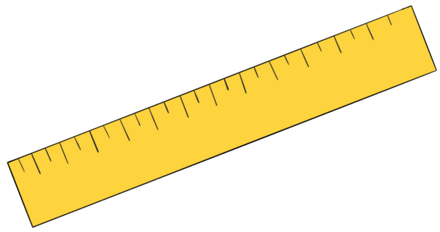


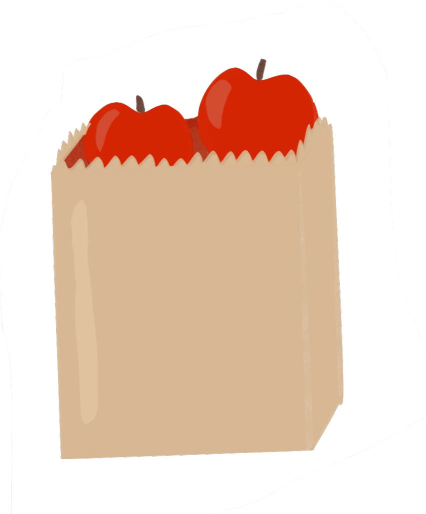
Lesson 1: Introduction to Measurement and Length

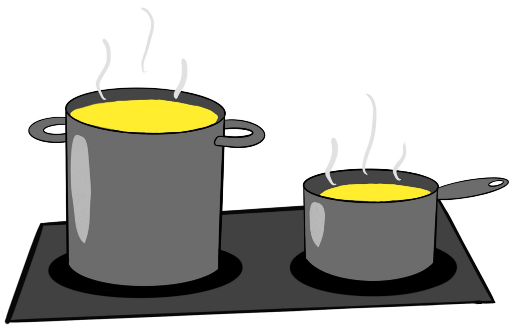
Welcome to your course in physical science. The first thing we need to do is define what we mean by physical science. It's sometimes easier to define physical science by telling what it is not! Physical science is the study of those things in our world which are NOT alive. Life science and biology are courses which focus on living things. In physical science our focus will be on the non-living things.

We'll look at things like measurement, energy, forces and simple machines which make up the non-living parts of our world. These non-living things definitely do affect us as living things and that's why it's a great idea to understand them better. So, our goal in this physical science course is to explore science concepts which primarily focus on non-living things.

We'll begin our study by looking at concepts of measurement first. Think about this question: why do we need to understand how to measure things? Write some ideas here:

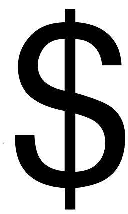
You may have written things like, "It's good to know how to measure so when you cook something, you get the recipe correct." Or, "It's good to know how to measure so when you build something, the parts fit together right." If one of your jobs around the house is helping with buying groceries for your family, you know it's important to pay fair prices at the supermarket. Understanding how quantities of groceries are measured helps you make sure you're getting the amount of goods for which you've paid.





Grocery shopping and cooking require good measurement skills.

As an adult, you may enter into a career where you sell products to others. A great example of this is a farmer or rancher. Because almost all farm products are sold by the pound, understanding how to correctly weigh your products is vitally important to the success of your farming business.

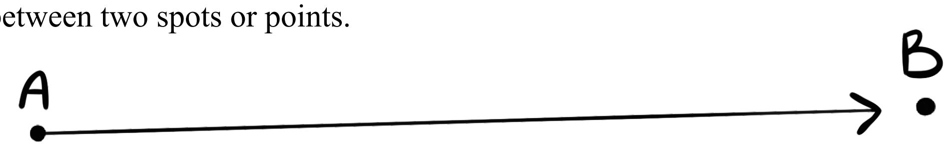


Marketing products you make requires that you understand how to measure them.

Another career example is the job of a nurse or pharmacist. These persons must correctly measure dosages of medications every day to ensure their patients get the response they expect from the medication. Additionally, doctors have to interpret the results of tests completed on their patients so understanding how these results are reported in regard to the units "behind" the numbers is very important. If you stop and think about it, almost everyone needs to understand how "stuff" in our world is measured.

Doctors, nurses and pharmacists must use accurate measurement skills on a daily basis to ensure that their patients receive excellent care.

