: Since the tank is 25 percent full, the tank is 75 percent empty. Convert 75 percent to its decimal equivalent. Multiply the total volume by 75 percent expressed in decimal form to determine how many liters of water are required to fill the tank.

$$\begin{aligned} 75\% &= 0.75 \\ 30.6 \times 0.75 &= 22.95 \end{aligned}$$

So, 22.95 liters of water are needed to fill the tank.

WORK IT OUT

How Does Shape Affect Volume?

Take two large sheets of card stock. Roll one piece to tape the longer edges together to make a cylinder. Tape the cylinder to the other piece of card stock which serves as the base of the cylinder. Fill the cylinder to the top with cereal. Pour the cereal from the cylinder into a plastic storage or shopping bag. Remove the cylinder from the base and the tape from the cylinder. Re-roll the cylinder along the shorter edges a tape together. Attach the new cylinder to the base. Pour the cereal from the plastic bag into the cylinder. What do you observe? How does the shape of a container affect its volume?

Key Terms

- volume
- cubic units

Key Concepts

- Volume is a measure of the space contained within or occupied by three-dimensional objects.
- Volume is measured in cubic units; the base unit for volume in the metric system is cubic meters (m^3)
- The liter (L) is a metric unit of capacity but is often used to express the volume of liquids. One liter is equivalent to one cubic decimeter, which is the volume of a cube measuring 10 cm × 10 cm × 10 cm.

Formulas

To determine the volume of a rectangular prism:

$$\text{Volume} = \text{length } (l) \times \text{width } (w) \times \text{height } (h)$$

or

$$V = lwh$$

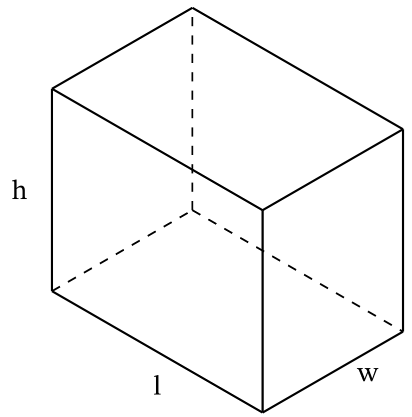


Figure 13: Rectangular Prism with Height (h), Length (l), and Width (w) Labeled

You can convert between metric volume units and metric capacity units using the relationships shown.

Videos

- How to Convert Cubic Centimeters to Cubic Meters
- Converting Metric Units of Volume

9.4 Measuring Weight

Figure 14: Weight scale at the local Antigua market

Learning Objectives

After completing this section, you should be able to:

1. Identify reasonable values for weight applications.
2. Convert units of measures of weight.

3. Solve application problems involving weight.

   In the metric system, weight is expressed in terms of grams or kilograms, with a kilogram being equal to 1,000 grams. A paper clip weighs about 1 gram. A liter of water weighs about 1 kilogram. In fact, in the same way that 1 liter is equal in volume to 1 cubic decimeter, the kilogram was originally defined as the mass of 1 liter of water. In some cases, particularly in scientific or medical settings where small amounts of materials are used, the milligram is used to express weight. At the other end of the scale is the metric ton (mt), which is equivalent to 1,000 kilograms. The average car weighs about 2 metric tons.

   Any discussion about metric weight must also include a conversation about **mass**. Scientifically, mass is the amount of matter in an object whereas weight is the force exerted on an object by gravity. The amount of mass of an object remains constant no matter where the object is. Identical objects located on Earth and on the moon will have the same mass, but the weight of the objects will differ because the moon has a weaker gravitational force than Earth. So, objects with the same mass will weigh less on the moon than on Earth.

   Since there is no easy way to measure mass, and since gravity is just about the same no matter where on Earth you go, people in countries that use the metric system often use the words mass and weight interchangeably. While scientifically the kilogram is only a unit of mass, in everyday life it is often used as a unit of weight as well.

Reasonable Values for Weight

To have an essential understanding of metric weight, you must be able to identify reasonable values for weight. When testing for reasonableness, you should assess both the unit and the unit value. Only by examining both can you determine whether the given weight is reasonable for the situation.

VIDEO
Metric System: Units of Weight

Example 1 **Identifying Reasonable Units for Weight**

Which is the more reasonable value for the weight of a newborn baby:

- 3.5 kg or
- 3.5 g?

