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# Math on the Move

## Lesson 14 Measurement Systems

### **Objectives**

- Understand customary and metric units of measurement, weight, and capacity
- Convert between different units within one measurement system, including time

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In the distant past, there were no rulers or tape measurers. However, traders and businessmen still needed to know the approximate lengths of objects. To solve this problem, they used personal benchmarks to measure objects. The length of a foot came from the length of a human foot. A yard was the length from the tip of the nose to the end of an outstretched arm. An inch was the length of three barley kernels. This system was not very precise, since feet, arms, and kernels come in different sizes. To help make measurements more accurate, an English King standardized the measures and said that the length of his foot, his nose to arm, and his barley kernels would be the standard measures of a foot, yard, and inch. These became known as the **standard measurement system** of inches, feet, and yards.

- The **standard measurement system** is the set of all the units of measure used for length, weight, and capacity (how much something can hold) used in America. Other names for this system are **customary measure** and the **English measure**.

### **FACT**

- *Standard units for length are **inches** (in.), **feet** (ft.), **yards** (yd.), and **miles** (mi.).*
- *Standard units for capacity are **ounces** (oz.), **cups** (c.), **pints** (pt.), **quarts** (qt.), **gallons** (gal.)*
  - *Standard units for weight are **ounces** (oz.), **pounds** (lbs.), and **tons** (T.)*

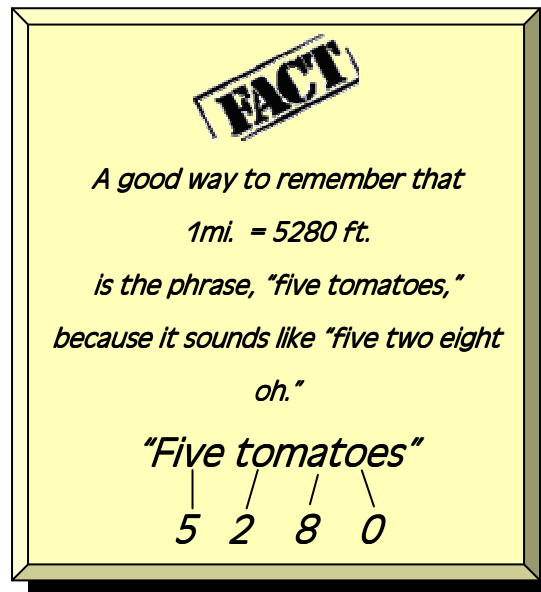
Notice that in the standard measurement system, ounces are used as units twice! In one setting, ounces measure the amount of liquid something can hold. At other times, ounces measure how heavy something is. These two measurements use the same name for the unit, but they are different. This is important. When measuring capacity, the term fluid ounces is sometimes used. Its abbreviation is fl. oz. If you see this abbreviation or are dealing with some form of liquid, the label, ounces, refers to capacity, not weight. Example: 4 ounces of water refers to how much water there is, not how much it weighs.

Each unit of length is related. For instance

$$12 \text{ in.} = 1 \text{ ft.}$$

$$3 \text{ ft.} = 1 \text{ yd.}$$

$$5280 \text{ ft.} = 1 \text{ mi.}$$



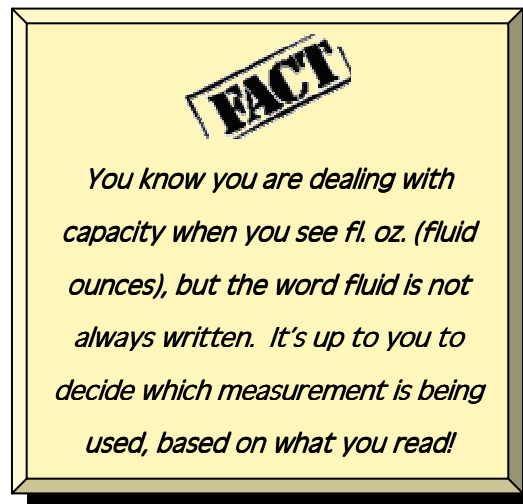
The relationships for capacities are:

$$8 \text{ fl. oz.} = 1 \text{ cup}$$

$$2 \text{ cups} = 1 \text{ pint}$$

$$2 \text{ pints} = 1 \text{ qt.}$$

$$4 \text{ qt.} = 1 \text{ gal.}$$



For standard weight,

$$16 \text{ oz.} = 1 \text{ lb.}$$

$$2000 \text{ lbs.} = 1 \text{ ton}$$

Let's explore this a little more.

