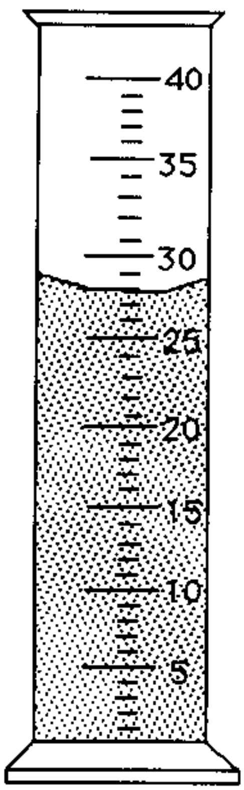
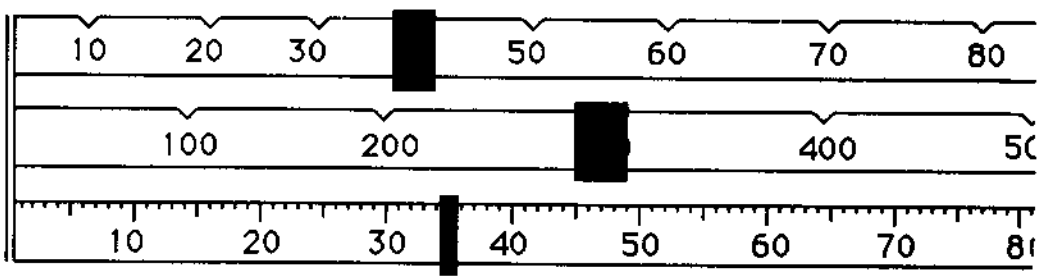
The Scientific Method And Scientific Measurement

A Unit of Study



Teacher's Guide



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The Scientific Method
and
Scientific Measurement

Unit of Study

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Teacher's Guide

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A Unit of Study

TEACHER'S GUIDE FOR

THE SCIENTIFIC METHOD AND SCIENTIFIC MEASUREMENT

A SCIENCE VIDEOTAPE PRESENTATION

GENERAL DESCRIPTION

This video-based presentation is designed for use in intermediate and junior high grades. Follow-up materials in the form of reproducible blackline masters reinforce the concepts presented and encourage further exploration through experimentation.

It is the overall goal of the producers to stimulate interest in science and to promote the exploration of science through hands-on involvement. All experiments, either demonstrated on tape or described in the blackline masters, are easy to perform and require handy, inexpensive supplies.

UNIT GOALS

After viewing this videotape and participating in the related activities, students should be able to:

- Identify the steps in the scientific method.
- Distinguish between the work of philosophers and the work of scientists.
- Identify units of measurement used in the English and metric systems of measurement.
- Make measurements using lab equipment, such as the balance scale, graduated cylinder, thermometers, and metersticks.
- Distinguish between weight and mass.
- Calculate the density of various objects.

MATERIALS IN THE UNIT

Videotapes

This unit contains two live-action videotapes. The titles and themes of each video is described here:

1. THE SCIENTIFIC METHOD
   This video describes how the scientific method developed as the popular approach used by scientists worldwide. The difference between philosophers, such as Aristotle, and scientists, such as Galileo, are shown. Aristotle believed that heavy objects would fall faster than lighter objects but never tested his ideas. Two thousand years later, Galileo decided to test the idea. Galileo is

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often credited with developing the method used by scientists to conduct experiments.

2. SCIENTIFIC MEASUREMENT
   This video introduces students to the English and metric systems of measurement. Early systems of measurement depended upon body parts, such as the digit, which was the width of a finger, or the cubit, which was from the elbow to the end of the index finger. In the 1700's, the French established the metric system based on the distance between the North Pole and the equator. This system of measurement is easy to use because it is based on powers of ten.

Teacher's Guide
This guide has been prepared to aid the teacher in utilizing materials contained within this unit of study. In addition to the introductory information, the guide contains the following:

- Suggested Instructional Procedures for each lesson.
- Activities for each lesson.
- Answer keys for blackline master activities.

Student Activities
Included in this unit of study are 11 student activities in the form of blackline masters for xerography duplication. These activities are designed to reinforce the information in the videotapes as well as provide extended learning activities for the students.

It is suggested that you preview this video and read the related Suggested Instructional Procedures before involving your students in the activities. In this way, you will become familiar with the materials and be better prepared to adapt the program to the needs of your class.

As you review the instructional program outlined in this Teacher's Guide, you may find it necessary to make some changes, deletions, or additions to fit the specific needs of your class. We encourage you to do so, for only by tailoring this program to your students will they obtain the maximum instuctional benefits afforded by the materials.

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LESSON 1
THE SCIENTIFIC METHOD
Time: 17:04

Suggested Instructional Procedures

A. Teacher Preparation

1. Preview the video.

2. Duplicate the 4 activity sheets for this lesson.

Video Summary:
The scientific method is used throughout the world by scientists in their quest for understanding and knowledge. The method was developed back in the 1600's by Galileo. It has varied through the years but is basically comprised of the following steps:

1. A problem is recognized.
2. A hypothesis is established.
3. An experiment is set up and conducted.
4. Observations are made.
5. A conclusion based on the experimental results is established.

B. Student Objectives
After viewing this live-action video and participating in the lesson activities, the students should be able to do the following:

- List the steps of the scientific method.
- Distinguish between the work of philosophers and the work of scientists.
- Explain the importance of observation to the work of scientists.
- Describe the need for careful experimentation with a control and only one altered variable.

C. Videotape Presentation

1. There are more scientists alive today than all the scientists of the past combined. This explains why there are so many exciting discoveries and inventions occurring in our time. There are, on the average, somewhere betwee 5,000 and 6,000 scientific documents written each day worldwide. These are indeed exciting times in which to live. Scientists around the world are contributing to our body of knowledge at an incredible rate. Scientists have inquiring minds that want to discover answers to the challenging questions of our natural world. Scientists must use an organized approach to

their experimentation, and that's where the scientific method comes into play.

2. Present the video.

D. Follow-up Activities

1. Activity sheet **"Optical Illusions"**
   Observation is critical to the work of scientists. This activity is designed to show how our eyes can be tricked.

2. Activity sheet **"Experiment Write Up Form"**
   This activity is designed as the basic outline or form for writing up an experiment. Students can use it for any experiment they conduct as a way to provide feedback on the experiment and its results.

3. Activity sheet **"Ice Cube Survival Test"**
   This is a challenge to students to develop a method for keeping an ice cube in its solid state for as long as possible. The students should bring in the materials they wish to use for this experiment. Use the Experiment Write-Up Form for students to report on their experiment.

4. Activity sheet **"Operation Egg Drop"**
   Here is an experiment that will really challenge students. They are to design a container no larger than a shoebox to protect a raw egg from a fall of 50 to 60 feet onto cement. See if a custodian can help by going to the school roof and dropping each container, one at a time, onto the pavement below. This makes a great experimental write up so include the write up as part of the experiment. Also, it is important to help students understand that if their egg drop fails, that is perfectly all right. Scientists fail more often than they succeed. They have to realize that every failure can bring them closer to success.

E. Class Discussion

1. Discuss the difference between a philospher like Aristotle and a scientist like Galileo. How is it possible that Aristotle's ideas about falling objects were accepted and believed for so long?