Solution

Using our reference weights, a baby weighs more than 3.5 paperclips, so 3.5 kilograms is a more reasonable value for the weight of a newborn baby.

Example 2 **Determining Reasonable Values for Weight**

Which of the following represents a reasonable value for the weight of three lemons?

- 250 g,

- 2,500 g, or
- 250 kg?

Solution

Because a kilogram is about 2.2 pounds, we can eliminate 250 kg as it is way too heavy. 2,500 grams is equivalent to 2.5 kilograms, or about five pounds, which is again, too heavy. So, a reasonable value for the weight of three lemons would be 250 grams.

WHO KNEW?

How Do You Measure the Weight of a Whale?

It is impossible to weigh a living whale. Fredrik Christiansen from the Aarhus Institute of Advanced Studies in Denmark developed an innovative way to measure the weight of whales. Using images taken from a drone and computer modeling, the weight of a whale can be estimated with great accuracy.

VIDEO

Using Drones to Weigh Whales?

Example 3 **Explaining Reasonable Values for Weight**

The blue whale is the largest living mammal on Earth. Which of the following is a reasonable value for the weight of a blue whale: 149 g, 149 kg, or 149 mt? Explain your answer.

Solution

A reasonable value for the weight of a blue whale is 149 metric tons. Both 149 g and 149 kg are much too small a value for the largest living mammal on Earth.

Converting Like Units of Measures for Weight

Just like converting units of measure for distance, you can convert units of measure for weight. The most frequently used conversion factors for metric weight are illustrated in .

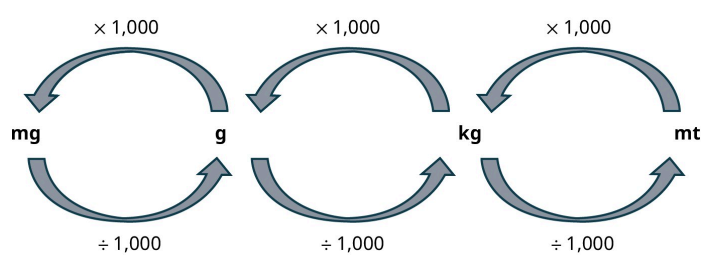


Figure 15: Common Conversion Factors for Metric Weight Units

Example 4 **Converting Metric Units of Weight Using Multistep Division**

How many kilograms are in 24,300,000 milligrams?

Solution

Use division to convert from a smaller metric weight unit to a larger metric weight unit. To convert from milligrams to kilograms,

Step 1: Divide the value of the weight in milligrams by 1,000 to first convert from milligrams to grams.

Step 2: Divide by 1,000 again to convert from grams to kilograms.

$$\frac{24{,}300{,}000 \text{ mg}}{1{,}000} = 24,300\text{g}$$
$$\frac{24{,}300\text{g}}{1{,}000} = 24.3 \text{ kg}$$

So, 24,300,000 milligrams are equivalent to 24.3 kilograms.

Example 5 **Converting Metric Units of Weight Using Multiplication**

The average ostrich weighs approximately 127 kilograms. How many grams does an ostrich weigh?

Solution

Use multiplication to convert from a larger metric weight unit to a smaller metric weight unit. To convert from kilograms to grams, multiply the value of the weight by 1,000.

$$127 \text{ kg} \times 1,000 = 127,000\text{g}$$

The average ostrich weighs 127,000 grams.

Example 6 **Converting Metric Units of Weight Using Multistep Multiplication**

How many milligrams are there in 0.025 kilograms?

Solution

Use multiplication to convert from a larger metric weight unit to a smaller metric weight unit. To convert from kilograms to grams,

Step 1: Multiply the value of the weight by 1,000.

Step 2: Multiply the result by 1,000 to convert from grams to milligrams.

$$0.025 \text{ kg} \times 1,000 = 25\text{g}$$
$$25 \text{ g} \times 1,000 = 25,000 \text{ mg}$$

So, 0.025 kilograms is equivalent to 25,000 milligrams.

VIDEO

Metric Units of Mass: Convert mg, g, and kg

Solving Application Problems Involving Weight

From children's safety to properly cooking a pie, knowing how to solve problems involving weight is vital to everyday life. Let's review some ways that knowing how to work with metric weight can facilitate important decisions and delicious eating.

Example 7 **Comparing Weights to Solve Problems**

The maximum weight for a child to safely use a car seat is 29 kilograms. If a child weighs 23,700 grams, can the child safely use the car seat?