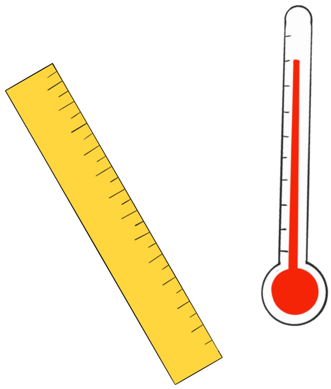
In this lesson we're going begin by studying the measurement of length. Length can be defined as how long it is from one spot to another. So, we might have spot A and then spot B. The length would be the distance between these two spots or points. These spots might be two points on a piece of paper or two locations in a field or on a map. Or they could be at two locations on an object, like top and bottom edges or distance from right side to left. So, length is defined as the distance between two spots or points.



Let's pretend that you just bought a piece of land with some pasture on it. You have some cows you'd like to move there to graze on the pasture. To keep the cows on your land (and not someone else's) it would make sense to build a fence around your property. In order to build the fence, you would have to know how much wire, how many fence posts and other supplies it would take to build the fence. To know these amounts, you'd have to know the length of the fence or at least how much of your land that you want to enclose with the fence.

This is an aerial view of pastures and corn fields. Being able to make accurate measurements of these fields allows a farmer to calculate supplies and equipment he or she might need in order to have success in farming these sections of land.

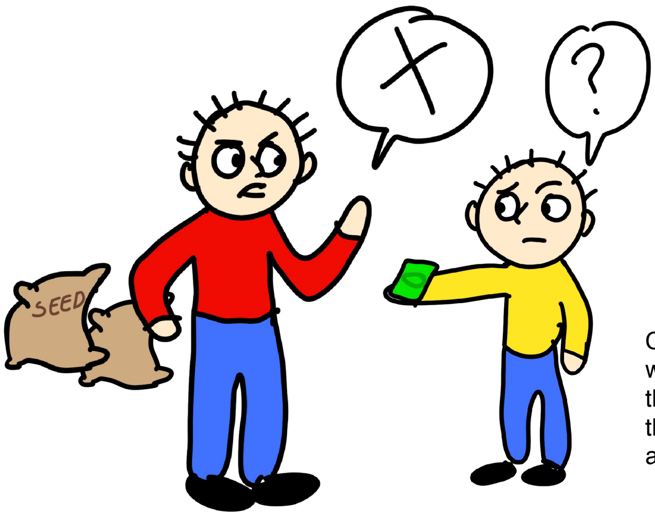
This brings up our first point that we must consider when we talk about measuring length (or, in actuality, any kind of measurement we take whether it be length or weight or temperature or intensity): to measure something means we are comparing what we're intending to measure to some sort of standard unit. This standard is a unit that "everyone" has agreed upon to use. An example of a standard used to measure length could be inches or feet or miles. When we measure weight, a standard could be ounces or pounds. What standards do we use when we measure the temperature of something? If you said degrees Fahrenheit or Celsius, you'd be correct. So, measuring something infers that we are comparing an unknown quantity to a known or standard quantity (standard unit).



When we make measurements of things, we compare the unknown amount (amount we're trying to find) with that of a known standard amount. With the measurement of length we might use a ruler on which the standard units are inches. With temperature, we might use a thermometer on which the standard units of measure are degrees.

In today's world, these standard units may seem second nature to you. In the United States, we are all familiar with long distances being measured in miles and shorter distances being measured in yards, feet or inches. However, if you've ever traveled to other countries, you have likely encountered that distances are measured using units other than feet or miles. These distances may be measured in meters or kilometers.

This brings up a second point about measuring things: standards have to be agreed upon by folks using those standards. Agreement between groups of people regarding the standard by which a "thing" was to be measured has not always been the case. In fact, in the fifteenth and sixteenth centuries, in France alone, it was estimated that there were over 250,000 different standards of measuring units. This vast array of units, as you might imagine, caused many disruptions in trade and also allowed for cases of fraud and, consequently, conflict to be quite high.