2. Review the steps of the scientific method.
   a. A problem is recognized through observation.
   b. A hypothesis is established to try and explain a solution to the problem.
   c. An experiment is set up and performed.
   d. Observations are made and data collected.
   e. A conclusion is written based on the observations from the experiment.

3. Here is an example of how important it is to use the scientific method. The caribou herds in Alaska were showing a decline in numbers. The Alaskan government thought that the problem rested with the predators of

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the caribou, the wolves. Caribou are like large deer and wolves are their natural enemies. So the state government paid people to shoot and kill the wolves. Fifty dollars was paid for every left ear of a wolf. After a few weeks, another counting of the caribou herds was made, and surprisingly, the results were even worse. More caribou died than before.
Finally a biologist was called in to investigate. He found that killing the wolves had made things worse because he knew that a healthy caribou could easily outrun a wolf. The wolves actually provided a service to the caribou. The wolves fed on the sick or old caribou. When people were allowed to shoot and kill the wolves, the caribou herd suffered because the sick ones were spreading disease. So the Alaskan government had made things worse by killing the wolves. The caribou herds had originally started to dwindle as a natural cycle. The scientist should have been called in right away.

F. Answer Key

- OPTICAL ILLUSIONS

1. AB and CD are the same. They are 6 cm.
2. EF and GH are the same length 1.4 cm.
3. BC appears longer than AB. AB and BC are each 2.5 cm.
4. They are the same size.
5. They are the same size.

- EXPERIMENT WRITE UP FORM

This is a form that can be used by students to write up experiments.

- ICE CUBE SURVIVAL FORM

Answers will vary.

- OPERATION EGG DROP

Answers will vary. Share different ideas and help students realize that the egg must be able to move with the impact. There is no way to know in advance which side of the container will land first, so the egg must be protected on all sides with material that will allow for some shifting. A baseball player doesn't try to catch a ball with a stiff mitt.

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THE SCIENTIFIC METHOD
SCRIPT OF VIDEO PRESENTATION

Is this what you think of when you hear someone say the word scientist? Lab coats, test tubes, and some weird experiment gone wild. These are the things Hollywood would have us believe. For many people, this is the image they have of a scientist. Of course, it is far from the truth.

Actually, most scientists today work in teams because everyone knows teamwork often accomplishes more than individuals working alone. When people work together on a project, there is a better chance for the brainstorming of ideas and creative thought. Often one person's idea will help other people to generate new ideas or solutions. Here at Fermi Lab in Batavia, Illinois, teams of scientists are working together to explore the basic building blocks of all matter. The key here is teamwork and cooperation.

Scientists are really just normal people who have a keen interest in their world and the workings of mother nature. Through their desire to learn about nature, there have been an unbelievable number of inventions and discoveries made. From electric pop-up toasters to space vehicles that carry people and satellites into orbit, science is about finding out about things. It's a search for answers. Scientists are always asking questions and then trying to explain things through experiments and observations. A scientist is like a detective gathering clues, investigating leads, and evaluating observations.

In the old days thousands of years ago, the search of knowledge used to be called philosophy. The word philosophy comes from the Greek language. The word *philos* means loved and *sophia* means wisdom. So philosophy is the love of wisdom.

Philosphers were considered to be the wisest of people and their teachings and ideas were respected without question. One of the most famous philosophers was Aristotle, who lived over 2000 years ago. He was so respected that people believed anything he said. The problem was, he wasn't a scientist; he never tested any of his ideas.

Aristotle once proclaimed that heavy objects fall faster than light ones. Because he had such a reputation as a great thinker, people believed what he said for 2000 years after he died. In fact, it wasn't until the scientist Galileo Galilei, living in the 1600s, conducted experiments to see if heavy objects fall faster than light ones. He rolled different marbles down a ramp and timed how long they took. He found that weight didn't affect how fast they fell.

One story says that Galileo conducted an experiment at the top of the Leaning Tower of Pisa. The story says that he dropped two different sized cannon balls.

This really isn't the Leaning Tower and this is an actor, not Galileo. Oh, and the actor will drop a softball and a shot-put instead of cannon balls. Well, here it goes. And the two land together, even though the shot-put is many times heavier than the softball.

Aristotle was wrong, but people believed what he had said for so long because it

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seemed to make sense. Aristotle probably observed something like an acorn fall and hit the ground. And then he probably compared that to something lighter, such as a leaf. Observing the falling of these two things led him to believe heavy objects fall faster than lighter ones. He never tested his ideas.

A scientist doesn't make statements of fact unless they have backed it up with experiments and tests. That's what separates philosophers from scientists.

What Aristotle forgot to take into consideration was the effect air pressure has on falling objects.

For instance, these two pieces of paper weigh exactly the same. One is crumpled up and then the two are dropped together. The crumpled one lands first because air gets in the way of the uncrumpled paper.

In this case, the book is hundreds of times heavier than the single sheet of paper. If we drop them together, the book lands first. However, if we put the paper on top of the book so that air doesn't get in the way, the two land together.

In the vacuum of space where there are no gases to get in the way, all things fall at the same rate. In fact, these Apollo astronauts conducted an experiment to prove that Galileo was correct. A hammer and a feather were dropped together on the surface of the moon. As you can see they land together.

The word science comes from an old Latin word *scientia* , which means knowledge. Science is becoming so specialized that it is being divided into smaller and smaller areas or fields of study. There are physicists, botanists, chemists, biologists, and many more. The suffix "ist" means one who specializes in something.

Galileo and the Englishman Francis Bacon are considered the founders of a method of investigation that is now referred to as "the scientific method." This method was introduced in the 1500's. It is organized into logical steps. The first step was to recognize a problem. This meant observing nature and the world around us and recognizing a problem.

Next, a hypothesis, which is an educated guess, is established. This is a way of explaining the problem or situation.

Then a prediction, or series of predictions, is made to explain the consequences of the hypothesis.

Next, experiments are performed to test the predictions and the hypothesis.

Finally the results of experimentation are evaluated and a conclusion concerning the original hypothesis is established.

Scientists are wrong more often than right, but they use this newly-gained knowledge to help establish a new hypothesis.

Scientists must know how to deal with failure. When data and results of experiments

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don't turn out as expected, they must rethink the problem and establish new ideas and experiments.

If a hypothesis stands up to many experiments, then it can become a theory. If a theory seems to be correct in all cases, it will become a scientific law.

However theories and laws can change. They are being tested all the time. If a new observation shows a theory or law to be incorrect, then it is changed or even dropped.

This method has been used throughout the world for the past few hundred years with great success. Yet, as good as the method is, it does not account for all scientific discovery. There have been many cases of discovery by trial and error.

An example is that Thomas Edison tested hundreds of metals for the filament of the lightbulb before he found the right combination of a tungstun wire in an airless environment.

Sometimes scientific discoveries are made by accident.

Becquerel found out about radiation when he placed a radioactive sample of uranium in a drawer with unexposed film. Later, when he went to the drawer, he found that something had exposed the film and a connection was made to the uranium sample.

Success in science has to do with a common attitude among scientists to strive for answers through experimentation. Scientists have a natural curiousity about nature and how it works.

As you can see, observation is a very important part of the scientific method. Observation is needed to discover a problem. Then, during the process of experimentation, observations are critical to collecting data and results.

It is important for scientists to be careful observers because it is possible for our senses to be fooled.