Solution

Step 1: Convert the child's weight in grams to kilograms.

$$23,700\text{g} \div 1,000 = 23.7 \text{ kg}$$

Step 2: Compare the two weights.

$$23.7 \text{ kg} < 29 \text{ kg}$$

Yes, the child can safely use the car seat.

Example 8 **Solving Multistep Weight Problems**

A recipe for scones calls for 350 grams of flour. How many kilograms of flour are required to make 4 batches of scones?

Solution

Step 1: Multiply the grams of flour need by 4 to determine the total amount of flour needed.

$$350\text{g} \times 4 = 1,400\text{g}$$

Step 2: Convert from grams to kilograms.

$$\frac{1{,}400\text{g}}{1{,}000} = 1.4 \text{ kg}$$

So, 1.4 kilograms of flour are needed to make four batches of scones.

Example 9 **Solving Complex Weight Problems**

The average tomato weighs 140 grams. A farmer needs to order boxes to pack and ship their tomatoes to local grocery stores. They estimate that this year's harvest will yield 125,000 tomatoes. A box can hold 12 kilograms of tomatoes. How many boxes does the farmer need?

Solution

Step 1: Determine the total estimated weight of the harvested tomatoes.

$$140\text{g} \times 125,000 = 17,500,000 \text{ g}$$

Step 2: Convert the total weight from grams to kilograms.

$$17,500,000\text{g} \div 1,000 = 17,500 \text{ kg}$$

Step 3: Divide the weight of the tomatoes by the weight each box can hold.

$$17,500 \text{ kg} \div 12 \text{ kg} \approx 1,458$$

So, the farmer will need to order 1,458 boxes.

Key Terms

- mass

Key Concepts

- Mass is the amount of matter in an object whereas weight is the force exerted on an object by gravity. The mass of an object never changes; the weight of an object changes depending on the force of gravity. An object with the same mass would weigh less on the moon than on Earth because the moon's gravity is less than that of Earth.
- In the metric system, weight and mass are often used interchangeably and are expressed in terms in grams or kilograms.

Videos

- Metric System: Units of Weight
- Using Drones to Weigh Whales?
- Metric Units of Mass: Convert mg, g, and kg

Formulas

You can convert between metric weight units using the conversion factors shown.

9.5 Measuring Temperature

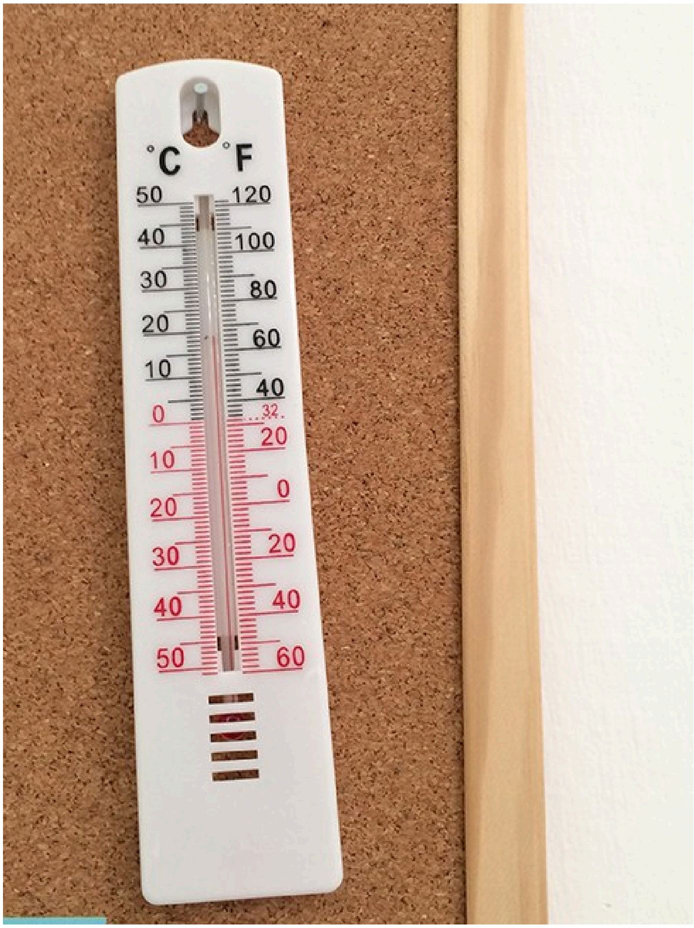


Figure 16: A thermometer that measures temperature in both customary and metric units.