**Example**

How many inches is 5 ft.?

**Solution**

We need to convert from feet to inches. Let's rewrite 5 ft. as a fraction.

$$\frac{5\text{ft.}}{1}$$

Now we recall two facts,

- Any fraction with an equal numerator and denominator is equal to 1.  $\frac{a}{a} = 1$
- Anything multiplied by 1 is unchanged.  $a \cdot 1 = a$

This means that we may multiply by a fraction equal to 1. Observe.

$$\frac{5\text{ft.}}{1} \left( \frac{12\text{in.}}{1\text{ft.}} \right)$$

← The fraction  $\frac{12\text{in.}}{1\text{ft.}}$  is equal to 1, because the top and bottom are equal. 12 in. = 1 ft.

Once again, anything over itself equals one. Just as this is true with numbers, it is true with units of measurement. Notice that when we multiply the above expression, we get

$$\frac{5\text{ft.} \times 12\text{in.}}{1\text{ft.}}$$

We now have feet in the numerator and feet in the denominator.

This means we may cancel feet out, as follows.

$$\frac{5 \cancel{\text{ft.}} \times 12 \text{ in.}}{1 \cancel{\text{ft.}}}$$

This leaves us with

$$\frac{5 \times 12\text{in.}}{1} = \frac{60\text{in.}}{1} = 60\text{in.}$$

We just converted from feet to inches. We know that this result is true, because if we lined up five 1-foot rulers, we could count 60 inches. Let's do some more examples.

**Example**

How many inches is 3 miles?

**Solution**

We need to convert from miles to inches.

*Step 1:* Write 3 miles as a fraction

$$\frac{3 \text{ mi.}}{1}$$

*Step 2:* Multiply by a fraction equal to 1 using the next lowest unit, in this case, feet.

$$\frac{3 \text{ mi.}}{1} \left( \frac{5280 \text{ ft.}}{1 \text{ mi.}} \right)$$

Since we want to cancel miles, we will write the fraction with miles on the bottom, so the units cancel, as you will

*Step 3:* Cancel units. In this case, we will cancel miles.

$$\frac{\cancel{3 \text{ mi.}}}{1} \left( \frac{5280 \text{ ft.}}{\cancel{1 \text{ mi.}}} \right)$$

Now we have to change feet to inches.

*Step 4:* Repeat Steps 2 and 3, until you have reached the unit you want.

$$\frac{\cancel{3 \text{ mi.}}}{1} \left( \frac{5280 \text{ ft.}}{\cancel{1 \text{ mi.}}} \right) \left( \frac{12 \text{ in.}}{1 \text{ ft.}} \right)$$
$$\frac{\cancel{3 \text{ mi.}}}{1} \left( \frac{5280 \text{ ft.}}{\cancel{1 \text{ mi.}}} \right) \left( \frac{12 \text{ in.}}{\cancel{1 \text{ ft.}}} \right)$$

Now, we have a fraction in terms of inches.

*Step 5:* Multiply all the numbers in the numerator and denominator.

$$\frac{3 \times 5280 \times 12 \text{ in.}}{1} = 190,080 \text{ in.}$$



## Algorithm

### To convert to a different unit:

1. Write what you are given as a fraction.
2. Multiply by a fraction equal to 1, making sure to allow for cancellation.
3. Cancel units that are on top and bottom.
4. If the fraction is still not in the desired unit, repeat steps 2 and 3 until you get the desired unit on top.
5. Multiply by the numbers on top and the bottom of the fraction.