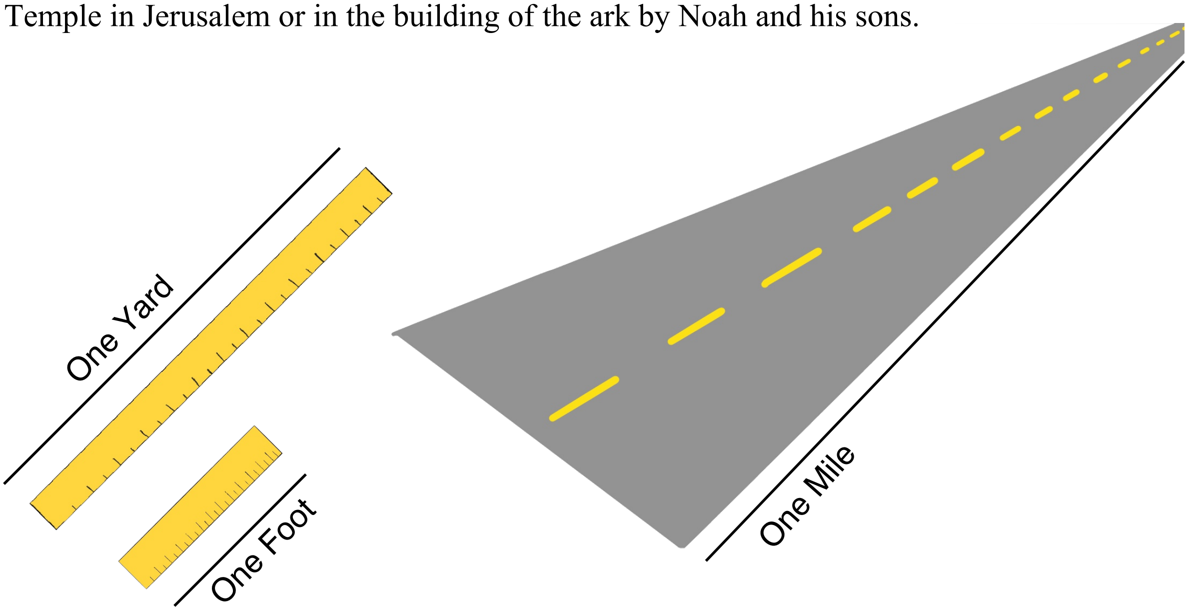


Conflicts can quickly arise when persons don't agree upon the standard of measurement they are using when buying and selling goods.

To combat these problems with establishing at least a nation-wide standard for measurement, government officials have stepped in to mandate that certain units be used. Eventually, these standards of measurement have spread across larger regions which has resulted in greater ease of commerce between individuals and countries. However, *adoption* of these standards may not always be the case. For example, while almost all nations of the world utilize the metric system of measurement, the United States is one of only three countries to fully adopt the metric system as its primary standard of measurement. Consequently, issues remain with conversion from one system to another.

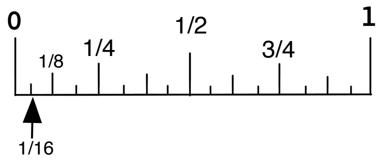
So, we've said that measurement is a comparison of an unknown amount to a known standard unit and that it's a very good idea to have persons agree upon the quantity of the standard amount. Let's go back now to our discussion of length.

We've said that length is a measure of the distance between two spots or points. Let's look now at the currently accepted standard units for length in the United States. You are likely very familiar with the system which utilizes inches, feet, yards and miles as the standard of measurement. This system is known as the English system. Most school rulers you find represent a foot which is thought by some to have had its origin in the cubit which was used by ancient Egyptians. You may have read about these cultures using the cubit in the description of the Temple in Jerusalem or in the building of the ark by Noah and his sons.



