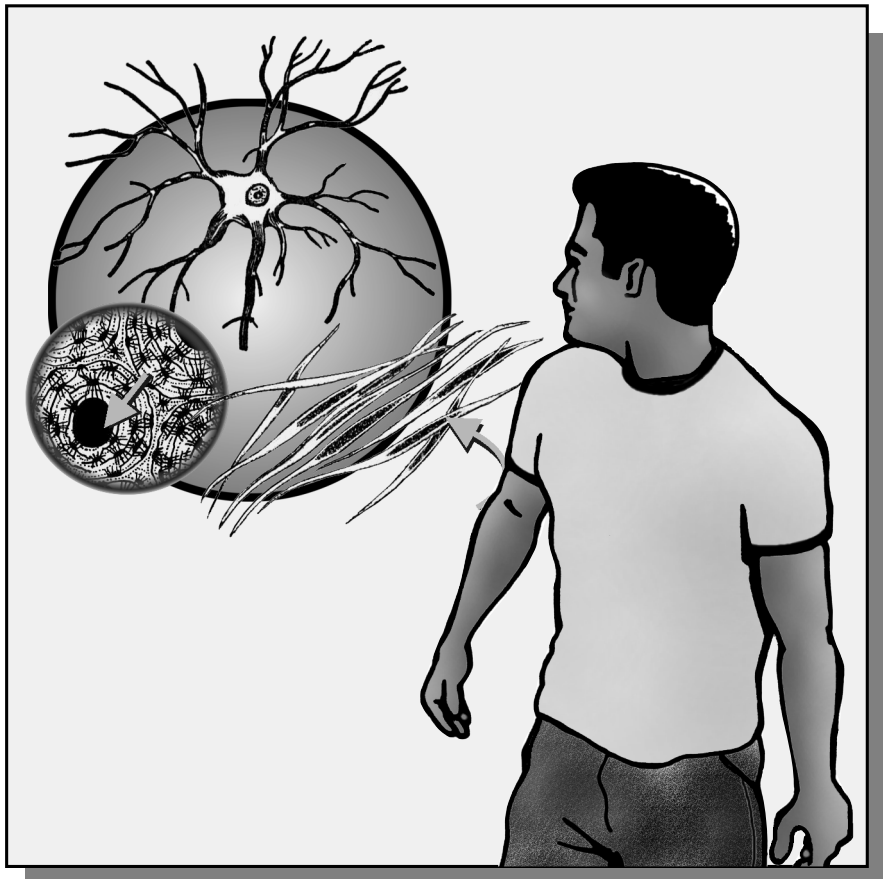
Natural Science Mysteries



Chapter 2

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Natural Science Mysteries

Chapter 2

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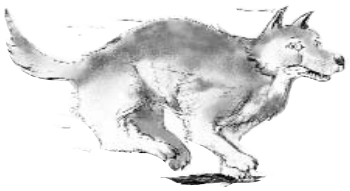
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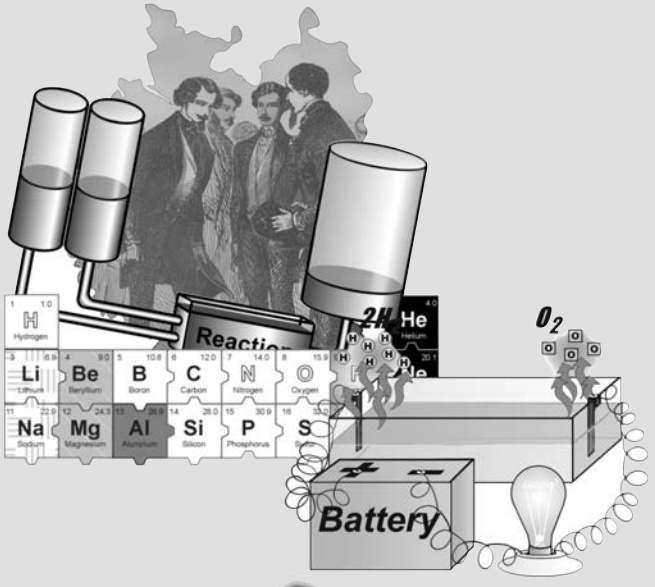
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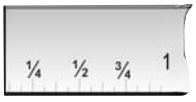
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"By knowledge, understanding and wisdom the true mysteries of life unfold as they are studied line by line and precept upon precept." —Ronald E. Johnson, C.Ph.D.





Lesson 1
Measurement

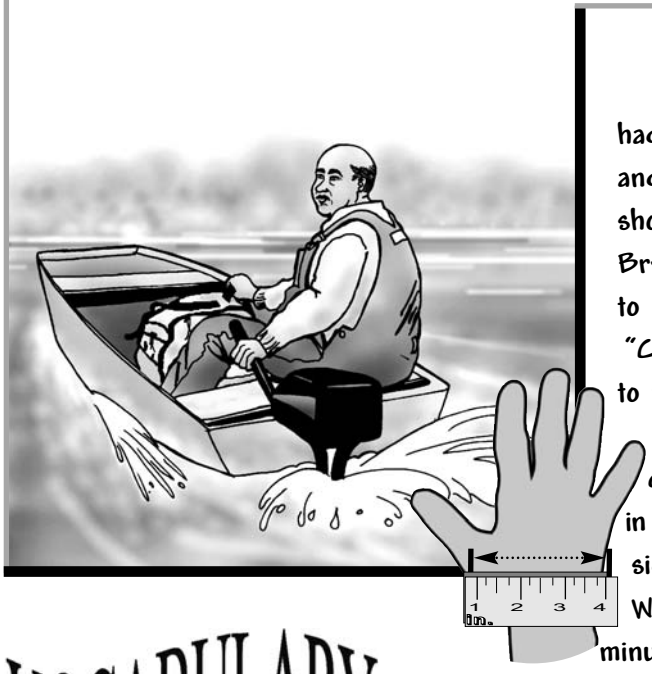
Chapter 2

Historical, English, and Metric Methods

Section 1

Lessons 1-5

MEASURING LENGTH AND DISTANCE



Bryan and his friend Tom were spending their summer on Danger Island. Sailors had given it that name because of frequent storms and dangerous ocean currents. The island's rocky shore had claimed more than its share of ships. Bryan and Tom would be working with a naturalist to restore the island to its wild state.

"Come on, come on," Bryan urged. "We're going to miss the ferry!"

Tom came out of the little grocery store carrying a loaf of bread. Tom did not have room in his backpack for the bread, so he tied it to the side of the pack. "It's only a quarter of a mile. We can hike that distance in less than five minutes! We have plenty of time," he predicted.

"Maybe, but the ferry runs only once every two weeks all the way to Danger Island," Bryan said, "and my pack weighs almost sixty pounds!"

The two boys ran down to the dock. The ferry was still loading. One of the crew members said, "Your packs cannot be brought into the passenger area. Put them by the other supplies."

Bryan and Tom shrugged out of their heavily loaded packs with relief and leaned the packs against the last of the crates to be loaded by ferry crew members.

As they walked across the gangplank to the passenger area, Bryan noticed a small boat, powered by an outboard motor, pull up to the dock. A round-faced man in blue coveralls climbed up the wooden ladder at the end of the dock. Suddenly, he grabbed Tom's backpack and hurried down the ladder. The man dumped the pack in his open boat, twisted the motor throttle and sped across the open water."Stop!" Bryan yelled. "Stop that man!"

VOCABULARY

Fathom: an English unit of length, equal to six feet, used primarily to measure river or ocean depths

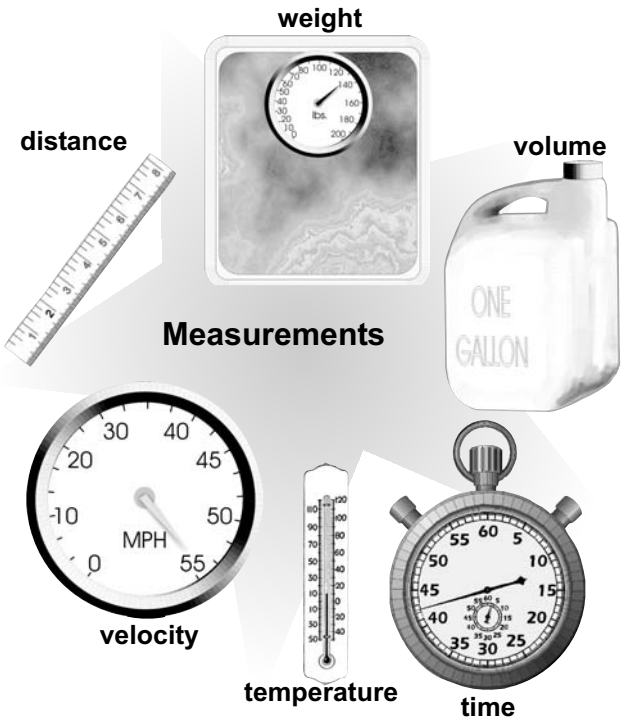
Hand: an English unit of length, equal to four inches, used primarily to specify the height of horses

Yard: the standard English unit of length, defined today in terms of the meter, a yard is 0.9144 meters

Inch: an English unit of length, equal to 1/36 of a yard or 2.54 centimeters

A quarter of a mile, five minutes, sixty pounds, two weeks: all of these are examples of measure. Measuring things is an essential part of modern life. Fast food restaurants serve quarter pound hamburgers. Service stations price gasoline by the gallon. Parking meters tick off the minutes before more coins are required. People plan their weekend activities by a weather forecast that predicts a high temperature of 78ºF. Interstate highways have speed limits of 70 miles per hour. Each of these is an example of measurement —weight, volume, time, temperature and velocity.