### Convert 3 pints to fluid ounces.

$$\frac{3 \text{ pt.}}{1}$$

$$\frac{3 \text{ pt.}}{1} \left( \frac{2 \text{ cups}}{1 \text{ pt.}} \right)$$

$$\frac{3 \text{ pt.}}{1} \left( \frac{2 \text{ cups}}{1 \text{ pt.}} \right)$$

$$\frac{3 \text{ pt.}}{1} \left( \frac{2 \text{ cups}}{1 \text{ pt.}} \right) \left( \frac{8 \text{ fl.oz.}}{1 \text{ cup}} \right)$$

$$\frac{3 \text{ pt.}}{1} \left( \frac{2 \text{ cups}}{1 \text{ pt.}} \right) \left( \frac{8 \text{ fl.oz.}}{1 \text{ cup}} \right) = \frac{3 \times 2 \times 8}{1} \text{ fl.oz.}$$

$$= 48 \text{ fl.oz.}$$

### Example

You are baking a cake that calls for 4 c. flour. Unfortunately, all you have is a measuring cup for ounces. How many ounces should you use?

### Solution

First we will write our fraction.

$$\frac{4 \text{ cups}}{1}$$

Then we will multiply by 1, with cups on bottom.

$$\frac{4 \text{ cups}}{1} \left( \frac{8 \text{ oz.}}{1 \text{ cup}} \right)$$

Now we will cancel out cups

$$\frac{\cancel{4} \text{ cups} \left( \frac{8 \text{ oz.}}{\cancel{1} \text{ cup}} \right)}{1}, \text{ Then we will multiply the numbers in the top and bottom}$$
$$= \frac{32 \text{ oz.}}{1} = 32 \text{ oz.}$$

**Example**

A full grown blue whale weighs 300,000 lbs. How many tons is this?

**Solution**

Write 300,000 lbs. as a fraction.

$$\frac{300,000 \text{ lbs.}}{1}$$

Make a fraction equal to 1 that cancels out pounds.

$$\frac{300,000 \text{ lbs.}}{1} \left( \frac{1 \text{ ton}}{2,000 \text{ lbs.}} \right)$$

Notice this time that we have something other than 1 on the denominator. The lbs. still cancel, but do not cancel the number 2,000.

$$\frac{300,000 \cancel{\text{ lbs.}}}{1} \left( \frac{1 \text{ ton}}{2,000 \cancel{\text{ lbs.}}} \right)$$

Now we multiply the numbers on the top and bottom

$$= \frac{300,000}{2,000} \text{ tons}$$

Our final step is to simplify the fraction.

$$= 150 \text{ tons}$$



**Example**

How many miles is 27,878,400 inches?

**Solution**

$$\begin{aligned} & \frac{27,878,400 \cancel{\text{in.}}}{1} \left( \frac{1 \cancel{\text{ft.}}}{12 \cancel{\text{in.}}} \right) \\ & \frac{27,878,400 \cancel{\text{in.}}}{1} \left( \frac{1 \cancel{\text{ft.}}}{12 \cancel{\text{in.}}} \right) \left( \frac{1 \cancel{\text{mi.}}}{5280 \cancel{\text{ft.}}} \right) \\ & = \frac{27,878,400 \times 1}{1 \times 12 \times 5280} \text{mi.} \\ & = \frac{27,878,400}{63,360} \text{mi.} \\ & = 440 \text{ mi.} \end{aligned}$$

**Example**

How many pounds is 3760 oz.?

**Solution**

$$\begin{aligned} & \frac{3760 \cancel{\text{oz.}}}{1} \left( \frac{1 \cancel{\text{lb.}}}{16 \cancel{\text{oz.}}} \right) \\ & \frac{3760}{16} \text{lbs.} \\ & = 235 \text{ lbs.} \end{aligned}$$

As you can see, making sure to write the units of each number is extremely important. You also need to remember each conversion fact!



1. Jim and Stanley are organizing a company party at the beach. Their boss, Michael, tells them they will need 2 gallons of milk for the party. They bring 6 quarts of milk. Did Jim and Stanley buy enough milk?
  
2. Toby ran a 5 mile race on Wednesday. Dwight says that he ran 10,000 feet the other day from a black snake. Who ran farther?
  
3. Phyllis and Angela are having an argument. Angela says that she is 63 inches tall. Phyllis says that she is 5 feet and 7 inches tall. Angela says she is the taller of the two. Phyllis says that she is. Who is taller?
  