Read the message to yourself. (Pause) Did you read "She saw the birds sitting on the birdhouse"? Well, look again because it really says, "She saw the the birds sitting on the birdhouse."

Our sense of sight can be fooled if we aren't careful. Over the years scientists have tried to develop equipment that can help with observations.

One important discovery was made by an amateur scientist named Anton Van Leeuwenhoek who was interested in finding out about pepper. He thought that pepper must have a very gritty, sharp surface because it can make us sneeze. He made magnifying lenses and a simple microscope that were the most powerful of his day. He made an instrument to help the sense of sight. This led to better and better magnifying instruments that can open up the invisible world of the extremely small to our vision.

He found that pepper was really round and smooth, which disproved his hypothesis, but it led to so much more.

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It wasn't long before he started looking at pond water and found one-celled animals swimming about.

One experiment can lead to other ideas and further experimentation.

Here is an on-going experimental site in the Great Smokey Mountains. The scientists here are interested in finding out more about the effects of ozone on plant life. They have set up these domes to house different test situations. Each dome has the same number and variety of plants to be studied. All plants receive the same amount of water and sunlight. The water and sunlight are called variables. Anything that may change or vary in appearance or form is called a variable.

When conducting an experiment, it is important that the variables are controlled so that only one variable is tested.

In the case of this ozone experiment, the variable is the amount of ozone gas introduced into each of the different domes. Each dome receives a different amount of ozone gas. One dome receives no ozone gas. That dome is the control for the experiment.

The control in an experiment is the standard for comparison. Results from the other domes will be compared with the control. Every day the plants are measured for growth. The number of leaves are counted, and the height of each plant is recorded. These scientists even have a special sensor that can determine the amount of photosynthesis that takes place. The sensor compares the exchange of carbon dioxide and oxygen from selected leaves and then can determine the amount of food making carried on by the plant.

When experimenting, scientists must be sure that they are only testing one variable. They must have more than one test subject and obviously careful observations and recorded data is crucial to understanding the outcome.

So, in review, the scientific method developed by Galileo and Bacon back in the 1500s has helped scientists worldwide organize their approach to learning about our world.

The method itself is organized in a series of steps starting with recognizing a problem. Then additional observations are made to learn as much as possible about the problem. Then a hypothesis or educated guess is made to try to answer the question or problem at hand. Then an experiment is developed to test the hypothesis.

During the experiment part of the process, care must be taken to only test one variable. A control is needed for comparison. Data and test results must be carefully observed and recorded.

Once the experiment is completed, the results are analysed and interpreted. If the hypothesis is disproved, then it is rejected and a new hypothesis may be written. If the hypothesis holds up to the experiment, then further testing may be carried out. If it continues to hold up under many experiments, it may become a theory. And if the theory seems correct in all cases, then it may become a scientific law.

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Scientists must be able to deal with disappointment and failure. They should understand that each failure adds to knowledge and can lead closer to the final solution to problems. Scientists have inquiring minds that want to discover answers to the challenging questions of our natural world.

Technology is the use of science in a practical way. Signs of technological advancement are all around us. Science and technology are not the same, but they are connected.

Scientific knowledge is used to develop new inventions and new inventions help to make further scientific discovery and it's the desire of scientists to find out about the unknown that keeps the whole sequence going.

Back in the early 1900s, the United States Patent Officer in charge of patenting inventions suggested that the office be closed. He reasoned that everything useful to man had now been invented and therefore the office was no longer needed. He made a slight error, especially when we consider everything that has happened since the early 1900s.

There will never be an end to the human desire to create, invent, and explore. Humans are interested in knowledge. Discoveries of one kind lead to fresh questions and problems. It is a cycle that will never stop.

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LESSON 2
SCIENTIFIC MEASUREMENT
Time: 21:06

Suggested Instructional Procedures

A. Teacher Preparation

1. Preview the video.

2. Duplicate the 7 activity sheets for this lesson.

Videotape Summary:
This video is about the English and metric systems of measurement. It describes some of the key measurements used in ancient time, such as the digit and cubit. It describes the English system and how the metric system was developed. Laboratory measuring equipment is shown and directions for their proper use are provided.

B. Student Objectives
After viewing this live-action video and participating in the lesson activities, the students should be able to do the following:

- Identify some early units of measurement, such as the digit, palm, span, and cubit.
- Identify some common English measurements.
- Describe how the metric system was established.
- Change from one unit of the metric system to another by moving the decimal point.
- Calculate volume and density of different objects.
- Use various laboratory equipment to make measurements.

C. Videotape Presentation

1. This video is about the importance of careful and proper laboratory measurements. The use of equipment is described and demonstrated. The English and metric systems of measurement are presented and contrasted.

2. Present the video.

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D. Follow-up Activities

1. Activity sheet **"The Metric System"**
   This activity is designed to provide practice with changing from one unit to another in the metric system.

2. Activity sheet **"Reading Graduated Cylinders and Measuring Line Segments"**
   This activity is for practicing measuring with graduated cylinders and rulers.

3. Activity sheet **"Using The Triple Beam Balance"**
   This activity is for quick practice making measurements with a balance scale.

4. Activity sheet **"Measuring In The Metric System"**
   This activity could be used as a quiz for it covers many measurement situations.

5. Activity sheet **"Finding The Density Of Water"**
   This experiment is designed to have students calculate the density of water.

6. Activity sheet **"Finding The Density Of Wood"**
   This experiment is a good follow-up to the previous experiment. This one has students calculate the density of wood.

7. Activity sheet **"Finding The Density Of A Rock"**
   This is a good experiment to help demonstrate how water displacement can be used to measure the volume of something that has an odd shape.

E. Class Discussion

1. Have students measure their desks in digits, palms, spans, and cubits. Compare results and discuss why they vary so much.

2. Discuss why the metric system is easier to use than the English system.

3. Only the United States and Burma use systems of measurement other than the metric system. Why doesn't the United States switch over to the metric system? What are the problems of such a switch? How could a switch be beneficial to the United States? (*The United States loses a great deal of trade every year because our products are measured in English units while the rest of the world uses the metric system. It would be difficult to change over because it would mean resizing machinery used in manufacturing.)*

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F. Answer Key

- THE METRIC SYSTEM

    1 millimeter equals .001 m
    1 centimeter equals .01 m
    1 decimeter equals .1 m

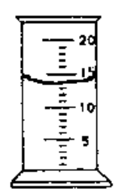
    1 dekameter equals 10 m
    1 hectometer equals 100 m
    1 kilometer equals 1000 m

    1 milliliter equals .001 L
    1 centiliter equals .01 L
    1 deciliter equals .1 L
    1 dekaliter equals 10 L
    1 hectoliter equals 100 L
    1 kiloliter equals 1000 L

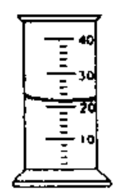
    1 milligram equals .001 g
    1 centigram equals .01 g
    1 decigram equals .1 g
    1 dekagram equals 10 g
    1 hectogram equals 100 g
    1 kilogram equals 1000 g