Scientists, too, are interested in measurement. Until a measurement theory can be described in scientific terms of numbers, it is only a general principle. For example, to say that an object falls faster and faster under the pull of gravity is not as useful as saying that an object falls at the rate of 32 feet per second every second. To say that water changes to ice when the temperature gets colder is not as specific as saying that water changes to ice at 32ºF. The use of numbers gives exactness to statements.



Length is one of the most common quantities that is measured. Early measurements of length were based on the human body. For instance, a shopkeeper measured fabric by using his outstretched arm. From his thumb and forefinger to the tip of his nose was considered to be one yard. Because of complaints that the length varied depending on the shopkeeper, shopkeepers began to place two marks, one yard apart, on a cutting table and used the marks to measure the material.

Different measurement methods were developed for distances. The Romans were noted for their well-disciplined armies. Soldiers were trained to march so that each one had the same stride. A double step was

VOCABULARY

Foot: an English unit of length, equal to 1/3 of a yard or 12 inches
Mile: an English unit of length, equal to 1,760 yards or 5,280 feet
Conversion factor: a number that converts from one unit of measure to another unit of measure by multiplication or division
Meter: the standard metric unit for length, set equal to the distance light travels in a vacuum during 1/299,792,458 of a second; most other units of length are measured from the meter, including the English units for length; a meter is 39.37 inches
Centimeter: a unit of length in the metric system equal to 1/100 of a meter, 2.54 centimeters is one inch
Millimeter: a unit of length in the metric system equal to 1/1000 of a meter, 100 millimeters is about four inches.
Kilometer: a unit of length in the metric system equal to 1,000 meters; a kilometer is about 0.62 miles

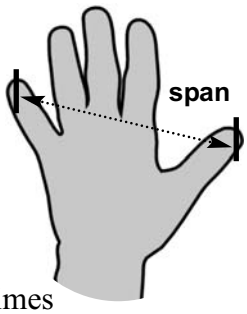
the distance from where the right foot came down to the next place the right foot came down. The distance of a double step was a *pace*. A Roman pace was about five feet, or 60 inches in length.

Not everyone used this distance as a pace. Captain William Kidd, the well-known pirate, buried his treasure. Like other pirates, he used a pace that was his alone. So 400 paces east from the rock that looked like a skull might be much farther than the five foot pace of the Romans.

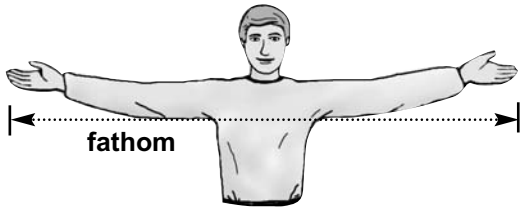
The Roman pace also gave the name to the mile. The word for 1,000 is *milli*. When soldiers had walked 1,000 paces, they had gone a *milli*. The word became a mile. The Roman mile was equal to about 5,000 feet.

The Bible tells of a measurement called a *cubit*. It is the distance from the elbow to the end of the outstretched fingers. Directions for Noah's ark were given in cubits.

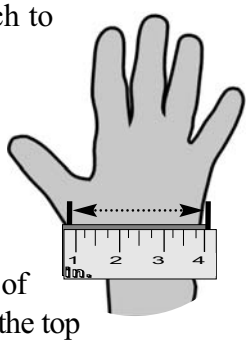
Hold out your hand with the fingers spread apart. A *span* is the distance from the tip of your thumb to the tip of your little finger. A span is about nine inches.



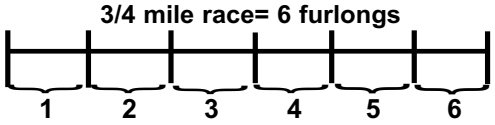
Outstretched arms were also used in ancient times to measure objects. A ***fathom*** is the distance from the tip of the fingers on one hand all the way across to the tip of the fingers of the other hand. A fathom was equal to six feet. A fathom is also about equal to the height of a person. A fathom was used by riverboat captains to measure the depth of the channel. Samuel L. Clemens wrote the books *Huckleberry Finn* and *Tom Sawyer.* Clemens is better known as Mark Twain. Clemens piloted a riverboat on the Mississippi River. The words *mark twain* were a riverman's call that a channel was two fathoms deep. *Twain* means *two*. Riverboat pilots sought out a channel at least two fathoms deep in which to navigate safely.



A ***hand*** is the distance from across the back of the hand. It is four inches. This term is still in use today among horse breeders. The height of a horse from the ground to the top of the shoulders is given in hands. An average horse is about 14 to 15 hands tall.



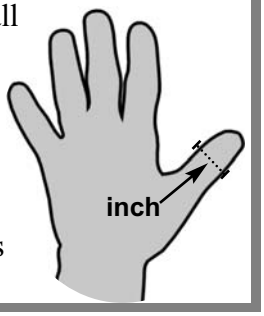
The *furlong* is a term used in racing of horses, which originally meant the average length of a field. A horse could pull a plow 1/8 of a mile without a rest. Today, racetracks are measured in furlongs. A 3/4-mile race is six furlongs.



As one can imagine, people found all of these different measurements confusing. Most ancient measurements of length have disappeared. English units of measure that are still in use for distance are the inch, foot, yard and mile.

A ***yard*** was the distance from the tips of the fingers of an outstretched arm to the nose. To make an unvarying standard, the British inscribed two marks exactly one yard apart on a metal bar. From this standard, created in 1845, all other official yard markers were measured.

The original ***inch*** was of English origin, and began as the average length of the distance across



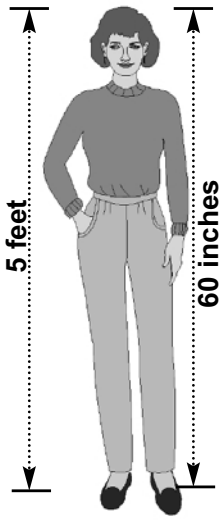
a man's thumb. Later, King Edward II of England, who reigned from 1307 to 1327, defined an inch by law as the length of three barley grains laid end to end. Today, it is defined as 1/36 of a yard. A yard contains 36 inches, or three feet.

A ***foot***, like the inch, was defined from the human body. A foot was the length of a human foot. Obviously, a foot could vary from one individual to another. The legend is that the foot was first measured from the foot of Charlemagne, a ruler who lived about 800 A.D. If he did serve as the model of the foot, then he had big feet. Today, a foot is defined as 1/3 of a yard. A foot contains 12 inches.



The British wanted both the furlong and ***mile*** to come out as an even number of yards, so they defined a furlong as 220 yards and a mile as 1,760 yards. Rather than the 5,000 feet that the Romans used, an English mile had 5,280 feet exactly. (1,760 yards * 3 feet per yard = 5,280 feet.)

Converting from one measure to another is easy by remembering the ***conversion factor*** and deciding whether you should multiply or divide. When going from larger units to smaller units, multiply. For instance, to replace feet by the equal measure in inches, the number of feet is multiplied by 12. Example: The height of a person who is five feet tall is converted to inches as follows: 5 feet x 12 inches (per foot) = 60 inches.



When converting smaller units to larger units, divide. To change inches to feet, you divide by 12. Example: An amateur weather watcher measures the rainfall in inches each day. At the end of the year, his locality has received 84 inches of rain. Converting to feet is computed as follows: 84 inches / 12 inches (per foot) = 7 feet. The slash mark (/) is read "divided by."

To convert yards to feet, multiply by three. To convert feet to yards, divide by three. Example: If a bolt of cloth is seven yards long, its length is converted to feet as follows: 7 yards x 3 feet (per yard) = 21 feet.

To replace feet with miles, you know that you must either multiply or divide by the conversion factor 5,280. The final answer in miles will be a number that is smaller than the same distance expressed in feet. To change feet to miles, you divide by 5,280. Example: A mountain is 14,110 feet high. The height of its summit can be converted to miles as follows: 14,110 feet / 5,280 feet (per mile) = 2.67 miles.

1 foot	=	12 inches
1 yard	=	3 feet
1 mile	=	5,280 feet

Rather than inches, feet, yards and miles, most of the world uses the metric system for measuring length. A ***meter*** is the standard metric unit of length. A meter is defined as the distance light travels in a vacuum in 1/299,792,458 of a second. The meter has become the base standard unit for length worldwide. Other metric units of length are measured from the meter. Even the English yard is defined in terms of the meter.

If a strip of paper one-meter long were cut into 100 pieces of equal length, each piece would be 1.0 ***centimeter*** in length. A meter

contains 100 centimeters. If each of the one-centimeter strips were cut into 10 pieces of equal length, each piece would be 1.0 ***millimeter***. A meter contains 1,000 millimeters. For longer measurements, a ***kilometer*** is used. A kilometer is 1,000 meters.