4. While he was attending Cornell University, Andy drank 1 gallon of milk in 1 hour. Kevin says that he drank 120 fl oz of soda that day for lunch in 1 hour. Who drank more liquid?

As you may know, the standard measurement system is only used in America. The rest of the world uses a different system, the **metric system**.

- The **metric system** is a system of measurement that uses prefixes and powers of 10 to define its units.

**FACT**

*Powers of ten are  
..., 0.001, .01, .1, 1, 10, 100, 1000,...*

**FACT**

*A prefix is a set of letters that goes before a word to change its meaning. For example, the prefix "re" means again, so redo means do again!*

The base-units used in the metric system are as follows.

Base unit name	What it Measures
meter (m)	distance
gram (g)	weight
liter (L)	capacity

1 meter is about 1 yard.

1 gram is about  $\frac{1}{28}$  of an ounce. A paperclip is about 1 gram.

1 liter is about 1 quart.

A prefix can be added to these units to produce a multiple of the unit. These multiples will be in powers of 10, and they are as follows.

Prefix	milli-	centi-	deci-	<i>base unit</i>	deka-	hecto-	kilo-
<b>Abbreviation</b>	m	c	d		da	h	k
<b>Decimal</b>	.001	.01	.1	1	10	100	1000

To name a metric unit, we attach a prefix to the beginning of a base unit. One instance of a metric unit is the milligram. Milligram is abbreviated mg, and it means .001 times one gram.

**Example**

How many meters are in a kilometer?

**Solution**

In this case, meters are the base unit. We abbreviate kilometer, km. If we look at the chart, we see that "kilo-" means 1000, so there are 1000 meters in a kilometer.

**Example**

How many liters are in 1 mL?

**Solution**

For this problem, liters are the base unit. Looking at the chart we see that "m" is the abbreviation for "milli-", and we see that "milli-" means .001. There are .001 liters in 1 mL.

What if we wanted to convert from cg into hg? Looking at the chart we see that cg is a centigram and hg is a hectogram. The chart given only shows how we go from base units to other prefixes, not one prefix to another.

There is a simple method for converting between all units in the metric system.

**Example**

Convert 2 centigrams (cg) into hectograms (hg).

**Solution**

*Step 1:* List all the abbreviations of the prefixes in order from largest to smallest

k   h   da   **b**   d   c   m



We use the letter *b* here to show the base units space. The base unit is grams.

**Problem Solving Tip**



To help you remember the order of the letters, make up a silly sentence, such as

***"Kathy hid Dana's Barbie dolls Christmas morning."***

Step 2. Write the number given to us above the unit given to us.

k h da b d <sup>2</sup>c m

We were given 2 cg, so we write the 2 above the "c".

Step 3. Count how many spaces we have to go from our initial unit to our desired unit

k h da b d <sup>2</sup>c m

4 spaces

We move 4 spaces to the left to go from centi- to hecto-.

Step 4. Move the decimal place that many spaces in the direction we drew the arrows.

2. Add zeros as place holders → .0002

Step 5. Write the new units next to our final number.

.0002 hg *or* .0002 hectograms

Let's try a couple more!

**FACT**

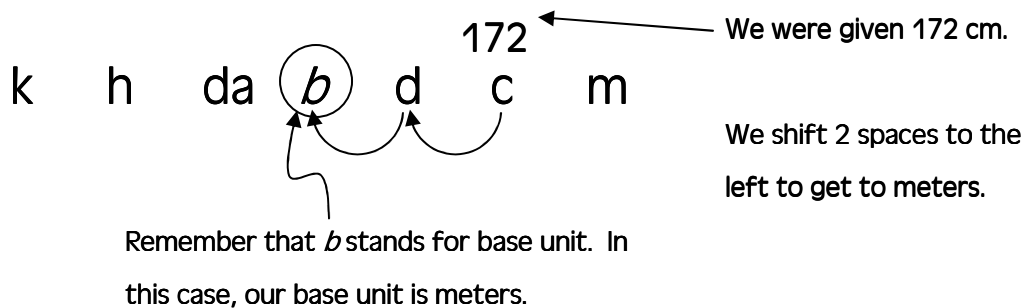
If you do not see a decimal point, it is always after the digits place. 2 is the same as 2.0, and 350 is the same as 350.0

**Example**

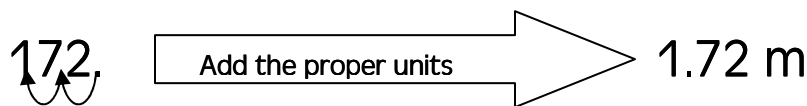
Francisco is 172 cm (centimeters) tall. How tall is he in meters?