- READING GRADUATED CYLINDERS AND MEASURING LINE SEGMENTS

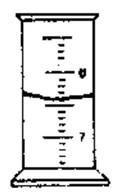
1. 12 ml
2. 32 ml
3. 1.6 ml
4. 18 ml



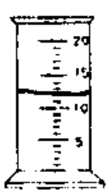
5 14 ml



6 22 ml



7 7.6 ml

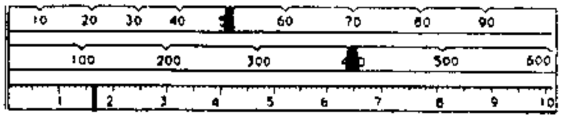


8 12.5 ml

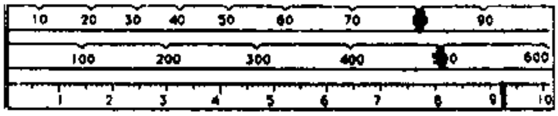
9. 7.5 cm 10. 4.3 cm 11. 10.6 cm 12. 6.7 cm 13. 12.2 cm

- USING THE TRIPLE BEAM BALANCE

1. 434.5 g
2. 266.3 g

3


3 451.7 grams

4


4 589.3 grams

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- MEASURING IN THE METRIC SYSTEM

1. height = 1.5 cm length = 3.4 cm width = 4 cm
2. 13 ml
3. 467.5 grams
4. 9 cm3
5. a. 4.3 cm b. 6.6 cm c. 1.5 cm d. 3.5 cm

- FINDING THE DENSITY OF WATER

Conclusions: The density of water is 1 gram per cubic centimeter.

- FINDING THE DENSITY OF WOOD

Conclusions:
1. The density of water is 1 gram per cubic centimeter.
2. The density of wood is less than 1 gram per cubic cm.
3. Wood floats because it is less dense than water.

- FINDING THE DENSITY OF A ROCK

Answers will vary. The rock will have a density greater than the density of water, so the rock sinks.

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SCIENTIFIC MEASUREMENT
SCRIPT OF VIDEO PRESENTATION

Measurement is happening all around you--- How far did the car drive? How much flour for the cake? How fast can you run? And what is the temperature for today?-- are all examples of daily measurements.

Humans have used systems of measurement for thousands and thousands of years. Most of the early systems were totally based on body parts. For instance, the Egyptians used units, such as the digit, which was the width of a finger; the palm, which was the distance across your four fingers; the span, that extended from your pinky to the tip of your thumb; and the cubit, which was from the elbow to the tip of the middle finger. So to measure a table we might say one cubit, one span and a digit wide.

The nice thing about this system was everyone carried the necessary measuring tools with them at all times.

However, what would happen if everyone in your class was asked to measure a lab table and then construct a cardboard model of the lab top at home? What would we find the next day at school when everyone brought in their cardboard models? (pause) Did you think that they would all be different sizes? No, actually they would all be the same as long as everyone measured carefully.

You were probably thinking that everyone has different sized digits, palms, spans, and cubits--and you're right, but as long as each person is using their own measurements and their measuring tools that they carry with them, then their model should be the same size as the original tabletop. However, if someone forgot their measurements at school and they called a friend for the missing information, there would be a problem. So, even though the system was based on body parts, it worked as long as one person did the measuring. The problems arose when someone in one town asked to have a stool made and gave measurements with their units when the craftsman ended up using his units. Unless the people were exactly the same size, there would be trouble.

The English used units of measurements that were set up and established by kings, queens, and other rulers. In fact, this measuring device is called a ruler because it was probably based on a ruler's foot size.

Of course the problem was that as new people took rule, their body parts became the new units of measurement. It was finally decided that the units of measurement needed to be standardized. That is to say, they needed to be agreed upon as a certain amount or length. As an example, the English used the length of Queen Elizabeth's arm as the value of a yard.

The French were also trying to decide on a system of standardized measurement in the 1700s. They didn't stick with a system based on body parts such as the English.

Instead, the French invented a new system based on the meter as the base unit of length.

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The French had just calculated the distance from the North Pole to the equator and decided to make one ten-millionth that distance the length of a meter. They made a master copy of this distance on a bar of metal made of platinum and iridium. This bar is kept in a vault under the same temperature both night and day so that it won't expand or shrink.

This new system that the French developed is easy to use because it is based on powers of ten. For measuring lengths greater than a meter, units were used that were 10 times, 100 times, and 1,000 times larger than the meter. The decameter is 10 meters, the hectometer is 100 meters, and the kilometer is 1,000 meters long.

For measuring lengths smaller than a meter, the decimeter, centimeter, and millimeter are used. The decimeter is one-tenth the size of a meter. The centimeter is one one-hundredth the size of a meter. The millimeter is one one-thousandth the size of a meter.

Another way of thinking of these small units is that there are ten decimeters in one meter; there are 100 centimeters in a meter; and there are 1,000 millimeters in a meter.

This system is used all over the world. In fact, the metric system is the most popular system in the world. The sad thing is that the United States is the only major country that still depends on a system based on Queen Elizabeth's arm. Not even England, the country that developed the system, uses it any longer. England, like the rest of the world, uses the metric system. Scientists worldwide use the metric system because it is logical and easy to use.

Let's look more closely at the system to see why it's so popular.

First of all, as stated before, it is based on powers of ten. There are base units of length, volume, and mass. The unit for length is the meter. The base unit for volume is the liter, and the base unit for mass is the gram.

Then all people need to know are prefixes that identify the different larger or smaller units of measurement.

There are six prefixes to remember for all these possible powers of ten. Here they are: The prefix "deca" means ten times greater. "Hecto" means one hundred times and "kilo" means one thousand.

On the other side of the base units are these prefixes. The "deci" means one tenth. The prefix "centi" means one one-hundredths and the prefix "milli" means one one-thousandth. The prefixes always mean the same thing whether we are talking about meters, liters, or grams.

Scientists use graduated cylinders to measure volume. Volume is the amount of space a substance occupies. The graduates come in different sizes but are all marked off in easy-to-read divisions. Here are three different sized graduates. Which would be the most exact? (pause) If you look closely you will see that the smallest graduate is marked off with the most exact markings.

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When reading a graduated cylinder, care has to be taken.

As you can see, the fluid you are measuring is curved inside the cylinder. To determine the level of the fluid, a scientist looks at the bottom of the curved surface. This is called the meniscus. The mark closest to the meniscus is the reading for that liquid.

When making a reading, it is essential that the graduated cylinder is sitting on a flat, smooth surface. You can't get a good reading while holding the cylinder in your hand.

To measure mass, a platform balance or a balance scale is used. The object being massed is compared with the mass of known measures. In the case of the platform scale, the unknown is placed on one side and known masses are used on the other side to reach a balanced condition. The known masses are totalled to determine the mass of the object.

On a balance beam the known weights are already attached to the scale and are simply moved over to reach a balanced situation.

Either of these scales can be used to get very exact results. They can measure as little as a hundredth of a gram. When you consider that a paper clip is about one gram, you can see that these instruments are very exact. Here is an equal arm balance used for very small measurements. Notice that this is a very delicate and precise instrument.

This brings us to a often confused concept of measurement. The terms weight and mass are often thought of as the same thing. People use the two terms to mean the same thing. This is a grave mistake because weight and mass actually measure two different things.

Weight is the amount of gravitational pull on an object. The weight of an object is a determination of how strongly gravity is pulling down on that object. We usually measure weight with a spring scale. A spring inside the scale is stretched by the pull of gravity on the object.