1 centimeter	=	10 millimeters
1 meter	=	100 centimeters (or 1,000 millimeters)
1 kilometer	=	1,000 meters

Conversion from one system to another (metric or English) is seldom necessary. If a country uses English units, then speed limits and distance markers are stated in miles, yards, or feet. If a country uses the metric system, then the measurements are given in metric units. However, as a quick conversion, remember that a length of four inches is about 100 millimeters and one meter is a little longer than a yard. A meter is 39.37 inches, or 3.37 inches, longer than an English yard.

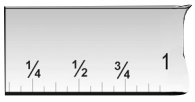
Bryan and Tom ran to the end of the dock. They stood helplessly and watched as the man, the boat and Tom's backpack disappeared out of view around the curve of the harbor.

The captain met with them briefly. "I saw what happened," he sympathized. "That man is well known in these parts. His name is James Olsen. I'll notify the authorities. They will be on the lookout for him. Now, find a place to stand and we will get underway."



Life Principle:

"A man's success is measured in terms of the obstacles he had to overcome along the



Lesson 2
Measurement

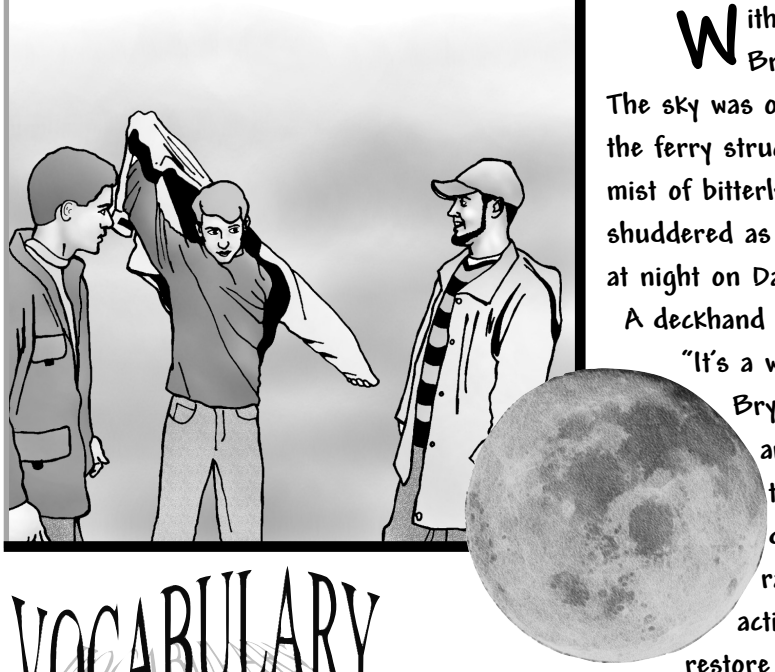
Chapter 2

Origin of the Calendar

Section 1

Lessons 1-5

MEASURING LONG PERIODS OF TIME



Within fifteen minutes, the ferry carrying Bryan and Tom was in the open water. The sky was overcast and the wind cold. Suddenly, the ferry struck a wave and splashed a stinging mist of bitterly cold water on the boys. Tom shuddered as he mumbled, "It is going to be cold at night on Danger Island!"

A deckhand asked their business on the island. "It's a working summer vacation for us," Bryan explained. "The island has deer and moose, even two wolf packs. During the next 12 weeks, we'll work under the direction of my uncle, who is a park ranger, to remove evidence of human activity during the last century. We'll restore the natural habitat."

The deckhand suggested to Tom, "Why don't you go through the unclaimed lost and found for a coat. Most of the items have been in the bin for a year or more and no one has claimed them. You're going to need it. It's four hours out to the island."

Tom did as the deckhand suggested and found a bright yellow raincoat. He put it on with obvious relief. "At least I'll not freeze to death before we reach the island!"

Later, the deckhand asked,"Have you heard about the rumored lost treasure on Danger Island? Mr. Murphy died mysteriously more than two decades ago. He allegedly had made some sort of important discovery. Whatever it was died with him. His widow, Rebecca Murphy, and her granddaughter, Del, live in an old, rundown lodge on the island. It has been closed for business since Mr. Murphy died."

VOCABULARY

Dinghy: a small boat such as a lifeboat
Day: a 24-hour period during which Earth completes one rotation on its axis
Rotated: spun around a central axis
Month: the period of time for the Moon to go around the Earth; 29.5 days
Year: the period of time for Earth to complete a single revolution in its orbit around the Sun; 365 days, 5 hours, 49 minutes and 12 seconds

By 1:30 p.m. the ferry arrived at Rocky Port, a sheltered bay on Danger Island. The deckhand said, "The dock is long gone. I'll take you ashore in the rubber ***dinghy***."

Bryan said, "My uncle said he would meet us at the shelter, but it looks deserted."

In the scene with Bryan and Tommy on the ferry, several different measures of time are mentioned. You probably spotted them. References to time include fifteen minutes, a second later, summer, 12 weeks, century, four hours, year, two decades, and 1:30 p.m. Days, months and years are used around the world to measure periods of time.

Cultures of the world arrived at different standards for measuring distance. Only when they began trading with one another and comparing length did they realize the need for standard units of measure.

For measuring time, however, cultures were in agreement even without being in communication with one another. The ancient Babylonians in Persia and the Mayans of the Yucatan peninsula in Mexico both arrived at similar methods of marking the passage of time. From ancient times, cultures used the ***day*** as the unit for measuring time.

The day was marked by a celestial event that was easy for anyone to observe. During one day, the Sun rose, crossed the sky, set, and then after a period of darkness, rose again. The period from sunrise to sunrise was called one day.

One day is the time Earth spins once on its axis. Ancient people did not know the Earth ***rotated*** on its axis. For them, Earth's rotation on its axis appeared to give the Sun its daily motion across the sky. Ancient astronomers measured the day as the time from sunrise to sunrise. The length of the day measured by sunrise varied a few minutes from one day to the next. By taking an average throughout the year, they arrived at a better value for a day.

Ancient people also used the Moon to mark the passage of time. A ***month*** is based on the changing appearance of the Moon. During a month, the Moon goes through its complete cycle of phases. It begins as a new moon and cannot be seen because the side that faces Earth is not illuminated by sunlight. Then after a couple of days, the Moon can be seen as a thin crescent shortly after sunset. After a week, the Moon is half illuminated, and after another week becomes a full moon. The average time between two full moons is 29.5 days. A month receives its name from the word *moon*.



A ***year*** is the time required for Earth to ***revolve*** in its orbit around the Sun once. Ancient people did not know

VOCABULARY

Revolve: to orbit a central object; the Earth orbits the Sun in one year

Lunar calendar: a calendar based on the motion of the Moon; 12 lunar months of 29.5 days each gives a lunar year of 354 days

Solar calendar: a calendar based on the apparent motion of the Sun

Julian calendar: a calendar authorized by Julius Caesar that has 365 days for three years and 366 days (a leap year) every fourth year

Gregorian calendar: a calendar sponsored by Pope Gregory XIII that is similar to the Julian calendar but removes leap days in centenary years not divisible by 400

Centenary year: the first year of a new century (such as 1800, 1900, 2000)

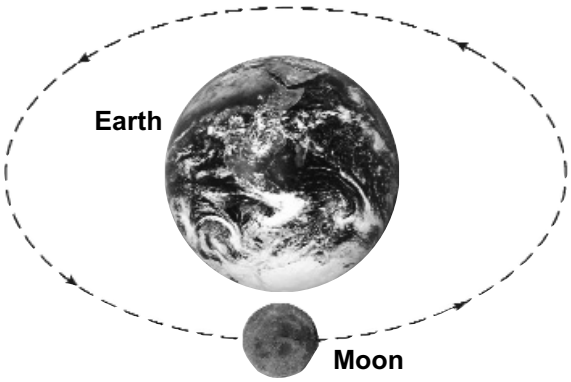
Leap year: a 366-day year with February 29 being an additional day; occurs in centenary years that are divisible evenly by 400 and in other years whose last 2 digits are divisible by 4

that the Earth revolved around the Sun. For them, the Earth's movement appeared to cause the changing seasons. On the first day of summer, the Sun rises well to the north of east. At midday, its rays are nearly overhead. Each day the point on the eastern horizon where the Sun rises changes slightly. The Sun's rays have a slightly different slant at noon. After a year, the Sun again rises at the same point on the horizon.