**Solution**

Again, we will list all the abbreviations for the metric system and place the number above the units given to us



Since we had to go 2 units to the left, we move our decimal point 2 units to the left.



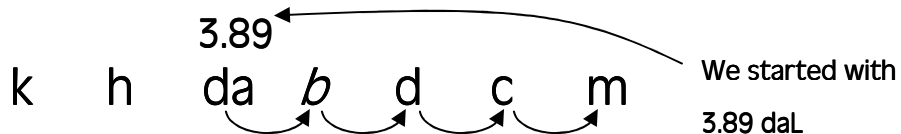
Francisco is 1.72 meters tall.

**Example**

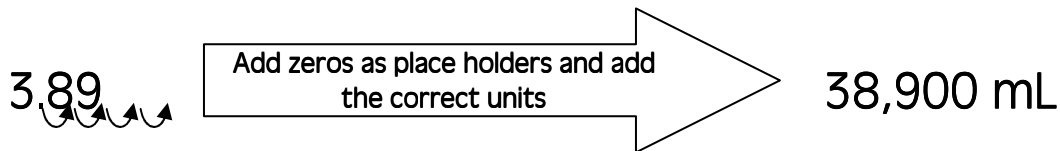
You have 3.89 daL of water. How many mL of water do you have?

**Solution**

Start by listing the abbreviations in order from largest to smallest.



We moved 4 spaces to the right, so we move our decimal point 4 spaces to the right



Our answer is 38,900 milliliters.

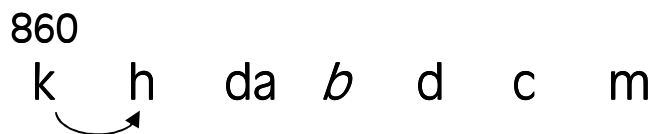
**Example**

The average bull weighs approximately 860 kg. How much is this in hg?

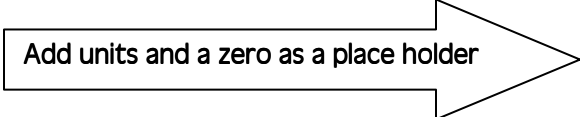
**Solution**

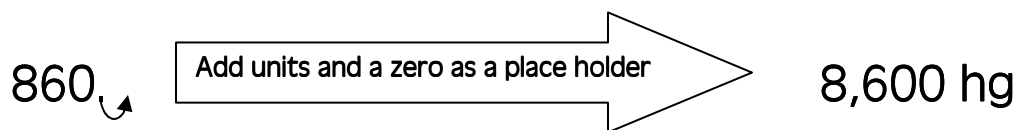
First, list the abbreviations along with the initial units given to us.

860  
k h da b d c m



Now we move the decimal 1 place to the right.