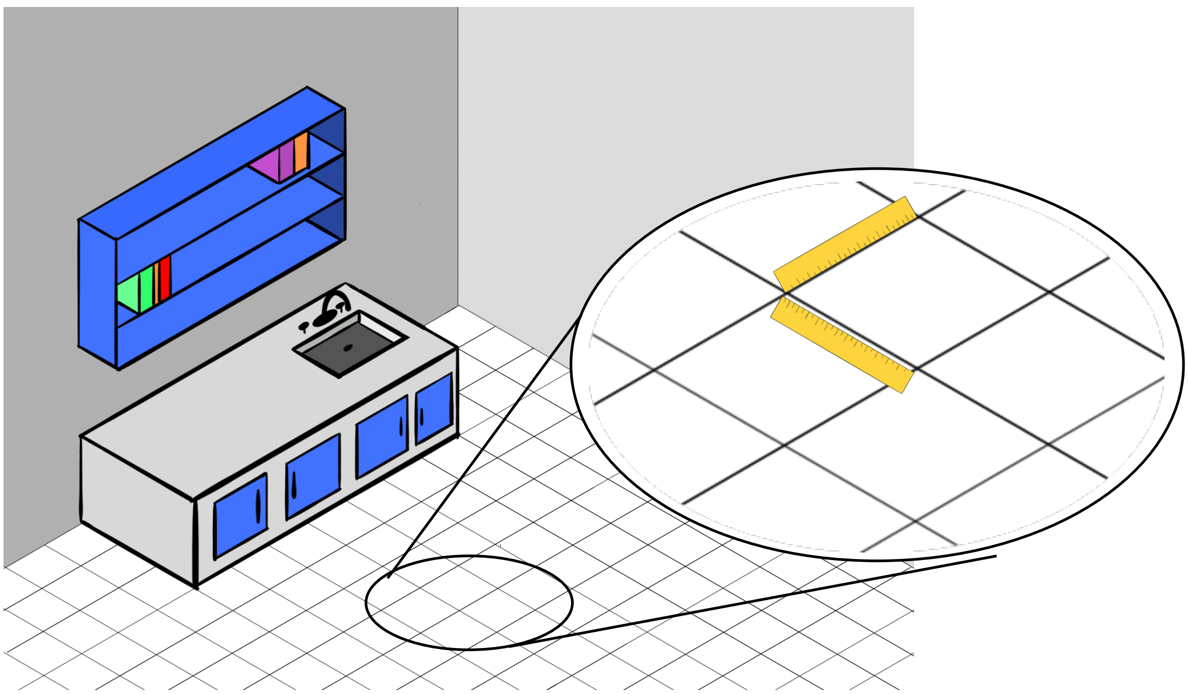
The foot is divided into twelve equal portions known as the inch. Therefore, twelve inches equal one foot. Three feet when placed end-to-end make up one yard. We can also say that 36 inches (3 x 12 inches) equal one yard. When 5280 feet are lined up end-to-end, we have one mile.

We can also take inches and divide them into smaller pieces to make the inch more useful for measuring smaller lengths. If we divide an inch into four equal parts, we'd be using one-fourth inch units. If we divided it into eight equal parts, each portion would be an eighth of an inch. If we divided it into sixteen equal parts, each part would be a sixteenth of an inch and so on.



Not drawn to scale.

If you're ever in need of measuring the length of something and don't have a ruler or yardstick handy, the distance from the tip of your index finger to your first joint on your finger is approximately one inch. Also, the standard size for floor tiles used in public places like schools and hospitals is 1 foot by 1 foot. Lining up three tiles side-by-side can help you measure a yard.



Remembering the numerical values and comparisons between the inch, foot, yard and mile and then the smaller parts of a portion of an inch can be challenging. This is a disadvantage of using the English system of measurement and where the metric system can be much more practical to use. The metric system is officially known as the SI or International System of measurement.

Unlike the English system of measurement, the metric system relies on the standard units being in multiples of tens. Because of this, the metric system is often referred to as a decimal system. The metric system has identified base units for length, mass (sometimes referred to as weight which we'll discuss in our next lesson) and time. The base unit for length is the meter. The base unit for mass is the gram. The base unit for time is the second. Multiples of these base units are in sets of tens and have a prescribed set of prefixes. On the chart below, you'll find several of the more commonly used prefixes. Let's take a closer look at them now.