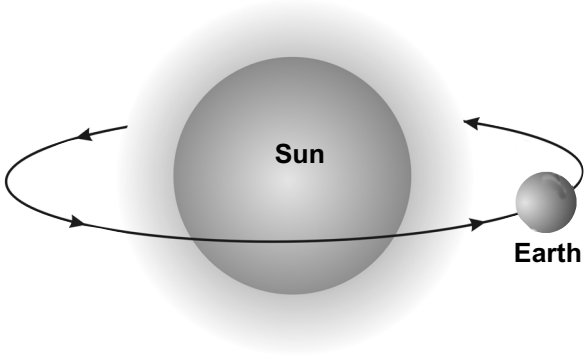
During a year, the seasons go through a complete cycle: spring, summer, fall and winter. On the first day of summer the daylight hours are at their longest and the Sun's rays are more direct. At noon, the Sun is high overhead. At the start of fall, the daylight hours and the nighttime hours are the same length. At the start of winter, (December 21st or 22nd) the day is its shortest. The Sun's rays slant in from the south. At noon, the Sun remains low in the southern sky. At the start of summer, (June 21st or 22nd) the daylight hours and nighttime hours are the same length.

The cycle of the seasons is a year. The early Egyptians calculated the length of the solar year as 365 days.

Ancient astronomers were not sure whether to measure time by the Sun or Moon. A ***lunar calendar*** is one based on the motion of the Moon. Twelve lunar months of 29.5 days each gives a lunar year of 354 days.



A ***solar calendar*** is based on the motion of the Sun. The solar year is 365 days.



The ancient Babylonians lived along the Tigris and Euphrates Rivers. The region is the oldest continually inhabited area on Earth and is now called Iran and Iraq. The Babylonians set the month equal to 30 days. A month of 30 days times 12 months is a 360-day year. With 360 days in a year, all three ways of measuring time (day, month and year) come out even.

For ancient people, for whom work with fractions was awkward, 360 had advantages. A year of 360 days could be divided into shorter segments without any days left over. Half of a year was exactly 180 days. One third of a year was exactly 120 days. One fourth of a year was 90 days. Unfortunately, despite being so convenient, such a system was simply inaccurate. There are actually 365 days in a year, so each year the ancient calendar was in error by 5 days. The start of summer began five days earlier each year, thus accumulating error. Some cultures adopted the Babylonian 360-day year and kept the seasons right by celebrating a 5-day holiday added at the end of each year.

Other people, including the Romans, used a lunar calendar of 354 days (12 months of 29.5 days = 254 days). Because it differed by about 11 days from the solar year, each year special days fell 11 days earlier compared to the

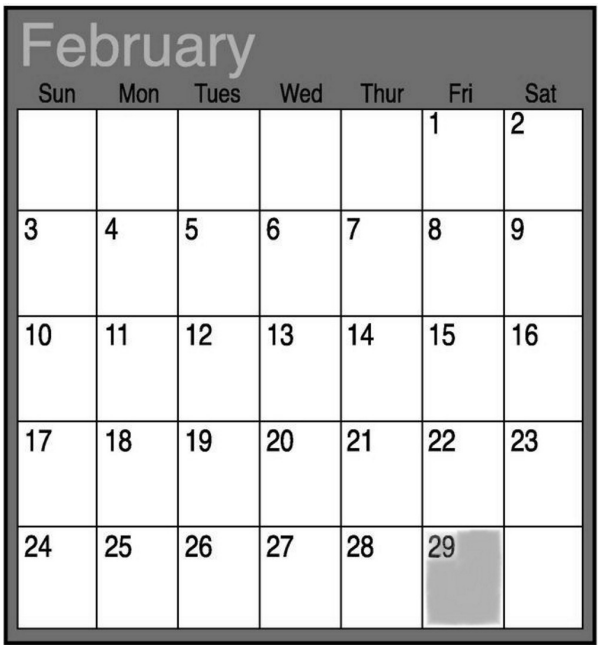
seasons. An original date in spring would gradually move into winter.

One solution was to calculate an extra month every so often and insert it into the calendar. The extra month kept the calendar in line with the seasons. Sometimes the calendars became hopelessly confused because of dishonest officials. Suppose a governor was appointed to a term of office for three years. To stay in power longer, a dishonest politician would order that extra months be inserted to lengthen the year.

By the time Julius Caesar (100 B.C. - 44 B.C.) came into power in Rome, about 48 B.C., the Roman lunar calendar had fallen into complete disarray. In 46 B.C., Julius Caesar agreed to reform the Roman calendar. He required the Roman Empire to adopt a solar calendar of 365 days with an extra day every four years. The purpose of the leap day was to keep the calendar in agreement with the seasons. Many other countries adopted the Roman calendar, called the Julian calendar.

Although the ***Julian calendar*** did a better job of keeping the seasons and year together, it still had a slight error. The Julian year was equivalent to a year of 365 1/4 days. One-fourth of a day was six hours. However, more recent calculations have shown that the Earth revolved around the Sun every 365 days, 5 hours 48 minutes and 46 seconds. The Julian calendar was too long by about 11 minutes 14 seconds each year. Although slight, the error in time accumulated each year.

By 1500 A.D., the calendar was off by 10 days. Normally, the first day of winter fell on about December 22. Instead, winter started on December 12. A new calendar was designed to remove the error. The new calendar was named the ***Gregorian calendar*** in 1582 after Gregory the Great, a religious leader of the later 1500s. The Gregorian calendar was identical to the Julian calendar except it removed leap days in each ***centenary year*** not divisible by 400. The year 1600 had a leap day. But the new calendar removed the leap day from 1700, 1800 and 1900. Because it was divisible by 400, the year 2000 had a leap day, making 2000 a ***leap year*** of 366 days. Leap year also occurs in non-centenary years when the last two digits of the year are divisible (evenly) by four. During any leap year, the extra day on the calendar is always February 29th. Most years are not leap years and are known as *common years*.



Not all countries agreed to use the new calendar at first. But in 1752, Great Britain and most of the English-speaking countries changed to the new Gregorian calendar. Because of the delay, the error had grown to 11 days. England matched the seasons with the calendar by skipping September 3 through September 13. The day after September 2 became September 14. Many people became upset because eleven days had disappeared overnight. It did cause confusion. George Washington was born on February 11 in 1732 under the Julian calendar. When the colonies switched to the new calendar in 1752, Washington's birthday changed to February 22.

Today, the Gregorian calendar is the one used for most commercial activities and the one used in the United States. The Gregorian calendar is a solar calendar because its year is based on the relationship of the Earth to the Sun.

Some countries maintain a separate calendar for religious observances. For instance, the Jewish calendar alternates months of 29 days and 30 days. A lunar month is 29.5 days, so it could be called a lunar calendar. However, an extra month is calculated about every three years to keep the Jewish calendar in harmony with the solar calendar.

The Muslim calendar goes through a cycle of 30 years in which 19 of the years have 354 days and the others have 355 days. Because the Muslim calendar is approximately 11 days shorter than the Gregorian calendar, Muslim holy days fall 11 days later each year.

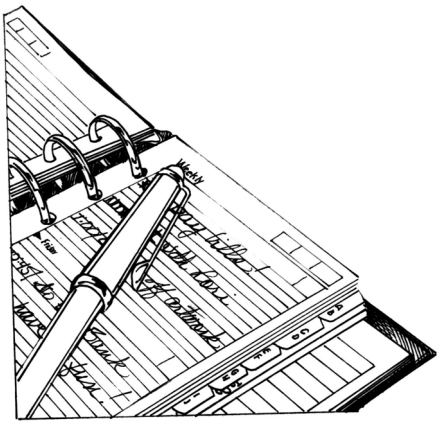
The deckhand told Bryan and Tom, "The shelter is that wooden shack. You'll have to step out in the water because the rocks might damage the boat." He helped Bryan with his pack. Tom sloshed ashore.

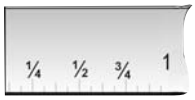
The two boys turned around and watched until the rubber dinghy returned to the ferry. Then the ferry motored around the island and out of view. The boys turned and trudged up to the simple wooden shed. Tom asked, "Where is your uncle? What if everyone left the island and we're here all alone?"

Life Principle

"The time which we have at our disposal every day is elastic . . ."

—Marcel Proust





Lesson 3
Measurement

Chapter 2

Decades, Centuries and Millenniums to Seconds, Minutes to Hours

Section 1

Lessons 1-5

MEASURING SHORT PERIODS OF TIME



The boys waited for Bryan's uncle. Bryan looked at the Sun showing through the milky white clouds. "It is about 2 o'clock," he said. "Let's give my uncle a few more minutes and then we'll see where the trail takes us. In the meantime we can eat." Bryan opened a plastic bag of trail food containing nuts, cereal and dried fruit.

Tom took only a few seconds to wolf down his share of the snack. As the boys finished eating, a very business-like German Shepherd dog came bounding down the trail. The dog stopped and watched the boys cautiously. A young, incredibly skinny girl walked into view. The boys could tell she was a girl because she had a ribbon in her hair.



The girl said, "Hi! My name is Del. This is Sam, my dog. If you are Bryan and Tom, I have a message from Ranger Eldridge: Meet him at the edge of the ***bog***. I'll walk with you part way."

The girl talked incessantly. After a mile, the trail divided. Del took the left branch. She said, "This is the way to the lodge. Leave your pack here because you can pick it up on the way back. You take the right branch of this trail another couple of miles. The trail divides a lot, but stay on the main branch. You can't miss it."

Looking at the Sun to judge the time of day, as the boys did, was one of the first ways men measured time. The three easiest periods of time to measure are the day, month and year because they are based on events that repeat at regular intervals. Other intervals were invented for shorter and longer periods of time.