Learning Objectives

After completing this section, you should be able to:

1. Convert between Fahrenheit and Celsius.
2. Identify reasonable values for temperature applications.
3. Solve application problems involving temperature.

When you touch something and it feels warm or cold, what is that really telling you about that substance? **Temperature** is a measure of how fast atoms and molecules are moving in a substance, whether that be the air, a stove top, or an ice cube. The faster those atoms and molecules move, the higher the temperature.

In the metric system, temperature is measured using the Celsius (°C) scale. Because temperature is a condition of the physical properties of a substance, the Celsius scale was created with 100 degrees separating the point at which water freezes, 0 °C, and the point at which water boils, 100 °C. Scientifically, these are the points at which water molecules change from one state of matter to another—from solid (ice) to liquid (water) to gas (water vapor).

CHECKPOINT

When reading temperatures, it's important to look beyond the degree symbol to determine which temperature scale the units express. For example, 13 °C reads "13 degrees Celsius," indicating that the temperature is expressed using the Celsius scale, while 13 °F reads "13 degrees Fahrenheit," indicating that the temperature is expressed using the Fahrenheit scale.

VIDEO

Misconceptions About Temperature

WHO KNEW?

How Many Temperature Scales Are There?

Did you know that in addition to Fahrenheit and Celsius, there is a third temperature scale widely used throughout the world? The Kelvin scale starts at absolute zero, the lowest possible temperature at which there is no heat energy present at all. It is primarily used by scientists to measure very high or very low temperatures when water is not involved.

Converting Between Fahrenheit and Celsius Temperatures

Understanding how to convert between Fahrenheit and Celsius temperatures is an essential skill in understanding metric temperatures. You likely know that below 32 °F means freezing temperatures and perhaps that the same holds true for 0 °C. While it may be difficult to recall that water boils at 212 °F, knowing that it boils at 100 °C is a fairly easy thing to remember.

But what about all the temperatures in between? What is the temperature in degrees Celsisus on a scorching summer day? What about a cool autumn afternoon? If a recipe instructs you to preheat the oven to 350 °F, what Celsius temperature do you set the oven at?

lists common temperatures on both scales, because we don't use Celsius temperatures daily it's difficult to remember them. Fortunately, we don't have to. Instead, we can convert temperatures from Fahrenheit to Celsius and from Celsius to Fahrenheit using a simple algebraic expression.

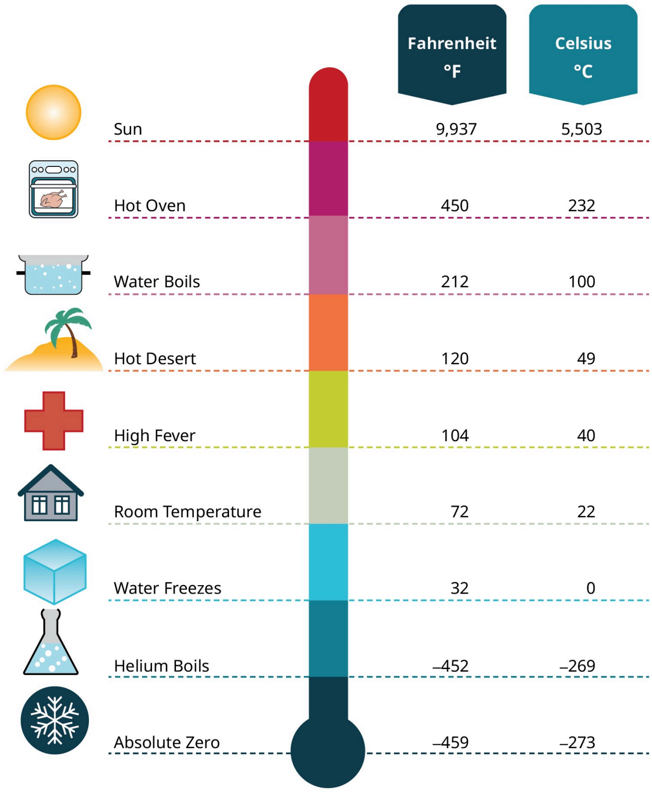


Figure 17: Common Temperatures

FORMULA

The formulas used to convert temperatures from Fahrenheit to Celsius or from Celsius to Fahrenheit are outlined in .

