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WORKSHEET 14 EXPERIMENTING SKILLS

Using the International System of Units (SI)

In the United States, few people besides scientists use the International System of Units (known as **SI** for *Système Internationale d'Unités*) regularly. SI is becoming more common for two reasons.

- Once you learn and practice SI, it is easier to use than the standard English system.
- As communication systems and businesses become increasingly global, there is a growing need for a worldwide standard measurement system.

These are reasons why students are required to learn SI in school. We already use SI for many things. For instance, most beverages are sold in 2 L or 3 L bottles. What other items are measured with SI units?

_____

_____

Match 'Em Up!

Match the SI unit with the dimension that it measures:

1. _____ meter	**a.** volume
2. _____ gram	**b.** area
3. _____ liter	**c.** mass
4. _____ square kilometer	**d.** length

Match the SI prefix with its meaning:

5. _____ *nano-*	**e.** one-tenth
6. _____ *centi-*	**f.** one thousand
7. _____ *micro-*	**g.** one-thousandth
8. _____ *kilo-*	**h.** one-millionth
9. _____ *deci-*	**i.** one-billionth
10. _____ *milli-*	**j.** one-hundredth

Help is on the way!

An SI Conversion Chart is provided for you in Appendix I on page 79.

Remember

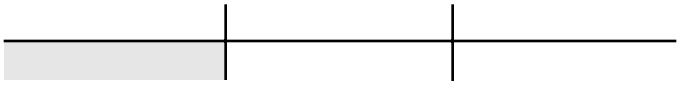
As you read, watch for words such as *nanosecond, kilocalorie, milliliter,* and *micrometer.*

Conversions

Convert between SI and English units with the following factors :

mass	volume	distance
1 lb = 454 g	1 gal = 3.78 L	1 ft = 0.305 m
1 g = 0.0022 lb	1 L = 0.26 gal	1 m = 3.28 ft

There is a handy method of doing conversions based on this figure:



Here's an example: How many centimeters is 38 ft?

Step 1: Put the known quantity in the upper-left space, as follows:

38 ft		

Step 2: Put a conversion factor (also called an *equality*) in the next set of boxes to the right. Make sure that the units match diagonally. We started with feet on top, so we'll put feet on the bottom when we fill in the conversion factor, as follows:

38 ft	0.305 m	
	1 ft	

Note: There are two conversion factors listed above for feet and meters. You can use either one as long as you put feet on the bottom.

Step 3: Cross out, or cancel, the units that appear on both the top and the bottom, as follows:

38 ~~ft~~	0.305 m	
	1 ~~ft~~	

Step 4: Now ask, "Is the unit that's **not crossed out** the one I want?"

- If the answer is yes, then continue to Step 5.
- If the answer is no, return to Step 2.

For our example, the unit that's left is meters. We're looking for centimeters, so we'll return to Step 2.

Step 2: Remember to match units diagonally.

38 ~~ft~~	0.305 m	100 cm
	1 ~~ft~~	1 m

Step 3: Cross out the matching units.

38 ~~ft~~	0.305 ~~m~~	100 cm
	1 ~~ft~~	1 ~~m~~

Step 4: Is the unit that's **not crossed out** the one I want? Yes, we've got centimeters, so we're ready to solve the problem.

Step 5: To solve the problem, multiply the numbers on the top row:

$38 \times 0.305 \times 100 = 1{,}159$

Then multiply all of the numbers on the bottom row:

$1 \times 1 = 1$

Now, divide the top row's product by the bottom row's product:

$1{,}159 \div 1 = 1{,}159$

The answer is **1,159 cm!**

Your Turn

The following problems will help you practice your metric-to-metric, English-to-SI, and SI-to-English conversions. Be sure to show your work.

1. How many meters is 1,602 ft?

2. How many pounds is 12 g?

3. How many gallons is 0.2 L?

4. How many deciliters is 5 L? (Hint: How many deciliters are in 1 L?)

5. How many meters is 63.9 cm?

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WORKSHEET 15

EXPERIMENTING SKILLS

Measuring

Try this puzzle. Suppose that you are given a bottle of water and three beakers. One of the beakers holds 30 mL, one holds 40 mL, and the largest of the three beakers holds 200 mL when full. There aren't any markings on any of the beakers. Describe how you could put exactly 20 mL of water in the large beaker without using any other equipment.

_____

_____

_____

_____

_____

_____

Tools of the Trade

You probably already know that beakers are used for measuring liquid volume. We say that the **dimension of measurement** for a beaker is volume. Examine the following chart, and fill in the empty boxes.