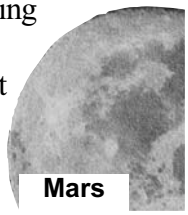
VOCABULARY

Bog: a swampy area
Celestial: having to do with the heavens
Decade: a period of 10 years
Century: a period of 100 years
Millennium: a period of 1,000 years
Watch: a period of time assigned to a soldier to stay alert as a guard or sentry; the Romans assigned soldiers to stand watch for three hour periods

In addition to the day, month and year, another common interval of time was the week. A *week* was 7 days. It was not announced by a ***celestial*** event, although a week was about the length of time for the Moon to go through one of its four phases. From full moon to quarter moon was about seven days. A quarter moon was one in which the Moon appeared to be half full. It was called a quarter moon because it was one fourth of a complete lunar cycle—new moon, first quarter, full moon, third quarter, and back to new moon.

The days of the week were named after the Sun, Moon and planets visible to ancient people. The seven days of a week were matched with the seven bright objects that move through the night sky—Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn. *Sunday* is named after the *Sun*. It is Sun's day. *Monday* is named after the *Moon*. It is Moon's day.

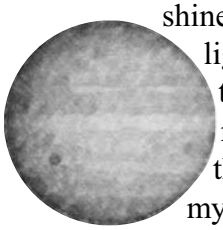
Because of its red color, Mars was often associated with the blood shed during fighting. The Romans considered Mars the third most important light in the sky after the Sun and Moon. They named the third day of the week Mars' day. The English version of *Tuesday* came from the Norse god of war, *Tiu*.


Mars

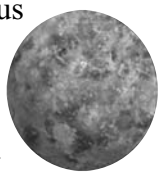
The Romans named Wednesday after the planet Mercury. It was the fastest moving of the planets. Mercury went around the Sun once every 88 days. The Romans considered Mercury the speedy runner who carried messages for mythical gods. They pictured Mercury as having wings on his feet. The English word *Wednesday* was named for *Woden*, the chief Norse god. He was usually shown riding his speedy eight-footed horse. Two fast flying ravens rode on Woden's shoulder.


Mercury

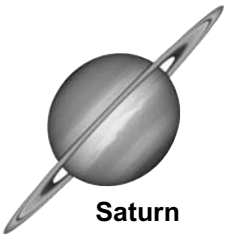
The Romans named the next day after Jupiter. They called it Jove's day. Jupiter shines with a particularly steady light. It is often found high in the night sky and appears to rule everything else. Jove ruled the other gods in Roman mythology. The English word, *Thursday,* is from *Thor's day*, a reference to the Norse god of thunder.


Jupiter

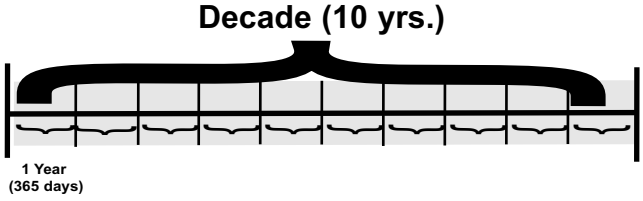
The Romans named Friday after Venus. Venus shines with a brilliant white light. The Romans worshiped Venus as the goddess of love and beauty. The English word, *Friday,* is named after Woden's wife, *Frigg*. She was supposed to be especially lovely.


Venus

Saturday was *Saturn's day*. In Roman mythology, Saturn was the most ancient god and the father of Jove. According to astronomers of that time, the planet Saturn was the farthest from the Sun. Saturn moved slowly, a fitting name for an elderly god.


Saturn

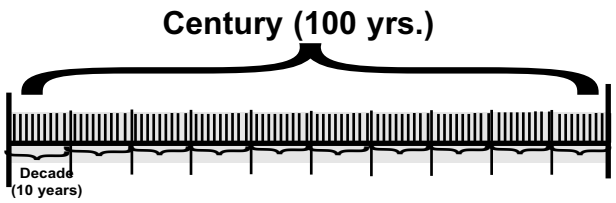
For longer periods of time, years were grouped by powers of ten. A ***decade*** was a group of 10 years. The prefix *dec* means ten.



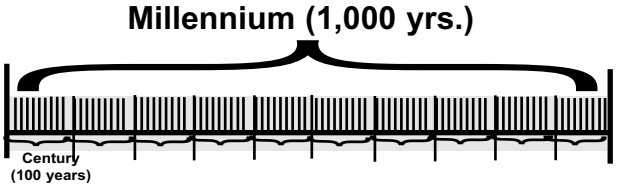
VOCABULARY

Hour: 1/24 of a day, 60 minutes
Minutes: 1/60 parts of an hour, 60 seconds
Seconds: 1/60 parts of a minute, the metric and English standard unit of time from which other units of time are measured

A ***century*** was a period of 100 years. The prefix *cent* means 100.



A ***millennium*** was a span of a 1,000 years. The prefix *milli* means 1,000.



For early people, the correct time of year was more important than the correct time of day. Sailors depended on knowing the time of year to seek safe harbor to avoid winter storms. Hunters knew that animals migrated at specific times of the year. Caravans crossed the desert in the wet season so they would have water. Farmers measured the time of year most carefully. Their livelihood depended upon planting crops at the right time.

Businessmen, who sold goods on credit, and moneylenders expected payment by certain dates. Customers of Roman shopkeepers would ask, "When is payment due?"

"Calens," the businessmen would reply. *Calens* meant the first of the month, and was the word from which *calendar* was formed. An accurate calendar ensured that people who borrowed money paid it back on time.

Farmers in an area did cooperate to set aside a certain day as market day. On that day, they carted their produce into town for sale. As long as they knew the right day, what time they came into town or how long they stayed did not matter. Farmer's lives were governed by years, months and days.

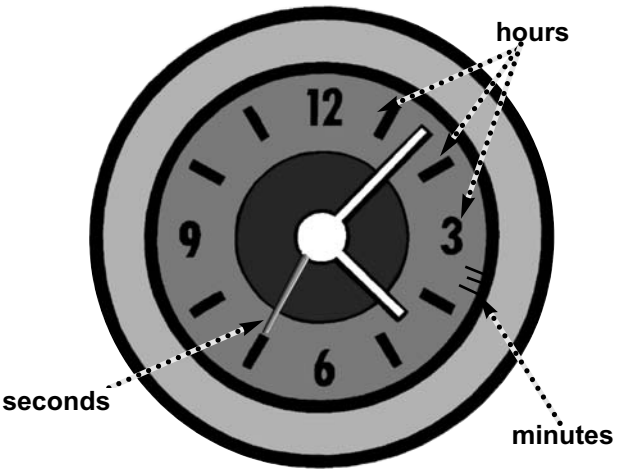
Ancient cultures were seldom concerned about periods of time shorter than a day. People who lived on farms had little need for knowing the exact time of day. They worked from early morning to late evening. They could see from the Sun the approximate time of daylight remaining for work. Farmers took a break from the chores whenever they desired.

The military, however, knew that a sentry could not be at top alertness all day. Therefore, guard or sentry duty was divided into shorter intervals, each known as a ***watch***. The daytime hours were separated into four watches. The first began at sunrise and the forth ended at sunset. The nighttime hours were also broken into four watches. The first one started at sundown and the fourth ended at sunrise. The third watch was the most difficult. It began at midnight and lasted through the darkest part of the night.



The Egyptians invented the division of time known as the ***hour***. The Egyptians thought of the day as having one dawn hour, 10 daylight hours and one dusk hour, a total of 12 hours. Although they applied the 12 hours to daylight times, they also thought of the evening hours as having 12 hours. The day, then, was made of 24 hours.

The first accurate clocks and watches were made about 400 years ago. Until then, mechanical clocks were so inaccurate they



had only hour hands. Desire for more accurate time led men to develop timepieces that showed divisions of times shorter than an hour. An hour was divided into 60 ***minutes***. The word *minute* was from a Latin word meaning *small*. A minute was divided into 60 ***seconds***. The word *second* is from a Latin word meaning *second part*; that is, a second division of an hour into a smaller period of time.

Until about 60 years ago, the day was used as the standard unit of time. The other divisions of time were defined in terms of the day. However, as astronomers timed the rotation of Earth with accurate clocks, scientists observed that the speed of rotation of the Earth was changing. The effect of tides acted as brakes and slowed Earth's rotation. The slowing was irregular but amounted to about

1 year	=	365 days, 5 hr, 48 min, 46 sec
1 day	=	24 hours
1 hour	=	60 minutes
1 minute	=	60 seconds

one second a year. In the year 2000, the Earth slowed by 1.3 seconds. Changes in the Earth's rotation were irregular and could not be predicted with accuracy. For that reason, in 1964, countries agreed to use the second as the time standard. Scientists defined the length of the second by regular, but very rapid, motion of atomic particles. Atomic clocks based on events that take place in the cesium atom provide a precise measure of a second. Once the second was defined, it became the standard upon which the other units of time were based. A minute was defined as 60 seconds, an hour was given by 3,600 seconds and a day was measured as 86,400 seconds.