860,  8,600 hg



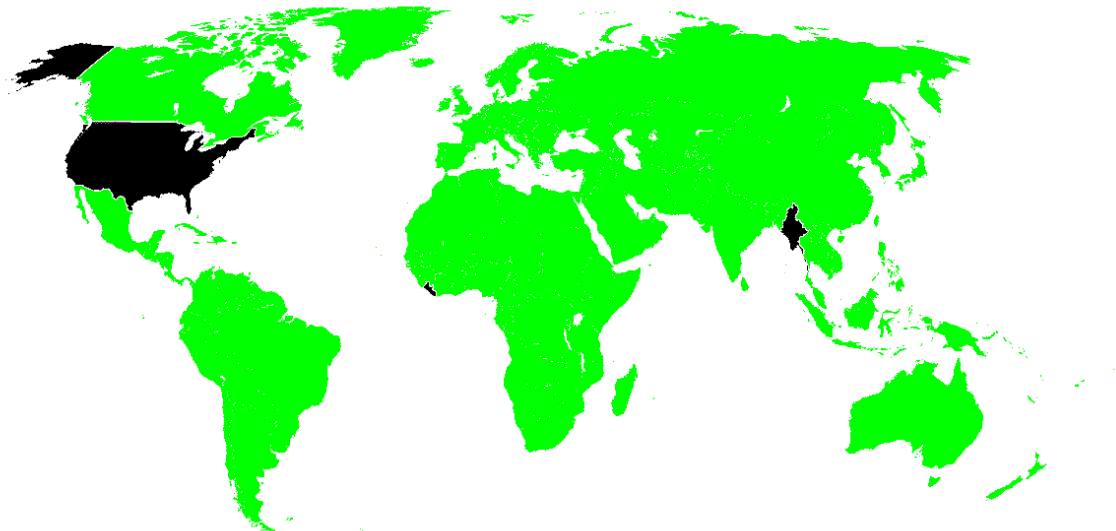
860 kilograms is 8,600 hectograms.



5. A recipe for brownies calls for 3.5 dL of oil, but your measuring cup only reads mL. How many mL of oil do you need to make the brownies?
6. You went to the gym yesterday and lifted 50 kg. Your friend Jose came up to you and said, "Well I can lift 40,000 grams!" Who lifted more, you or Jose?

7. You want to travel to a different country, and your travel agent says he can get you a deal on any city under 8000 km from New York City. Based on the list below, which cities can you get deals on?

City	Distance from NYC
London, England	557,200 dam
Mexico City	86,740 hm
Montreal, Canada	592,000 m
Madrid, Spain	5,772,000 m
Cape Town, South Africa	125,750 hm



On this map of the world, the green (light grey) areas use the metric system. As you may be starting to see, the metric system is easier to use than the standard system, because conversions only require moving the decimal. This is why so many nations use metric units instead of customary units.

One measurement system that is universally agreed upon is the measurement system of time. We measure time based on how long it takes for the Earth to travel around the sun. When the Earth



travels around the sun once, we call this one year (yr.). A lot happens in one year. To help us stay organized, the time period of one year is divided into many parts, called seconds (sec.), minutes (min.), hours (hr.), days (days), and weeks, (wk.).

The units of time, like units of length, capacity, and weight, are all related.

1 second

60 sec. = 1 minute

60 min. = 1 hour

24 hr. = 1 day

7 days = 1 week

52 wk. = 1 year

365 days = 1 year

**Example**

How many minutes are in 3 hours?

**Solution**

Let's use the fraction method we used for converting standard units of measurement.

We know that 1 hr. = 60 min., so

$$\frac{3 \cancel{\text{hr.}}}{1} \left( \frac{60 \text{ min.}}{1 \cancel{\text{hr.}}} \right) = \frac{3 \times 60}{1} \text{ min.} = 180 \text{ min.}$$

**Example**

How many hours are in 3 weeks?

**Solution**

We know 1 wk. = 7 days,

and 1 day = 24 hr.

$$\frac{3 \cancel{\text{weeks}}}{1} \left( \frac{7 \cancel{\text{days}}}{1 \cancel{\text{week}}} \right) \left( \frac{24 \cancel{\text{hr.}}}{1 \cancel{\text{day}}} \right) = \frac{3 \times 7 \times 24}{1} \text{hr.} = 504 \text{ hr.}$$

There are 504 hr. in 3 weeks

**Example**

How many weeks are in 2100 days?

**Solution**

We know 1 wk. = 7 days

$$\frac{2100 \cancel{\text{days}}}{1} \left( \frac{1 \cancel{\text{wk.}}}{7 \cancel{\text{days}}} \right) = \frac{2100}{7} \text{wk.} = 300 \text{ wk.}$$

There are 300 weeks in 2100 days.

**FACT**

*Every time you convert to a smaller unit, the number gets larger. Every time you convert to a larger unit, the number gets smaller.*

**Example**

How many days are in 1,209,600 seconds?