Fahrenheit to Celsius	Celsius to Fahrenheit
$C = \frac{5}{9}(F - 32)$	$F = \frac{9}{5}C + 32$

Example 1 **Converting Temperatures from Fahrenheit to Celsius**

A recipe calls for the oven to be set to 392 °F. What is the temperature in Celsius?

Solution

Use the formula in to convert from Fahrenheit to Celsius.

$$C = \frac{5}{9}(F - 32)$$
$$C = \frac{5}{9}(392 - 32)$$
$$C = \frac{5}{9}(360)$$
$$C = 200$$

So, 392 °F is equivalent to 200 °C.

Example 2 **Converting Temperatures from Celsius to Fahrenheit**

On a sunny afternoon in May, the temperature in London was 20 °C. What was the temperature in degrees Fahrenheit?

Solution

Use the formula in to convert from Celsius to Fahrenheit.

$$F = \frac{9}{5}C + 32$$
$$F = \frac{9}{5}(20) + 32$$
$$F = 36 + 32$$
$$F = 68$$

The temperature was 68 °F.

Example 3 **Comparing Temperatures in Celsius and Fahrenheit**

A manufacturer requires a vaccine to be stored in a refrigerator at temperatures between 36 °F and 46 °F. The refrigerator in the local pharmacy cools to 3 °C. Can the vaccine be stored safely in the pharmacy's refrigerator?

Solution

Use the formula in to convert from Celsius to Fahrenheit.

$$F = \frac{9}{5}C + 32$$
$$F = \frac{9}{5}(3) + 32$$
$$F = 5.4 + 32$$
$$F = 37.4$$

Then, compare the temperatures.

$$36\ ^{\circ}\mathrm{F} < 37.4\ ^{\circ}\mathrm{F} < 46\ ^{\circ}\mathrm{F}$$

Yes. 37.4 °F falls within the acceptable range to store the vaccine, so it can be stored safely in the pharmacy's refrigerator.

Reasonable Values for Temperature

While knowing the exact temperature is important in most cases, sometimes an approximation will do. When trying to assess the reasonableness of values for temperature, there is a quicker way to convert temperatures for an approximation using mental math. These simpler formulas are listed in .

FORMULA

The formulas used to estimate temperatures from Fahrenheit to Celsius or from Celsius to Fahrenheit are outlined in .

Fahrenheit to Celsius	Celsius to Fahrenheit
$C = \frac{F-30}{2}$	$F = 2C + 30$

VIDEO

Temperature Conversion Trick

Example 4 **Using Benchmark Temperatures to Determine Reasonable Values for Temperatures**

Which is the more reasonable value for the temperature of a freezer?

- 5 °C or
- –5 °C?

Solution

We know that water freezes at 0 °C. So, the more reasonable value for the temperature of a freezer is -5 °C, which is below 0 °C. At temperature of 5 °C is above freezing.

Example 5 **Using Estimation to Determine Reasonable Values for Temperatures**

The average body temperature is generally accepted as 98.6 °F. What is a reasonable value for the average body temperature in degrees Celsius:

- 98.6 °C,
- 64.3 °C, or
- 34.3 °C?

Solution

To estimate the average body temperature in degrees Celsius, subtract 30 from the temperature in degrees Fahrenheit, and divide the result by 2.

$$\frac{(98.6 - 30)}{2} = \frac{68.6}{2} = 34.3$$

A reasonable value for average body temperature is 34.3 °C.

Example 6 **Using Conversion to Determine Reasonable Values for Temperatures**

Which is a reasonable temperature for storing chocolate:

- 28 °C,
- 18 °C, or
- 2 °C?

Solution

Use the formula in to determine the temperature in degrees Fahrenheit.

$$F = \frac{9}{5}C + 32$$
$$F = \frac{9}{5}(28) + 32 = 82.4$$
$$F = \frac{9}{5}(18) + 32 = 64.4$$
$$F = \frac{9}{5}(2) + 32 = 35.6$$

A temperature of 82.4 °F would be too hot, causing the chocolate to melt. A temperature of 35.6 °F is very close to freezing, which would affect the look and feel of the chocolate. So, a reasonable temperature for storing chocolate is 18 °C, or 64.4 °F.