But strength of gravity changes from place to place. For instance, a person who weighs 60 kilograms on earth would only weigh 10 kilograms on the moon. The moon is about one-sixth the size of the earth, and it therefore has much less gravity. That's why this lunar rover is bouncing around so much on the moon where everything would weigh less.

However, the mass of an object isn't affected by changes in gravity. That's because the mass of an object is a measure of the amount of matter in an object. If we take the balance scale to the moon, the weights are affected as much as the object being massed, so the reading is the same as on earth.

For most situations on earth, mass and weight will appear the same, but it is important to know that they are really measuring different things.

Now let's see how easy it is to make very precise measurements using the metric system. If we were to measure the length of this piece of wood with a meter stick, this is what we would get. The piece of wood isn't as long as the meter and it comes closest to the 73 mark. The 73 stands for 73 centimeters. So we could say the wood is 73 centimeters long. If, for some reason, we needed this length in different units we could easily make the conversion. That's because the metric system is based on powers of ten and it's a decimal system. Our money system is a decimal system, and I bet you do just fine with it.

So here is how we change from one unit to another in the metric system. We'll use this chart to help show what's going on. The board is 73 centimeters long, so we'll write that here under the centimeter column. Now, if we need to know how many meters that is we will just move the 7 and 3 over to the meter column and then move the decimal point the same number of places in the opposite direction.

See, we move two places to the right on the metric chart, so we will move two decimal places to the left on the number.

Our answer is point seven three meters. In fact all of these numbers represent the same amount; they are just written with different units. Notice the digits, the seven and the three stay the same. The thing that changes is where the decimal point is written.

This makes the metric system a much easier system to use when converting from one unit to another. If we measured the same board in the English system, we would get 28 and 11/16 inches. To change this measure into feet, we would have to divide 28 by 12 because there are 12 inches in every foot.

There is a greater chance for making a mistake when you have to divide or multiply numbers. Remember, in the metric system there is no need to divide or multiply; just move the decimal point. Also the metric system uses decimals instead of fractions.

There would be no reason to learn fractions if we used the metric system instead of the English system. Yes, you heard me right. Just imagine no need to add, subtract, multiply, or divide with fractions. No need for equivalent, improper, mixed, and proper fractions. The only time we use fractions is when we measure in the English system.

Let's look at another example of converting from one unit to another in the metric system.

How much juice do we have? Well, we pour it into a graduated cylinder and find that it is between the 40 and the 50 mark on the cylinder. The lines on this graduate mean milliliters, so the volume of this liquid is 45 milliliters. We can easily change this to any other unit by moving the decimal point.

Now, if we had a larger amount of liquid, lets say one point five liters, we could change it to any unit easily. The number of milliliters is 1,500. Remember, no multiplying or dividing with awkward units; just move the digits and then move the decimal point, which is like multiplying or dividing by ten.

Temperature is another important measurement that scientists use in their work.

There are three different temperature systems that are used. You are probably most

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familiar with the Fahrenheit system that is used in the English system.

In 1714, Gabriel Fahrenheit invented a system for making measurements of temperature. His system was based on what he thought would be the lowest possible laboratory temperature. In his day, the lowest temperature came from a mixture of ice and salt. He placed a glass tube filled with mercury in such a mixture, and when the mercury stopped dropping, he marked the spot and labeled it zero.

It is thought that to get his other reference point, he put the thermometer in an assistant's mouth and marked that spot 100. He then divided the distance between these two spots into 100 equal markings. Each mark was a degree. On this scale, water freezes at 32 degrees and water boils at 212 degrees.

In 1742, Andres Celsius, a Swedish scientist, designed a new thermometer. It was based on one hundred steps, so was called the centigrade scale. "Centi" means hundred. Celsius decided that zero would be the freezing point of water, and the boiling point of water would be 100 degrees. He then divided the distance between the two into 100 equal divisions.

In 1828, Lord Kelvin, an English scientist, suggested a temperature scale that was based on a very cold temperature called absolute zero. Absolute zero is the temperature at which matter would stand still and have no heat energy at all. On the Fahrenheit scale, absolute zero is at -459 degrees. So Kelvin established this point as zero on his scale and then he applied the Celsius scale to that using the same spacing between degree marks. On the Kelvin scale the freezing point of water is about 273 degrees and the boiling point of water is 373 degrees. On the Kelvin scale there are no negative numbers.

Of these three temperature scales the Celsius scale is the one used by most scientists.

When using thermometers, it is important to treat them with care. Never shake a thermometer the way you shake a home thermometer. Don't ever place the thermometer in your mouth; in a lab you never know where the thermometer has been. Don't use a thermometer to stir things; use a stirring rod instead. Don't set the thermometer down in such a way that it could easily roll off the lab table. Remember that thermometers are made of glass and they can break easily. Most lab thermometers are filled with either red colored alcohol or mercury.

Scientists are constantly comparing different forms of matter. All of these instruments of measurement help to determine characteristics of specific substances.

One important quality of a substance is the density of the material it is made from.

Density is the mass of a substance per a certain unit of volume. Maybe you remember the old joke about which is heavier, a ton of lead or a ton of feathers. Well, they each weigh a ton, so neither is heavier than the other. However, the feathers would require much more room because their density is much less than the density of lead.

Each kind of matter has its own density. So one way to identify substances is by

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calculating their density. To do that, we must know the volume and mass of the object.

Density is equal to the mass divided by the volume. The mass of something is found with a balance scale.

The volume may be a little more challenging to find. If the object is shaped like a box with straight sides and edges, then we simply measure the length, width, and height of the object. Then we multiply the three numbers times each other to get an answer.

The formula is length times height times width.

For an object with an odd shape, we can use a special method called water displacement. An object submerged in water will displace or push aside an amount of water equal to the volume of the object.

So we can measure the volume of this rock by first recording a starting amount of water in the graduate. Then, when the rock is lowered into the graduate, the water will rise. The new level is recorded and the difference between the two water levels is compared. Subtract the starting level from the final level to get the volume of the submerged object.

It just so happens that one millileter of water equals one cubic centimeter. So every milliliter of water that rises is equal to one cubic centimeter of volume.

The density of water happens to be one gram per cubic centimeter. The density of this piece of wood can be determined by measuring the mass and volume of the wood. The mass is 10 grams.

Volume is equal to length times width times height. Each side of the cube of wood is two point five centimeters. So, here's the calculation: As you can see, the volume is 15.625 cubic centimeters. Density is equal to mass divided by volume. The mass is 10 grams and the volume is 15.625 cubic centimeters. So, the density of the wood is .64 grams per cubic centimeter.

If we place the wood in water, it floats because the density is less than the density of water, which is 1 gram per cubic centimeter. So objects with densities greater than water sink, and objects with densities less than water float.

Well, today we have explored the way scientists gather information through measurement. Tools have been developed to help them do their job.

To get accurate readings, people have to be careful in their approach to measurement. For instance, when using a ruler make sure you're lined up correctly. If you look closely at the ruler, you may see it is damaged at the end. One solution is to make your measurement from the first centimeter mark. Just remember that you have moved in one centimeter, so subtract one from the measurement you get.

Measurement is important to us all, but to scientists it is critical to analyzing and evaluating their experiments.

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THE SCIENTIFIC METHOD AND SCIENTIFIC MEASUREMENT
A Unit of Study

Cat. No. 2032

BLACKLINE MASTERS

Included in this package are 11 Blackline Masters. Specific instructions for their use are given in the Teacher's Guide under Suggested Instructional Procedures for each lesson.