For intervals shorter than the second, the divisions are powers of ten: one-tenth second, one-hundredth second, one-thousandth second and so on. Ordinary quartz watches available at a reasonable cost to consumers could measure time, accurate to one second a year.

Today, the second is the standard unit of time. All other units of time are defined from it. The English second and the metric second are identical. The English and metric system have the same units for measuring time, so conversion from one system to the other is not necessary.

As the boys walked down the trail, the girl continued to talk until Tom and Bryan were out of earshot. The last words they heard were, "The trail is used by moose. Give them the right of way or you may be flattened!"

The trail became harder with exposed rocks and roots. After climbing for what seemed more than two miles, the trail began a slow descent. The boys came to a green meadow, crossed by a meandering stream. In the far corner was a small pond. It looked muddy enough to be the bog. In the distance they saw a human figure wearing a broad-brim ranger's hat. He was waving his arms and yelling. A moose stood facing him. The magnificent animal towered over the man.

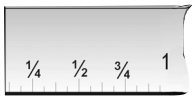
Bryan yelled, "He's under attack!"

Life Principle

"Time . . . days and hours— even minutes— frittered away can never be regained."



—General Samuel B. Griffith



Lesson 4
Measurement

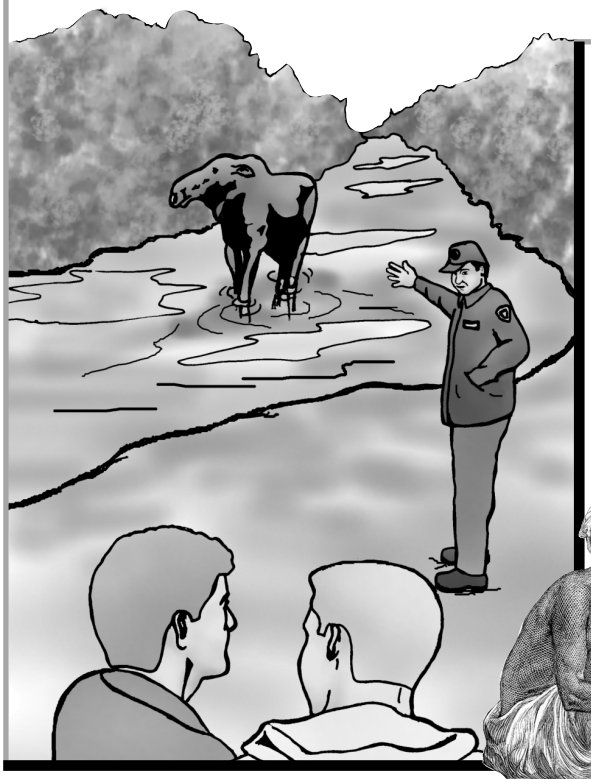
Chapter 2

Metric, Troy and Customary Systems

Section 1

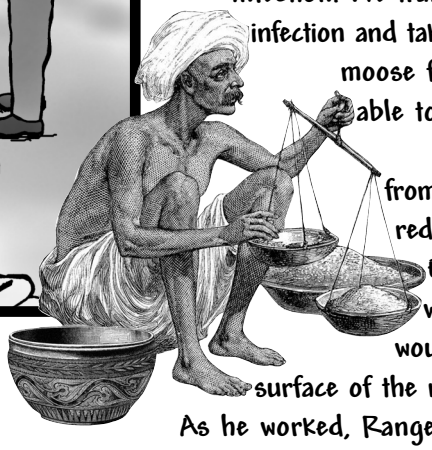
Lessons 1-5

MEASURING WEIGHT



Bryan and Tom raced through the meadow. The ground became softer. As they drew closer, they saw that the moose was not moving. Its legs were mired in the mud. The animal's head hung down and it seemed listless and confused. The animal also had an unpleasant odor.

"Great to see you, Bryan and Tom!" Ranger Eldridge boomed. "A tick infestation has weakened the moose. That horrible smell is from the infection. I've tranquilized her so I can treat the infection and take measurements. Once the moose feels better, she should be able to free herself."



An unpleasant odor came from the side of the moose that was red from infection. Ranger Eldridge suggested that Tom work that side. "The oozing wounds will not stain the slick surface of the raincoat."

As he worked, Ranger Eldridge said, "This is a young female. She probably weighs 450 ***kilograms***. Newborn calves weigh about 12 kilograms. A bull moose can grow to about 2.0 meters high at the shoulders and weigh about 725 kilograms. They have a stiff-legged, shuffling walk that makes them look clumsy. But with their long legs, they can really cover the ground. Moose seldom run, but when they do, they can hit speeds of nearly 60 kilometers per hour!"

"What happens if she doesn't get free?" Tom asked.

Ranger Eldridge said. "Wolves are an important part of the ecology for thinning out the ranks of deer and moose. Wolves take out the sick and weak ones. Unless this one can work herself free, she will become wolf food."

VOCABULARY

Kilogram: the metric base standard weight (about 2.2 pounds)
Weight: a measure of the force of gravity
Pound: a measure of weight equal to 16 ounces or 454 grams
Troy system: a system of weights employed by those who work with precious metals; a troy pound has 12 ounces

More than an hour passed before Ranger Eldridge was satisfied that he had done all he could for the moose. The time was late afternoon and the day was growing dark. Tom scanned the edge of the woods for signs of motion. Ranger Eldridge assured them, "Wolves in the wild never attack healthy humans. Never."

The ranger, as a scientist, used metric units to describe the moose. Ranger Eldridge talked about speed (60 kilometers per hour, about 37 miles per hour), length (2.0 meters or about 6.56 feet), and weight. The weights were in kilograms: 12 kilograms for the newborn, 450 kilograms for the young female, and 725 kilograms for the big bull moose.

Length and time were two of the first measurements that became important to people. Another important quantity was ***weight***. Shopkeepers used a balance beam scale to measure weight. The beam scale consisted of a horizontal rod that was held at its center but free to tilt up or down at each end.



VOCABULARY

Ton: a measure of weight in the customary system equal to 2,000 pounds
Mass: a measure of the amount of matter
Customary system: the system of weights and measures in the United States that includes the yard and pound
Gram: a metric unit of mass equal to 1/1,000 of a kilogram
Metric ton: a metric unit of mass equal to 1,000 kilograms

Suspended at each end were identical pans. When the pans were empty, the balance beam was level. If an object to be weighed were placed in one pan, that side of the balance beam dropped down. To bring it back into balance, weights of known value were added to the second pan until both pans balanced.

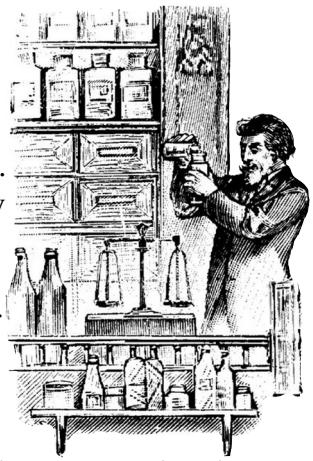
What kept the pans in balance were the loads in each pan and not the size of the objects. The shopkeeper would have weights of a standard amount. The three most common weights were *grain*, *ounce* and ***pound***.


barley

The grain was the smallest weight. It was used to measure expensive goods such as perfume, spices, gemstones or metals such as gold and silver. Originally, a grain was named after the weight of a barley grain. Suppose a traveler had a copper coin from a foreign country. The traveler wanted to use the coin to pay for his purchase. The shopkeeper would first weigh the coin to see the value of copper that it contained. Then, the coin was put on one pan of the balance and barley grains added until the pans came into balance. In England, 24 barley grains were needed to balance a penny's worth of copper.

Those who traded in gems and precious metals used the ***troy system***. The name *Troy* probably comes from the city of Troyes in France. The city held large fairs, and visitors to the fair became accustomed to the standards developed by merchants in that city. Travelers told of the use of the troy system of weights to the rest of Europe. In the troy system, a pennyweight was 24 grains, a troy ounce was 20 pennyweights and a troy pound was 12 ounces. The U.S. Mint adopted the troy pound for the regulation of coinage in 1828. The original United States silver dollars contained a troy ounce of silver.

Apothecaries (druggists) who dispensed medicine used a slightly different system. They retained the troy ounce and troy pound, but for smaller measurements, they used drams and scruples. Because of the necessity of being honest with weights when giving drugs to people for their health, the term *scruple* came into use in the English language. The phrase "he has no scruples," meant that the person was dishonest, a reference to an apothecary who intentionally cheated customers.



One of the responsibilities of a federal government was to encourage business by ensuring that a country's system of weights and measures was accurate and uniform. As time passed, rather than using grains of barley as standards, each country set up a system of authorized weights. The most common one was the troy system. Exact duplicates were made of the official troy standard weights. Goldsmiths or other merchants were required by law to use the exact duplicates. Exact duplicates of standard weights had to be carefully made. They were expensive. However, goldsmiths who refused to use the authorized weights lost customers and were in violation of the law.