Solving Application Problems Involving Temperature

Whether traveling abroad or working in a clinical laboratory, knowing how to solve problems involving temperature is an important skill to have. Many food labels express sizes in both ounces and grams. Most rulers and tape measures are two-sided with one side marked in inches and feet and the other in centimeters and meters. And while many thermometers have both Fahrenheit and Celsius scales, it really isn't practical to pull out a thermometer when cooking a recipe that uses metric units. Let's review at few instances where knowing how to fluently use the Celsius scale helps solve problems.

Example 7 **Using Subtraction to Solve Temperature Problems**

The temperature in the refrigerator is 4 °C. The temperature in the freezer is 21 °C lower. What is the temperature in the freezer?

Solution

Use subtraction to find the difference.

$$4 - 21 = -17$$

So, the temperature in the freezer is −17 °C.

Example 8 **Using Addition to Solve Temperature Problems**

A scientist was using a liquid that was 35 °C. They needed to heat the liquid to raise the temperature by 6 °C. What was the temperature after the scientist heated it?

Solution

Use addition to find the new temperature.

$$35 + 6 = 41$$

The temperature of the liquid was 41 °C after the scientist heated it.

Example 9 **Solving Complex Temperature Problems**

The optimum temperature for a chemical compound to develop its unique properties is 392 °F. When the heating process begins, the temperature of the compound is 20 °C. For safety purposes the compound can only be heated 9 °C every 15 minutes. How long until the compound reaches its optimum temperature?

Solution

Step 1: Determine the optimum temperature in degrees Celsius using the formula in .

$$\begin{aligned} C &= \frac{5}{9}(F - 32) \\ C &= \frac{5}{9}(392 - 32) \\ C &= \frac{5}{9}(360) \\ C &= 200 \end{aligned}$$

Step 2: Subtract the starting temperature.

$$200\ ^{\circ}C - 20\ ^{\circ}C = 180\ ^{\circ}C$$

Step 3: Determine the number of 15-minute cycles needed to heat the compound to its optimum temperature.

$$180 \div 9 = 20$$

Step 4: Multiply the number of cycles needed by 15 minutes and convert the product to hours and minutes.

$$15 \text{ minutes} \times 9 = 135 \text{ minutes}$$
$$135 \text{ minutes} = 2 \text{ hours } 15 \text{ minutes}$$

So, it will take 2 hours and 15 minutes for the compound to reach its optimum temperature.

VIDEO

Learn the Metric System in 5 Minutes

Key Terms

- temperature

Key Concepts

- Temperature is a measure of how fast atoms and molecules are moving in a substance, whether that be the air, a stove top, or an ice cube. The faster those atoms and molecules move, the higher the temperature.
- In the metric system, temperature is measured using the Celsius (°C) scale.
- The Celsius scale was created with 100 degrees separating the point at which water freezes, 0 °C, and the point at which water boils, 100 °C. Scientifically, these are the points at which water molecules change from one state of matter to another—from solid (ice) to liquid (water) to gas (water vapor).

Videos

- Misconceptions About Temperature
- Temperature Conversion Trick
- Learn the Metric System in 5 Minutes

Formulas

To convert temperature from Fahrenheit to Celsius:

$$C = \frac{5}{9}(F - 32)$$

To convert temperature from Celsius to Fahrenheit:

$$F = \frac{9}{5}C + 32$$

To estimate temperature from Fahrenheit to Celsius:

$$C = \frac{F - 30}{2}$$

To estimate temperature from Celsius to Fahrenheit:

$$F = 2C + 30$$

Projects

Cooking

1. Take a favorite recipe that uses customary measures and convert the measures and cooking temperature to the metric system.
2. Find a recipe that uses metric measures and convert the measures and cooking temperature to the U.S. Customary System of Measurement, using cups, tablespoons, or teaspoons as required.
3. What did you observe? Was it easier to convert from one system to another? Which system allows for more precise measurements? What kitchen tools would you need in your kitchen if you used the metric system?

Shopping

1. Compare the average gas price in California to the average gas price in Puerto Rico.

2. What conversions did you need to make to do the comparison?
3. Do you think that the price of the gasoline is affected by the units in which it is sold?

Sports

1. What system of measurement is used for track and field events? Why do you think this system is used?
2. What system of measurement is used for football? Why do you think this system is used?
3. Research various sports records. Which units of measurement is used? What do you think influenced the unit of measure used?