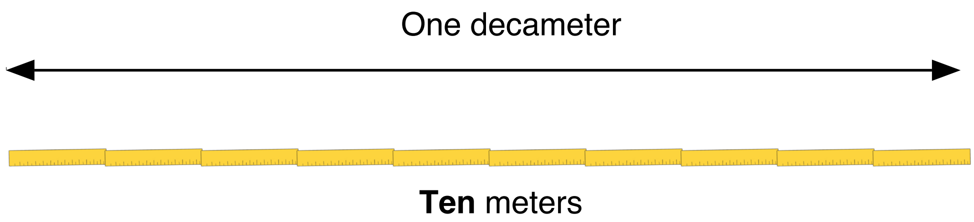
If we begin with the base unit for length as the meter and take ten of those lined up end-to-end,

Metric Prefix Table

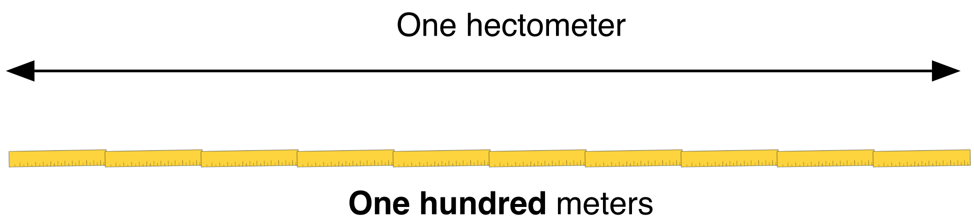
Prefix	Symbol	Multiplier	Exponential	
tera	T	1,000,000,000,000	10^{12}	
giga	G	1,000,000,000	10^{9}	
mega	M	1,000,000	10^{6}	
kilo	k	1,000	10^{3}	
hecto	h	100	10^{2}	
deca	da	10	10^{1}	
UNIT	NONE	1	10^{0}	← BASE UNIT
deci	d	0.1	10^{-1}	
centi	c	0.01	10^{-2}	
milli	m	0.001	10^{-3}	
micro	m	0.000001	10^{-6}	
nano	n	0.000000001	10^{-9}	
pico	p	0.000000000001	10^{-12}	

Example of how to read the table: If a unit has the prefix giga (denoted by adding G before the unit symbol), that unit is 1,000,000,000 (or 10^9) times bigger than the original unit. For example, a gigawatt (GW) is 10^9 times as big as a watt.

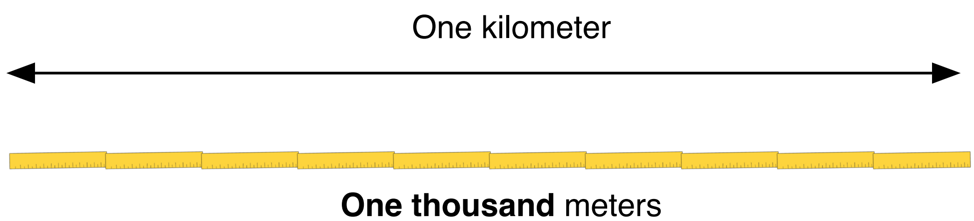
this length is known as a decameter. Think about a decade being a set of ten years. Therefore, a decameter is the same as 10 meters.



If we take ten decameters and line them up end-to-end (which is 10 x 10 or 100 meters) we have a hectometer. Look at the diagram here to see this relationship.



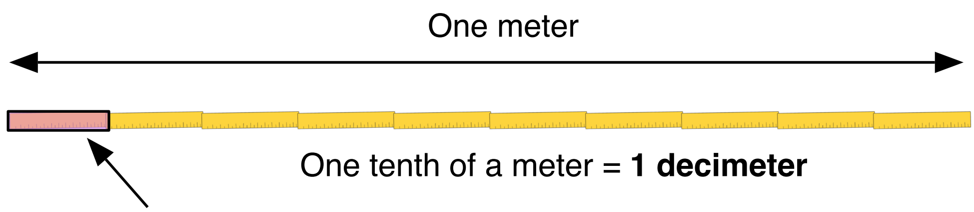
Then, if we line up 10 hectometers (10 x 10 hectometers or 10 x 10 x 10 meters = 1000 meters) we'd have a kilometer. So, there are 1000 meters in one kilometer!