**Solution**

We know 1 min. = 60 sec.,

1 hr. = 60 min.,

and 1 day = 24 hr.

$$\frac{1,209,600 \cancel{\text{sec.}}}{1} \left( \frac{1 \cancel{\text{min.}}}{60 \cancel{\text{sec.}}} \right) \left( \frac{1 \cancel{\text{hr.}}}{60 \cancel{\text{min.}}} \right) \left( \frac{1 \cancel{\text{day}}}{24 \cancel{\text{hr.}}} \right) = \frac{1,209,600}{60 \times 60 \times 24} \text{days} = 14 \text{ days}$$

There are 14 days in 1,209,600 seconds.

## Review

1. Highlight the following definitions:
  - a. standard measurement system
  - b. customary measure
  - c. metric system
2. Highlight the conversion facts for each measurement system.
3. Write one question you would like to ask your mentor, or one new thing you learned in this lesson.

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## Practice Problems

### Math On the Move Lesson 14

Directions: Write your answers in your math journal. Label this exercise Math On the Move – Lesson 14, Set A and Set B.

#### ***Set A***

1. Convert 12 ft. to inches.
2. Convert 633,600 in. into miles.
3. Convert the following metric measures.

a) 3.8 m $\longrightarrow$ km	b) 4 kg $\longrightarrow$ mg	c) 12.2 cL $\longrightarrow$ hL
d) 53.3 mm $\longrightarrow$ km	e) 9 g $\longrightarrow$ dag	f) 1.6 daL $\longrightarrow$ dL

4. What is the best unit of time to measure:
- a) how old you are
  - b) how long summer is
  - c) how long between pay checks (or allowances)
  - d) how long it takes to brush your teeth
  - e) how long it took you to read this lesson
5. How many
- a) seconds are in 15 minutes?
  - b) minutes are in a year?
  - c) full minutes and seconds are in 175 seconds?
  - d) full years and days are in 1,000,000 seconds?
6. Convert 15 minutes to seconds.
7. Convert 3 years to days.
8. Convert 7 years to seconds.

***Set B***

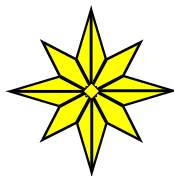
1. You decide that you want to make a basketball court in your backyard. You go to the basketball court in your local gym and decide to measure it, so you can make your own later. The only problem is, you don't have any tools to measure the gym! Explain, with words, how you would go about measuring the size of the basketball court.
2. How many seconds have you been alive?
3. If 1 inch  $\approx$  2.5 cm, how tall are you in cm? If 1 kg  $\approx$  2.2 lbs, how much do you weigh in kg?
4. Sometimes, distance is measured with time. For instance, a light-year is the distance traveled at the speed of light over one year. Can you think of any other ways that distance and time are related? (*Hint*: think about a car.)
5. José ran a race against Jesús. José ran the race in 24 minutes. Jesús ran the race 4 times faster than José. Why does this mean that Jesús' time was less than José's time? Why don't we just multiply  $24 \times 4$ ? What was Jesús' time?

ANSWERS TO  
TRY IT



1. No, since 2 gallons = 8 quarts
2.  $10,000 \text{ ft.} \div 5280 \text{ ft.} = 1.89\overline{39} \text{ mi.} \approx 2 \text{ miles}$   
 $2 \text{ miles} < 5 \text{ miles}$   
so Toby ran farther.
3. Angela is 5 ft and 3 in. That is less than Phyllis's height of 5ft 7 in, so Phyllis is taller.
4. 1 gallon = 128 oz, so Andy drank more.
5. 3.5 dL = 350 mL, so you need 350 mL of oil to make the brownies.
6. To solve this problem you must convert the measures to the same unit. You can either convert the 50 kg to 50,000 g, or you can convert 40,000g to 40 kg. Then you can compare  
 $50 \text{ kg} > 40 \text{ kg}$             or             $50,000 \text{ g} > 40,000 \text{ g}$   
So you lifted more than Jose.
7. Convert all the measures to km to compare them to 8000 km  
London is 5572 km.  
Mexico City is 8674 km.  
Montreal is 592 km.  
Madrid is 5772 km.  
Cape Town is 12,575 km.  
You can only go to London, Montreal, or Madrid

**NOTES**



**End of Lesson 14**