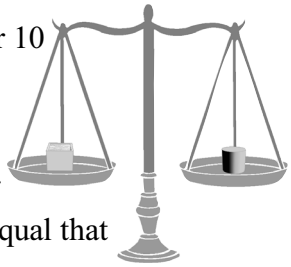
The expensive troy standards gave rise to a more relaxed, less rigid system known as the avoirdupois unit of measure. The word *avoirdupois* is from a French word meaning *goods of weight*. Farmers, shopkeepers and others who sold larger amounts such as grain, flour, meat and coal developed the avoirdupois system. The standard weights for this system were not as carefully controlled. A weight marked a pound might be slightly over or slightly under. However, because it was used to measure less expensive goods, the error did not matter as much.

The ***ton*** measured heavier loads such as coal. The American ton was 2,000 pounds. The British ton (known as a long ton) weighed 2,240 pounds.

All of these different and competing weights could be confusing among various merchants: Imagine the predicament in 1750 if a jeweler, a druggist and a merchant weighed a gold ring. Each one would express the weight in different units.

Following the French Revolution, the new French government of 1790 adopted a logical weight and measurement system based on powers of ten, which became known as the metric system. Most scientists and the majority of countries switched to the metric system. Druggists also changed from the apothecary system to the metric system.

When the metric system was first created, the kilogram was defined as the ***mass*** of a certain quantity of water. A cubic container 10 centimeters on a side holds one kilogram of pure water. The French made a solid cylinder of the metal, platinum, to equal that exact weight.



Later, when they tried to repeat the water measurement, scientists found it impossible to produce water to the same purity each time. Instead of water, they used the platinum cylinder as the standard. In 1889, the metal was replaced with an alloy of platinum-iridium of exactly the same weight. Today, the standard kilogram is still defined using the platinum-iridium bar as the standard. It is kept in a vault in France.

Rather than ounces, pounds and tons, most of the world uses the metric system for measuring mass. A kilogram

serves as the standard unit for mass worldwide. Other metric units of mass are measured from it.

The United States adopted as its ***customary system*** of measurement the pound of 16 ounces. In the customary system, the three most common weights are the ounce, pound and ton:

1 pound	=	16 ounces
1 ton	=	2,000 pounds

In changing from one unit to another, either multiply or divide by the *conversion factor*. When going from larger units to smaller units, multiply. For instance, in changing pounds to ounces, multiply by 16. Example: On average, about 11 pounds of chocolate are eaten each year for every person in the United States. That results in 11 (pounds) x 16 (ounces per pound) = 176 ounces.

When converting smaller units to larger units, divide. For instance, in changing pounds to tons, divide by the conversion factor of 2,000. Example: a ferry is marked that it can hold 5,000 pounds. To change pounds to tons, divide by 2,000: 5,000 (pounds) / 2,000 (pounds per ton) = 2.5 tons. The slash mark (/) is read "divided by."

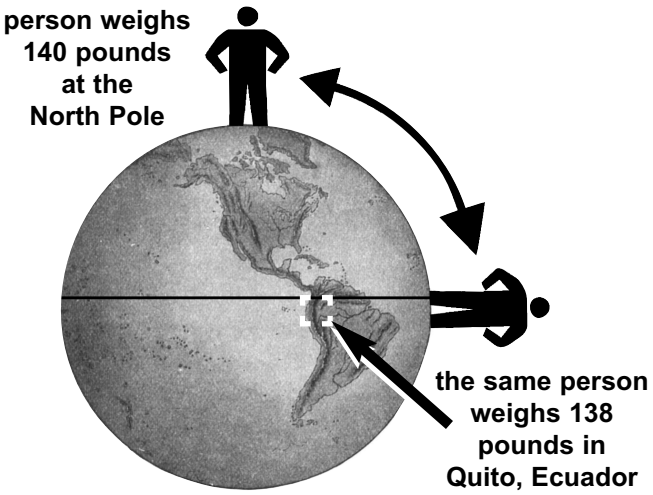
In the metric system, the three most common weights are the ***gram***, kilogram and ***metric ton***:

1 kilogram	=	1,000 grams
1 metric ton	=	1,000 kilograms

Most of the time, conversion between the system used in the United States and the metric system is not necessary. Goods are priced by the ounce or pound or by the gram and kilogram. However, for convenience, you should know a couple of easy "rules of thumb" (formulas) for conversions.

1 kilogram is about 2.2 pounds
1 pound is about 454 grams

Weight is the force of attraction of gravity. By moving farther from the center of the Earth, the attraction of gravity grows weaker. A person at the top of a tall building weighs slightly less than the same person at street level. The effect is even greater for a person on top of a mountain.



The Earth bulges more at the equator than at the poles. Quito, Ecuador is nearly on the equator of the Earth. A person there is about 26 miles farther from the center of the Earth than if he or she were at the North Pole. A person who weighs 140 pounds at the North Pole would weigh about 138 pounds at Quito, Ecuador. The two pounds of reduced weight are a result of the weaker force of gravity.

On the surface of the Moon, gravity is only one-sixth as great as on Earth. A person who weighs 140 pounds on Earth would weigh only about 23 pounds on the surface of the Moon. In space, where there is no resistance to the pull of gravity, objects float freely. Objects in space are described as being weightless. However, they are not massless.

Because weight can change from one place to another, scientists prefer to speak of mass. For two objects at the same place on Earth, either term can be used.

Scientists usually say they are *weighing* an object rather than saying they are *massing* the object. However, they do understand that mass does not change the way weight does. Weight varies depending on the pull of gravity. Mass is a measure of the quantity of matter in a body. Mass is the same regardless of the body's position on Earth or in space.

The ranger asked Tom and Bryan, "Where is your gear?"

Bryan explained about the stolen backpack and that the other pack had been left on the trail. "We can work around the lost backpack," Ranger Eldridge said. "Most of the time you'll be staying at the lodge. We camp out only when we go to the other side of the island."

Bryan learned that the lodge had been closed to the public for twenty-five years.

Ranger Eldridge explained, "The only permanent resident on the island is Mrs. Murphy. The girl you met lives with her in the summer. Right now, we're the only other humans anywhere on the island."

Tom asked, "Is it true about a treasure hidden on the island?"

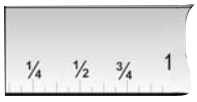
"Who knows?" the ranger shrugged, "Mrs. Murphy is cooking our evening meal. You can ask her, yourself."



Life

"Fixed reference points and standards are necessary for civilizations to progress beyond mere existence."

—Nancy Johnson



Lesson 5
Measurement

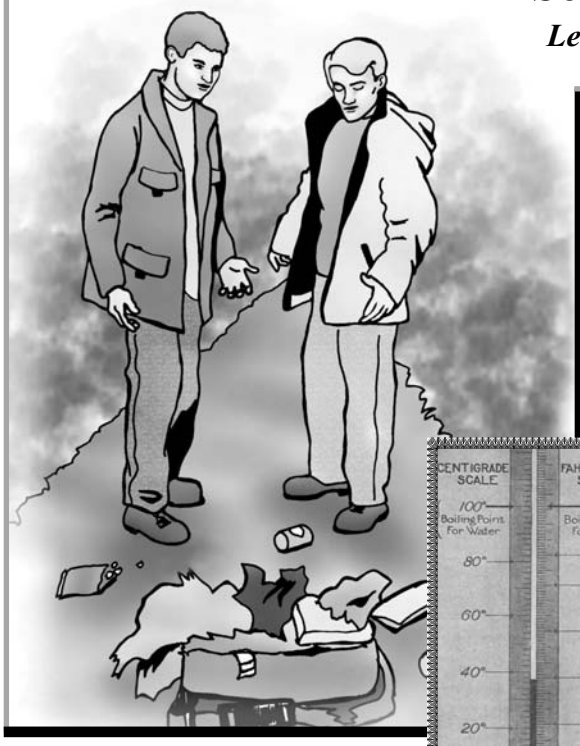
Chapter 2

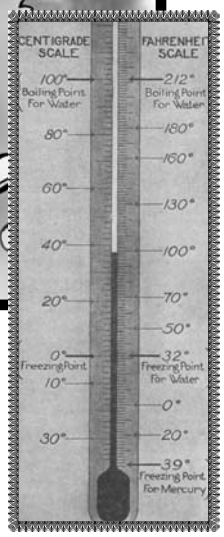
Measurement Standards of Galileo, Fahrenheit and Celsius

Section 1

Lessons 1-5

MEASURING TEMPERATURE





The boys planned to pick up Bryan's pack and hike to the lodge. Ranger Eldridge had come by boat. He would travel around the coast to the same destination.

When the boys arrived at the intersection where they had left the backpack, Bryan swept the beam of the flashlight around. The pack had been ripped open and contents flung out. Clothes, camp stove, sleeping bag, tent and a few food items were scattered all around. "Who did this?" Bryan wondered aloud.

Tom volunteered, "It looks like a vandal tore into it! But your uncle told us that we were alone on the island except for Mrs. Murphy and the young girl."

Bryan exclaimed, "Look at the frame of the backpack! It is bent out of shape! Only someone with tremendous strength could have done this!"

Bryan began picking up the scattered camping gear. Tom helped replace the items in the damaged pack, then they trudged toward the lodge. As soon as they topped the next ridge, they could see the lights of the lodge. Because of the darkness, very little about the lodge could be distinguished except that it appeared to be of ancient wood construction. Situated around it were small cabins.