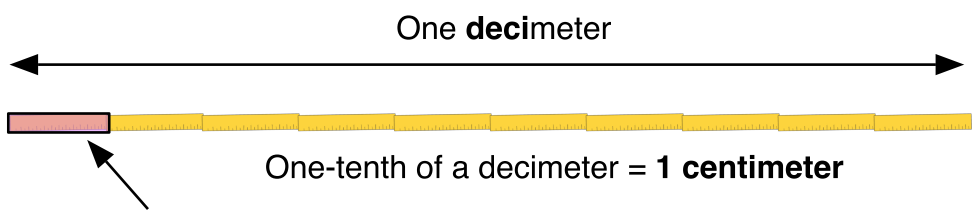
Take a look at the chart again to see the prefixes used for multiples of meters beyond the kilometer. Some of these prefixes may sound familiar to you in that they are used to describe the amount of "space" or memory found on electronic devices like your computer or cell phone. In these cases, the byte is the base unit.

As we mentioned above with the English system of measurement, the SI system is also useful when we need to measure very small distances. When dividing the base unit of length, the meter, into smaller pieces, another set of prefixes is utilized. These prefixes designate parts of the meter in parts of tens or more precisely in this case, multiples of tenths, hundredths, thousandths, etc.

If we take one meter and divide it into ten equal parts (see diagram below), each of these parts is known as a decimeter. We can say that one-tenth of a meter is a decimeter. We can also say that it takes 10 decimeters to make up one meter.



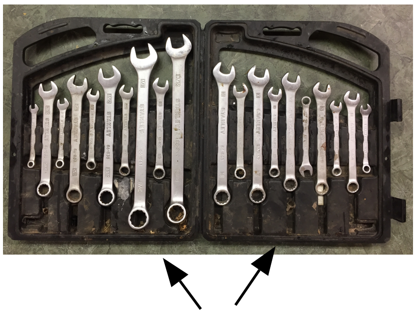
If we go one step further and divide each decimeter into ten equal parts, each of these parts is known as a centimeter. We can say that one-tenth of a decimeter is a centimeter. We can also say that it takes 10 centimeters to make up one decimeter.



Now, think for a moment. If it takes ten centimeters to make one decimeter, how many centimeters would there be in one whole meter? We have ten sets of ten, correct? This would make 100 total centimeters in a meter! We bring up this point because the prefix centi- refers to

100 as in century (100 years) or centurion (commander of 100 men in a military unit). Knowing that 100 centimeters are in a meter is very useful.

We'll go one step further in dividing meters because, like the centimeter, the next degree of division is frequently used in everyday life. Cars made outside the United States often require tools made for nuts and bolts in the metric system and the unit used is the millimeter. Car mechanics often have two sets of wrenches and sockets: one set with inches as the base unit and a second set with millimeters as the base unit.

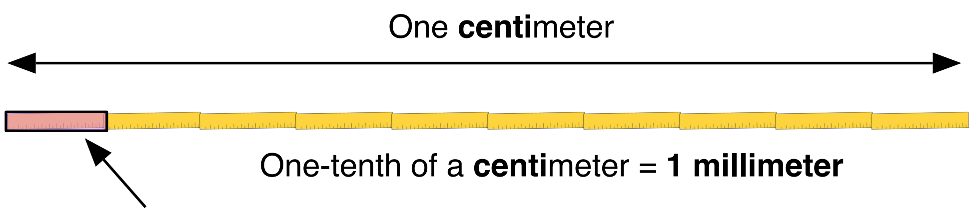


English system

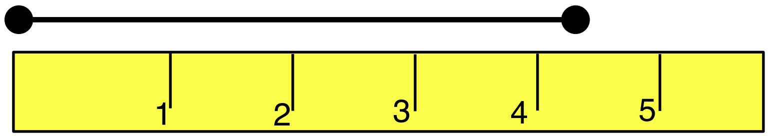
Metric system

Car mechanics often utilize two sets of wrenches. One set fits nuts and bolts in the English system (parts of inches) while the second set fits parts measured in the SI (metric) system.

If we take one centimeter and divide it into ten equal parts, each part is a millimeter. The prefix milli- means one-thousandth. So, if we have ten millimeters in each centimeter and there are 100 centimeters in one meter, we have 10 x 100 = 1000 millimeters in one meter. On most conventional meter sticks the smallest division is the millimeter. There are 1000 mm in a meter.