Lesson 1: THE SCIENTIFIC METHOD — **4 Blackline Masters**

Lesson 2: SCIENTIFIC MEASUREMENT — **7 Blackline Masters**

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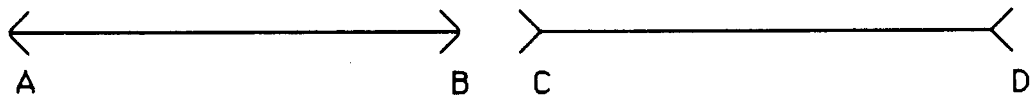
Name ________________

THE SCIENTIFIC METHOD
Optical Illusions

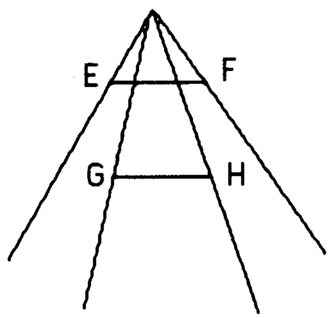
Make your guess first and then measure with a metric ruler.

1. Which line is longer AB or CD? __________

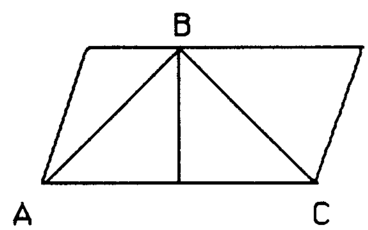


What are the actual lengths of the two lines? AB =   CD =

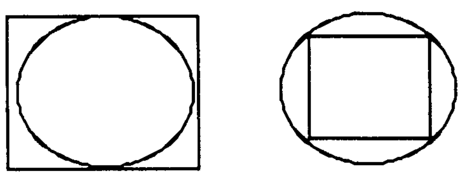
2. Which line is longer EF or GH? __________
   What are the actual measurements? EF =   GH =



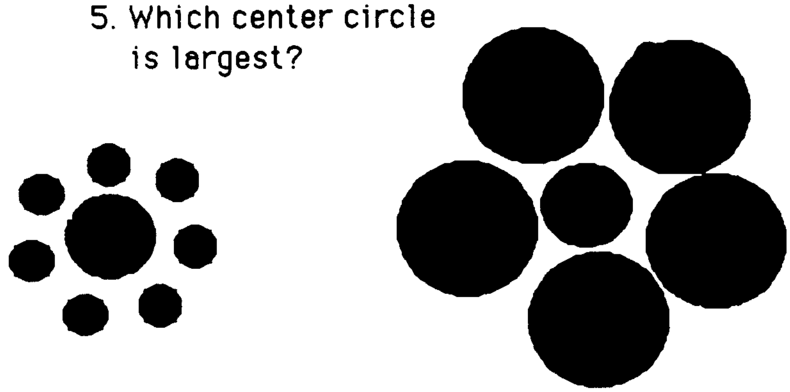
3. Which line appears longest?
   What are the lengths?
   AB =
   BC =



4. Which circle is larger?



5. Which center circle is largest?



Name ____________________

THE SCIENTIFIC METHOD
Experiment Write Up Form

PURPOSE OR PROBLEM:

HYPOTHESIS:

MATERIALS:

PROCEDURE:

OBSERVATIONS:

CONCLUSION:

Name ________________

THE SCIENTIFIC METHOD
Ice Cube Survival Test

PURPOSE: To develop a strategy to keep an ice cube in its solid state for as long as possible.

MATERIALS: ice cube
styrofoam cup
Students may select whatever materials they would like to keep the ice cube solid. No refrigerators, cold packs, or products designed to keep things cold allowed.

PROCEDURE:

1. Everyone will be given an ice cube of the same size.
2. Students will time how long their ice cube will stay solid.

OBSERVATIONS: Check the ice cube periodically to observe and record results.

1. Starting Time:
2. Time Cube Disappeared:

Total Lasting Time For Ice Cube:

CONCLUSION: Did your strategy for keeping the ice cube in its solid state work?

Why or why not?

Name ________________

THE SCIENTIFIC METHOD
Operation Egg Drop

PURPOSE: To design a container no larger than a shoebox to protect a raw egg from a fall of 50 to 60 feet onto a hard surface such as cement. Anything may be used inside the container to protect the egg. The egg may not be altered in any way. No glue or tape should touch the egg shell.

MATERIALS:
raw egg
container no larger than a shoebox (doesn't have to be a shoebox)
materials to protect the egg
masking tape to tape outside of container

PROCEDURE:

1. You will write up your egg drop containers as an experiment so remember the steps you go through when assembling your design.
2. Think about the forces that will act upon the egg and container.
3. Brainstorm some ideas for materials that may help to cushion the egg.
4. Collect the materials you wish to experiment with and build the container.
5. When the container is finished, take it to school for the official egg drop.
6. Someone will take the egg drop containers to the roof of the school where they are dropped off, one at a time.
7. When your egg drop is dropped, record observations below.

OBSERVATIONS: Record what happens to your egg drop. From how high was it dropped? How does it land? Does it bounce? What kind of sound does the container make when it hits? Are there any signs of damage to the container's outside?

CONCLUSION: Open the container carefully. Record and observe any changes inside the container.

Did your container protect the egg?

Name ________________

SCIENTIFIC MEASUREMENT
The Metric System

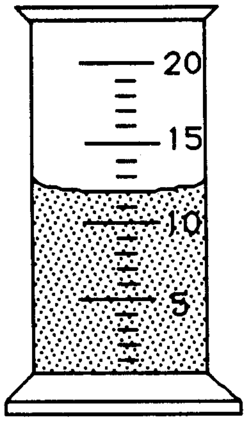
Milli	Centi	Deci	Base Unit	Deka	Hecto	Kilo
1 milli- meter equals ______m	1 ______ equals 0.01 m	1 deci- meter equals ______m	Length **Meter**	1 deka- meter equals ______m	1 ______ equals 100 m	1 ______ equals 1000 m
1 ______ equals 0.001 L	1 centi- liter equals ______ L	1 ______ equals 0.1 L	Volume **Liter**	1 ______ equals 10 L	1 hectoliter equals ______L	1 kiloliter equals ______L
1 milli- gram equals ______g	1 ______ equals 0.01g	1 decigram equals ______g	Mass **Gram**	1 ______ equals 10 g	1 hecto- gram equals ______g	1 ______ equals 1000 g

To convert from bigger to smaller units, move the decimal one place to the right for every step across the chart. To convert from smaller units, move decimal to the left one place for every step. Add zeroes as needed.

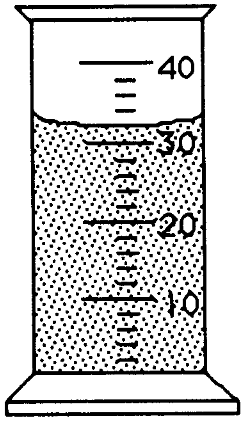
Name ____________________

SCIENTIFIC MEASUREMENT
Reading Graduated Cylinders and Measuring Line Segments

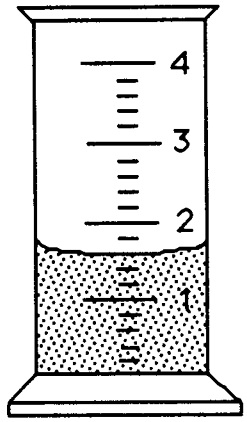
Read the meniscus line on these graduates.