Measurement device	Dimension of measurement
beaker	volume
stopwatch	
beam balance	
graduated cylinder	
	distance or length
	temperature

Precise measurements and accurate readings are very important aspects of scientific experimentation.

Here are some pointers for accurately measuring the volume of a liquid:

- Place the container on a flat surface.
- Make sure the container is at eye level when you read the volume.
- If you have trouble seeing the level, hold a blank piece of paper behind the container while you read the volume of the liquid.

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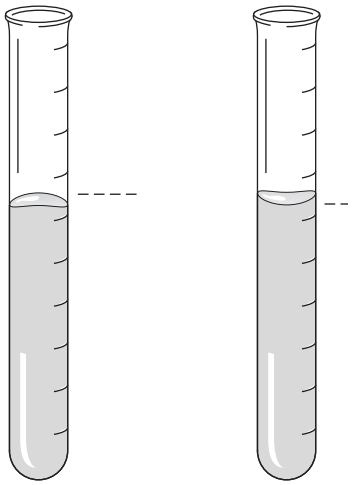
Measuring, continued

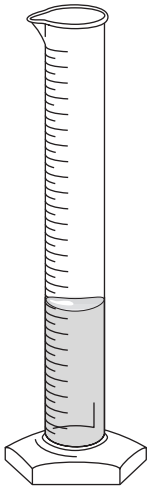
In a graduated cylinder or beaker, most liquids form a **meniscus**, or a curved upper surface. A meniscus is caused by surface tension. When a liquid, such as water, is more attracted to the walls of the container than to itself, it curves up at the edges like a smile. When some liquids, such as mercury, are more attracted to themselves than to the walls of the container, they curve down like a frown.

When you read the volume of a liquid, read it from the center of its meniscus, not from the curved edges.

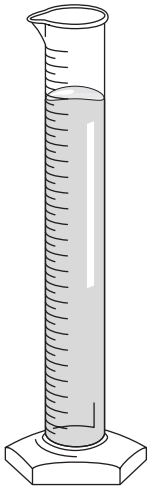


For practice, read the volume of the following liquids. Each longer graduation represents one milliliter.

1. Volume: _____



2. Volume: _____



Uncertainty in Measurement

Anne brought a 1 L bottle of vinegar from home to use in an experiment on volcanoes in science class. She poured the contents of the bottle into a large beaker and carefully measured it. She was surprised to find that the vinegar's measured volume was actually 1.02 L. Anne thought the bottle contained exactly 1 L of vinegar. What possible explanations can you think of for the difference?

Accuracy in Measurement

No measurement is 100 percent accurate. All measurements have some degree of uncertainty. When taking measurements, you should always ask yourself, "How accurate is this measurement?"

For a measurement to be of any worth, it must have something that indicates its reliability. A measurement's **accuracy** is expressed as its potential amount of error. For instance, the smallest unit of measurement on a metric ruler is usually a millimeter. The most accurate measurement you could possibly make with that ruler is to the nearest millimeter; thus, the measurement's accuracy is $\pm$ 0.5 mm.

This is important because not all measurements have the same accuracy. The total accuracy of your work is only as reliable as your *least* accurate measurement. Following is an example:

Ricardo added the following three liquids to a beaker:

- 7.9 mL of liquid *A*
- 2.1 mL of liquid *B*
- 250 mL of liquid *C*

Ricardo measured liquids *A* and *B* with a narrow graduated cylinder that had markings for every 0.1 mL. He measured liquid *C* in a beaker that had markings only for every 10 mL. Thus, the volume of liquid *C* was only accurate to within about 5 mL.

As a result, Ricardo correctly stated that the total volume of the mixture in the beaker was (7.9 + 2.1 + 250) mL = 260 mL ± 5 mL.

Matchmaker

Match the measurement devices below with their level of accuracy.

1. _____ metric ruler with markings as small as millimeters

2. _____ graduated cylinder with markings as small as 2 mL

3. _____ scale with markings as small as 0.01 g

4. _____ thermometer with markings as small as 1°C

a. about 0.5 g

b. about 1 mL

c. about 0.5°C

d. about 1 mm

e. about 0.5 mm

f. about 0.005 g

g. about 0.1°C

Troubleshooting

Think of accuracy in terms of money. When someone says, "That costs about $20," which of the following would you think is most accurate: (a) the price is correct, give or take $10; (b) the price is correct, give or take $1; or (c) the price is correct, give or take 1 cent? The most accurate estimate is probably (b).

Try This!

The next time your family buys gasoline, pay attention to how accurately the gas pump tracks the volume of gas—very accurately! For contrast, notice how accurately the car's gas gauge measures the amount of gas in the gas tank—not very accurately!