This brings up an important concept regarding how precise you can be when using measuring instruments. As we just mentioned, most meter sticks we have in today's world are made having the millimeter as the smallest unit. This means we can measure (with accuracy) to the nearest millimeter. We can, however, estimate beyond that measurement to a portion of a distance which happens to fall between two centimeter measurements. For example, suppose you've been asked to measure the distance between two points. When you place your meter stick to connect the two points, you find that the distance does not exactly end on one of the centimeter marks. You can then estimate to a degree beyond the centimeter measurement.



Not to scale.

Suppose your meter stick only had decimeter marks made on it. Consequently, you can be quite confident of a measurement which "lands" directly upon one of these decimeter marks. However, while it is permissible to estimate the length of distance which does not fall on one of these marks, your level of confidence in the accuracy of your result is decreased.

Don't let this discussion confuse you. Our purpose here is to make the point that we are definitely limited by the measuring tools we are provided with to make measurements.

Let's apply some of the concepts we've learned so far and practice measuring some lengths of lines. Using a ruler or meter stick, measure each line provided below. If you are using a "well-used" ruler (possibly having some of the marks rubbed away from years of use or that the end of the ruler is no longer as "correct" as it once was), know that it's "okay" to begin measuring your line at a point other than the zero mark. Just note that it's the difference of the two points which creates the distance between the two end points of the line. After you make your measurements, refer to the next page to see the measurements we found for each line. For this first set of lines, use the English system of measurements (inches).

LINE 1 ____ _____ inches

LINE 2 ____

_____ inches

LINE 3 ______ inches

LINE 4 ______ inches

Answers: Line 1: 3.0 inches Line 2: 5.0 inches Line 3: 1.5 inches Line 4: 3.5 inches

Now practice measuring these lines. Use the metric system of measurement (centimeters).

LINE 1 ______ cm

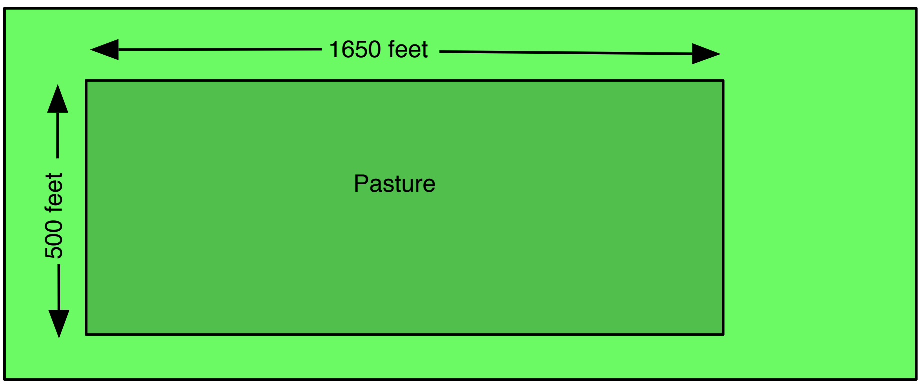
LINE 2 ______ cm

LINE 3 ______ cm

LINE 4 ______ cm

Answers: Line 1: 5 cm Line 2: 11 cm Line 3: 7 cm Line 4: 3.5 cm

Let's go back now to the example of building a fence around a pasture. Look at the diagram below which shows the dimensions of the pasture you intend to fence. How many feet of fencing will you need to fence this pasture?



Answer: 1650 + 500 + 1650 + 500 feet = 4300 feet.

Let's "switch gears" now and have *you* draw lines of specific lengths.

Draw a 3 inch line here:

Draw a 6 inch line here:

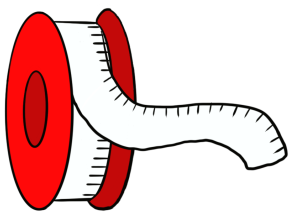
Draw a 12 cm line here:

Draw a 5 cm line here conected to a 7 cm line here:

Draw a straight line 5 cm longer than the line you just drew:

Have your mom, dad or teacher check your work.

Finally, know that the distances we need to measure may not always be in straight lines (or combinations of straight lines as you found in the previous exercise). Sometimes you may need to know the distance of a curved line. A cloth tape measure, like a seamstress may use, or piece of string can be useful for measuring a curved line. Carefully lay the string along the line and mark the beginning and ending points on the string. Then lay the string along your ruler or meter stick to find the length of the curved line.