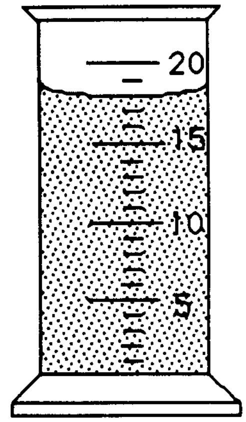
1. ________ ml



2. ________ ml

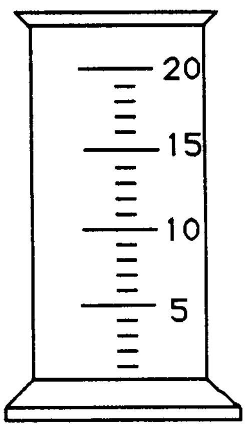


3. ________ ml

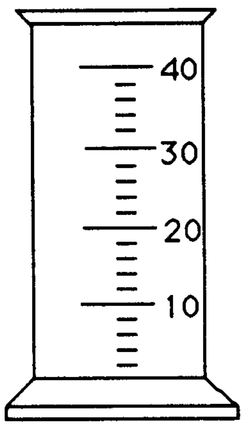


4. ________ ml

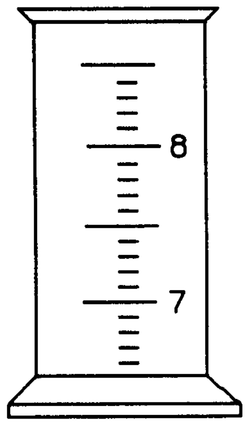
Draw a meniscus for each of the following graduates.



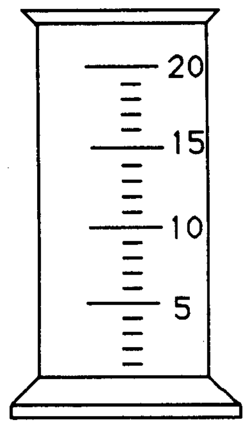
5. 14 ml



6. 22 ml



7. 7.6 ml



8. 12.5 ml

Measure the following line segments in centimeters.

9.

10.

11.

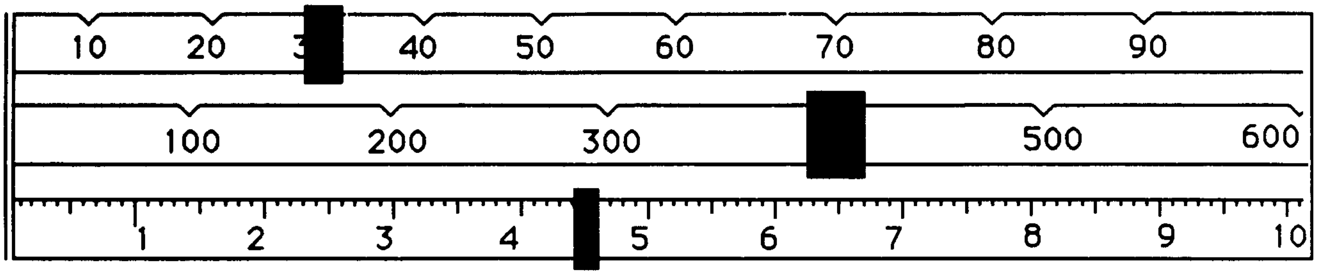
12.

13.

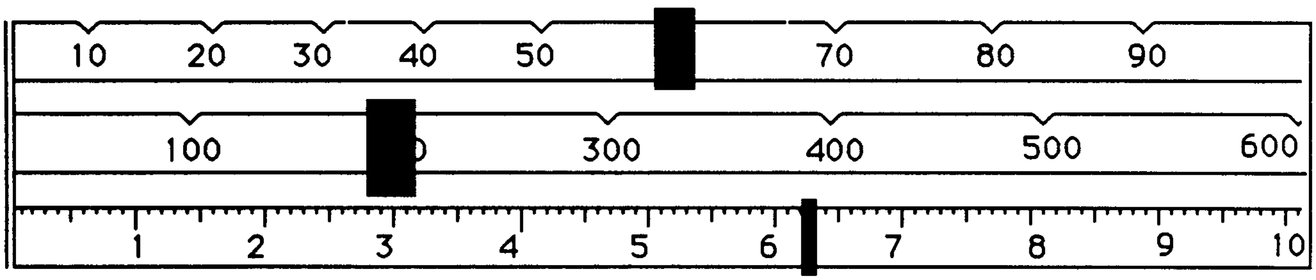
Name ________________

SCIENTIFIC MEASUREMENT
Using The Triple Beam Balance

Read the triple beam balances and record the mass in grams.

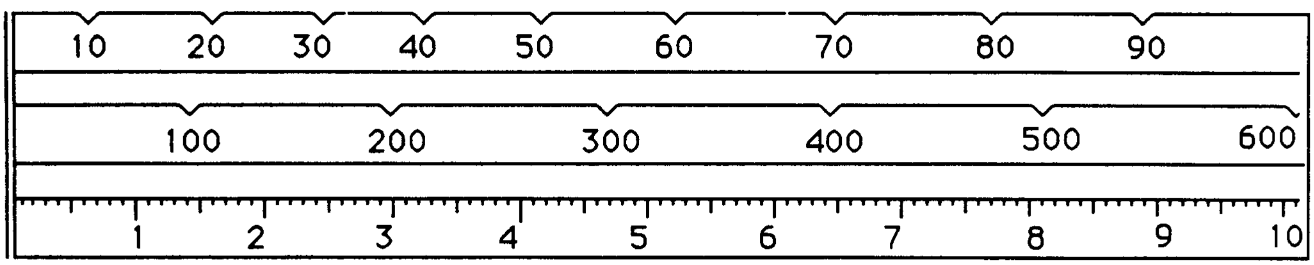
1.


1. ______ grams

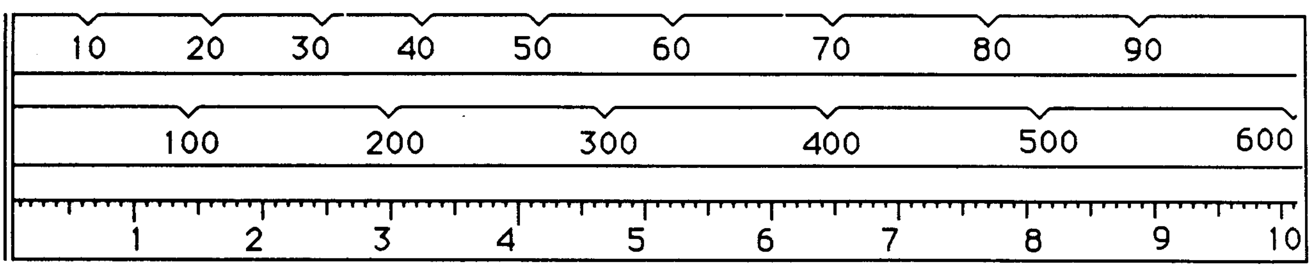
2.


2. _______ grams

Make marks on the following triple beam balances to show the grams indicated.

3.