A cloth tape measure makes measuring curved surfaces easier.

Let's pause now and review what we've learned in this lesson. We have learned that:

Physical science is the study of those things in our world which are NOT alive.

Measurement is important in studying non-living things.

Length can be defined as how long it is from one spot to another.

Measuring something means we are comparing what we're intending to measure to a standard unit.

Standards have to be agreed upon by persons using those standards.

The English system of length measurement utilizes inches, feet, yards and miles as the standard of measurement.

The metric system is officially known as the SI or International System of measurement.

The metric system relies on the standard units being in multiples of tens.

The base unit for length of the SI is the meter.

The base unit of the SI for mass is the gram and the base unit for time is the second.

Introduction to design challenges and labs:

In this course for each lesson you will find design challenges and/or labs. While these activities are optional for the course, you are highly encouraged to investigate and complete them. Let's look first at the design challenges.

The **design challenges** are projects in which you are challenged to create an object which meets certain specifications. These specifications are related directly to the concepts which were just presented in the lesson. They may also include concepts from previous lessons. These are fun, yet challenging projects and may require a good bit of time (and patience) to complete. We recommend you not place a deadline on them for completion, yet work efficiently to get the job done.

Supplies for these challenges can be just about anything you have around the house such as popsicle sticks, pipe cleaners, card stock, thread spools, soda straws or rubber bands. Items you can find at a craft store such as balsa wood sticks or strips, foam board, wooden dowels and wheels are highly recommended. Wood glue or hot glue to assemble these parts will also be necessary.

Simple tools such as scissors, a hand saw or drill will come in handy.

The labs, on the other hand, are activities similar to labs you have likely done in other science courses. They each have an objective or purpose which is fulfilled by gathering certain materials and equipment and then carrying out a prescribed procedure with the goal of experiencing an expected result. Like the design challenges, each may take a varying amount of time and effort to acheive the best results. Each lab requires materials you can find around your house or at your local grocery or hardware store.

For lesson 1, there are two design challenges. Each is relatively simple, yet provide you with opportunities to practice the concepts you've just learned about. We recommend you do them in order.

Design Challenge 1: In this challenge, you'll need to cut five lengths of wooden sticks. Pay close attention to the units you are being asked to cut. A good adage used by carpenters who build houses or furniture from wood is "measure twice, cut once" (meaning take your time and measure the specified distance two times, then make the cut). Doing so will greatly enhance your chances of an accurate cut. With each cut you make, your skill will be better and better.

Stick 1: cut a stick that's 4 inches in length.

Stick 2: cut a stick that's 6 ½ inches in length.

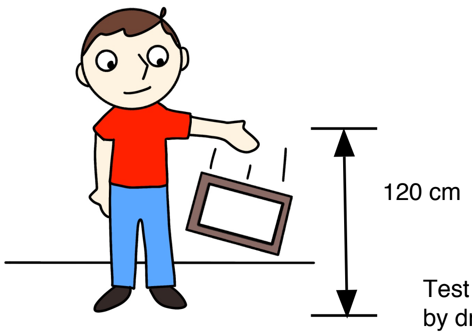
Stick 3: cut a stick that's 7 centimeters in length.

Stick 4: cut a stick that's 10 centimeters in length

Stick 5: cut a stick that's 0.7 decimeters in length

Design Challenge 2: In this challenge, you will need to build frame for a photo or picture. The frame needs to have the following dimensions (dimensions is just a "fancy" word for measurement): the inside opening needs to be 15 centimeters from the left edge to the right edge. The opening needs to be 10.5 centimeters from the top to bottom edge. The frame needs to be sturdily built. The test for sturdiness is as follows: the frame can be dropped from a height of 120 cm to a solid surface and not break.

You are strongly encouraged to make a drawing of your project before you begin actually building the frame. Making the drawing from two views such as from above or from the side can be very helpful to visualize the ideas you have. These drawings can help you identify problems you have in your design *before* you start cutting any pieces of supplies. A computer drawing program such as the free Google Sketchup (www.sketchup.com) can help you make these drawings.



Test the sturdiness of your picture frame by dropping it from a height of at least 120 cm onto a hard surface.