3. 451.7 grams

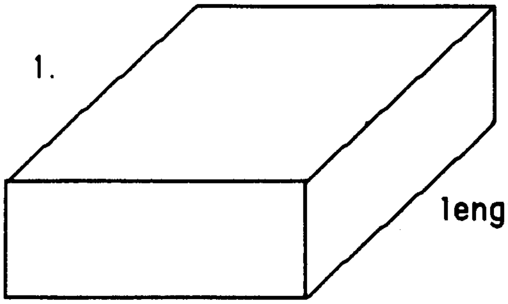
4.


4. 589.3 grams

Name ____________________

SCIENTIFIC MEASUREMENT
Measuring In The Metric System

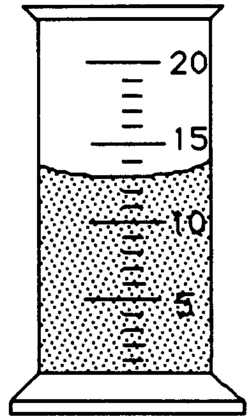
1.



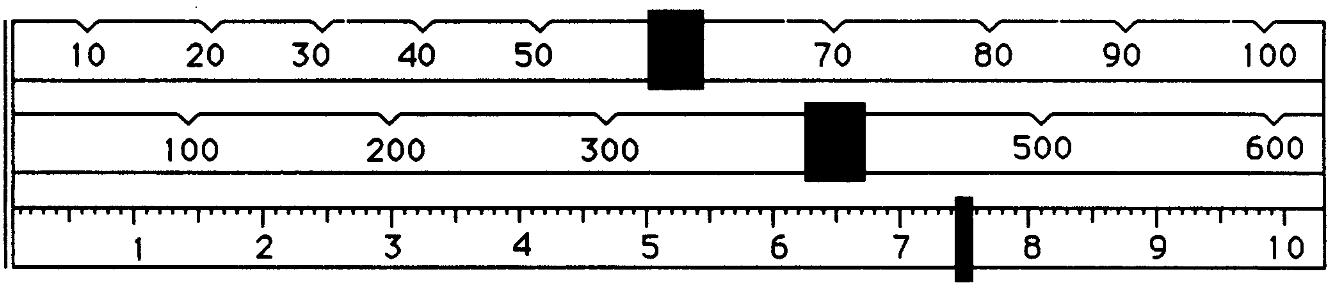
height =

length =

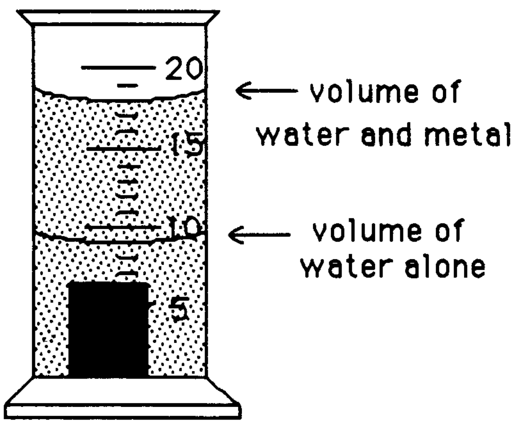
width =



2. _______ ml



3. _________ grams



4. What is the volume of the metal?

5. Measure the lengths of these lines.

a.) ____________________

b.) ______________________________

c.) _______

d.) ________________

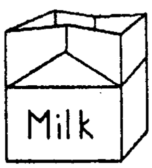
Name ________________

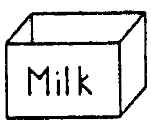
SCIENTIFIC MEASUREMENT
Finding the Density Of Water

PURPOSE: To calculate the density of water.

MATERIALS:
half-pint milk carton
scissors
metric ruler
graduated cylinder
water
balance

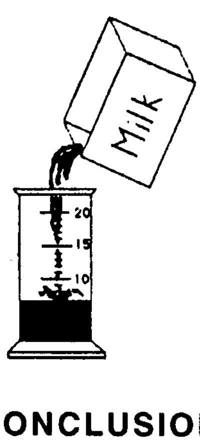
PROCEDURE:





1. You will only need the base of the milk carton. Open up the top and use the scissors to cut off the top.
2. Find the mass of the empty carton.
3. Fill the milk carton to the very top with water and then mass again.
4 Find the mass of the water alone by subtracting the mass of the empty carton from the combined mass of carton and water.
5. Pour the water from the carton into the graduated cylinder to find the volume of the water. (Remember 1 ml equals 1 cubic centimeter)
6. Verify the volume of the water by calculating the volume of the milk carton. Measure the length, width, and height and find volume with the formula: V = l x w x h.
7. To find the density of the water, divide the mass of the water by its volume. (Remember density equals mass divided by volume)

OBSERVATIONS:



Mass of carton ________________ grams

Mass of carton and water ________________ grams

Mass of water ________________ grams

Volume of water ________________ cm3

Density of water ________________ g/mL

CONCLUSION: What is the density of water?
The metric system is set up so that one milliliter of water is equal to a volume of one cubic centimeter and has a mass of one gram. How is this useful?

Name ________________

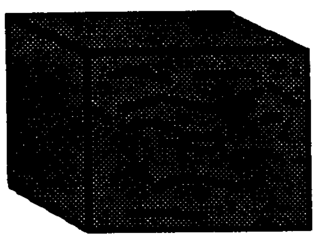
SCIENTIFIC MEASUREMENT
Finding the Density Of Wood

PURPOSE: To calculate the density of wood.

MATERIALS:
regular shaped piece of wood (about 2 inches square)
metric ruler
balance

PROCEDURE:
1. Measure the length, width, and height of the block of wood.
2. Find the volume of the wood. ($V = l \times w \times h$)
3. Find the mass of the block of wood.
4. Calculate the density of the wood. ($D = M / V$)

OBSERVATIONS:



Mass of wood ______________________ grams

Volume of wood ______________________ cm3

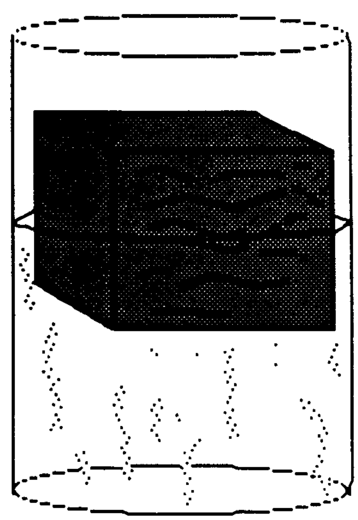
Density of wood ______________________ g/mL

CONCLUSION:

What is the density of water?

What is the density of wood?

How can you explain why wood floats?



Name ____________________

SCIENTIFIC MEASUREMENT
Finding the Density Of A Rock

PURPOSE: To calculate the density of a rock.

MATERIALS:
irregular shaped rock
graduated cylinder
balance

PROCEDURE:
1. Find the mass of the rock.
2. Put about 20 ml of water in the graduated cylinder and then drop the rock in.
3. Find the volume of the rock by water displacement. How much did the water go up after the rock was dropped in?
4. Calculate the density of the rock. (D = M / V)

OBSERVATIONS:

Mass of rock ______________________________ grams

Volume of rock ______________________________ cm3

Density of rock ______________________________ g/mL

CONCLUSION: What is the density of the rock?

How does that compare to the density of water?

Why do rocks sink in water?