Bryan carried a small compass with a thermometer built into it. Although the air had been warm when the boys were working with the moose, the temperature began falling as soon as the sun set. The boys knocked on the door to the lodge. Mounted on the outside wall was a thermometer. It read 10 degrees. Bryan

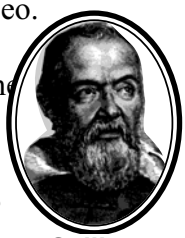
VOCABULARY

Temperature: a measure of the average heat energy in a body
Thermometer: an instrument to measure temperature
Daniel Gabriel Fahrenheit: German scientist who invented the alcohol and mercury thermometers and devised the Fahrenheit temperature scale with 180 degrees between the freezing temperature of water (32ºF) and the boiling temperature of water (212ºF)

checked his compass which had a built-in thermometer. It read 50 degrees. He wondered why each instrument gave a different temperature reading.

The first use of ***temperature*** as a useful scientific measurement was by doctors. A doctor usually measured body temperature by putting his hand on a patient's forehead. This was a rough guide because the doctor might have had a temperature, too; or the doctor might have had cold hands from being outside. Using hand-to-forehead as a guide to the patient's temperature was not very accurate.

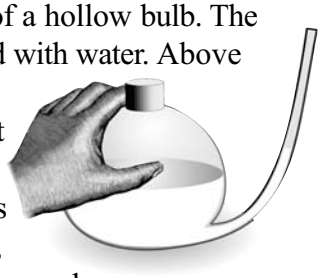
Measures of length and mass were known far back in history. About 300 BC, Philo of Byzantium described the first ***thermometer*** in his published work: *On Pressure Engines*. However, credit for the invention of the thermometer was given 2000 years later to a man named Galileo.



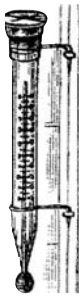
Galileo

In 1592, Galileo taught at the University of Padua, Italy. The school was noted as a medical school. Students from all over Europe came to Padua to study to become doctors.

While at Padua, Galileo made a thermometer based on the same principles described by Philo of Byzantium. In Galileo's design, a curving glass neck rose from the bottom of a hollow bulb. The bulb was partially filled with water. Above the water was an air bubble. The patient put his hand on the bulb. The heat of the patient's hand heated the air. Air, like most substances, expands as it is heated. The expanding air forced the water up the neck. The height of the water was a measure of the temperature. Galileo's thermometer was clumsy and not very accurate because changes in air pressure could affect the reading.



In 1709, ***Daniel Gabriel Fahrenheit***, a German scientist who lived in the Netherlands, invented an improved thermometer that used alcohol rather than air. Alcohol expanded in a much more predictable way than air. However, scientists avoided using it in thermometers because the clear liquid was difficult to see. Fahrenheit made the alcohol visible by adding food coloring.



Fahrenheit's thermometer had a bulb of colored alcohol at the bottom and a long hollow glass stem. A rise in temperature caused the alcohol in the bulb to expand and rise in the stem. The tiny opening in the stem amplified a slight temperature change. The height of the column of liquid changed noticeably with even a small rise in temperature.

VOCABULARY

Standard: an object or procedure that has been selected as a model against which other objects are compared, standards in weights and measures include the meter for length, kilogram for mass and Celsius degree for temperature

Boiling point: the temperature at which a substance changes from a liquid to a gas; also called the boiling temperature, most substances have a fixed boiling temperature; for water it is 100ºC or 212ºF

Freezing point: the temperature at which a substance changes from a liquid to a solid, also called the freezing temperature; most substances have a fixed freezing temperature, for water it is 0ºC or 32ºF

Anders Celsius: Swedish astronomer who devised the Celsius temperature scale with 100 degrees between the freezing temperature of water (0ºC) and the boiling temperature of water (100ºC)

Improved thermometers came into use for purposes other than measuring patients' temperatures. People mounted thermometers outside their windows and referred to them when getting dressed to go outside. The temperature readings helped people decide whether to wear heavy coats or light wraps.

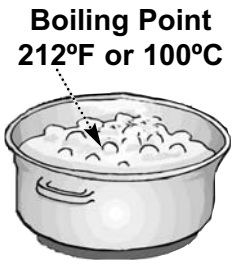
Alcohol remained a liquid during cold weather but tended to boil during hot weather. Consequently, the alcohol column separated in hot weather; bubbles of alcohol vapor formed in the thermometer, causing it to give inaccurate readings. When the alcohol cooled back down, the column of liquid remained separated. The thermometer was then too disrupted for accurate use.

Daniel Fahrenheit solved this problem, too. In 1714, he made a thermometer that used mercury in the column. Mercury was a liquid at room temperature. It did not freeze in bitterly cold weather and stayed a liquid at boiling temperatures. During a change in temperature, mercury expanded at an even rate. Fahrenheit's mercury thermometer was very accurate.

Despite the accuracy, scientists could not relate the reading of one thermometer to another unless they were constructed exactly alike. Suppose one thermometer had a big bulb of mercury but a very narrow hole along the length of the tube. Another thermometer might have a small bulb of mercury but a bigger hole along its length. The same temperature change would cause the mercury to rise higher in the first tube than in the second one.

Scientists thus were not able to compare readings on two different thermometers. Like length, mass and time, scientists saw the need for a standard. A ***standard*** is a quantity of known value that everyone agrees to use for a measurement. In the metric system, the *meter* was the standard for length. The *kilogram* was the standard for weight or mass. The *second* was the standard for time. Scientists needed a good standard for temperature.

While experimenting with his thermometer, Daniel Fahrenheit made a remarkable discovery. When water was heated, its temperature rose until it began boiling. Once it started boiling, the water did not get any hotter. It had a fixed ***boiling point***. The temperature was constant until all the water boiled away. Fahrenheit tested other liquids and found that many of them had fixed boiling points, too.



Going the other way, as the temperature fell, water had a fixed ***freezing point***. The water got colder and colder until ice started to form. The temperature hovered at the same reading until all of the water turned to ice. This discovery proved that water had a fixed freezing point. Fahrenheit tested other liquids and found that many of them had fixed freezing temperatures.



Fahrenheit knew that mixing salt with ice lowered the melting temperature. During an experiment on a cold day, he dipped his mercury thermometer into a mixture of salt and ice. He waited until it dropped to its lowest reading. He called this temperature 0ºF.

Fahrenheit used water to help fix two standard readings on his thermometer. He marked the boiling point of water as 212ºF. When testing the freezing point of pure water without salt, he found that it was 32ºF.

Daniel Fahrenheit had not only invented a thermometer, but he devised the first standard temperature scale. The Fahrenheit scale used the symbol *F*. His temperature scale had the freezing point of water as 32ºF and the boiling

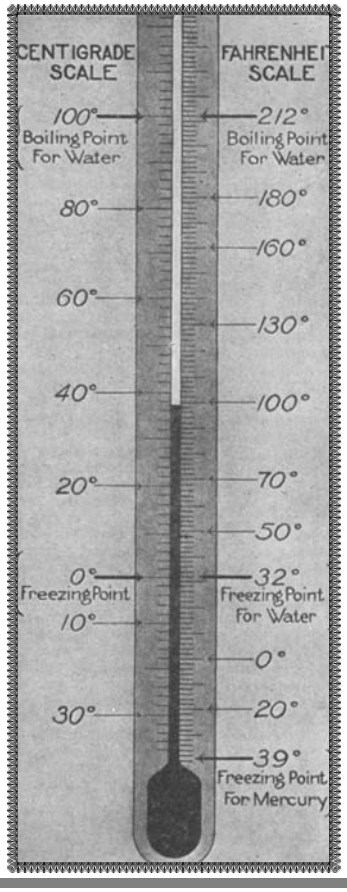
point of water as 212ºF. Between those two readings were 180ºF.

Fahrenheit's thermometer was one of the inventions that made weather forecasting possible. Amateur weather observers measured wind direction and speed, humidity, air pressure and temperature at a particular location. The telegraph, invented in 1837, made the rapid collection of weather information possible. Professional weather forecasters drew weather maps from the data. They predicted the weather for the next day.

Weather forecasters liked the Fahrenheit scale because most of the time temperature stayed between 0ºF and 100ºF.

Scientists, however, were not as enthused about the Fahrenheit scale because the beginning point at 0ºF could not be easily repeated in the laboratory. Ice, water and salt did not always produce a temperature of exactly 0ºF.

In 1742, Swedish astronomer ***Anders Celsius*** proposed a different scale. His design assigned the value 0ºC to the freezing point of water and 100ºC to the boiling point of water.



Scientists could mark a Celsius thermometer with standard temperatures without the need to compare physically one thermometer with another. If you were to place a Celsius thermometer in pure water and let it cool to the freezing point, you would notice the mercury level registers at 0ºC. If you were to put the thermometer in boiling water, you would notice the mercury level registers at 100ºC.


Anders Celsius

The Celsius scale has 100 marks between the freezing and boiling temperature of water. For a time, the temperature scale was called the Centigrade scale. The word *centi* means *100* and *grade* means *mark*. However, the official name for the scale is Celsius. It is a part of the metric system and is used by all scientists and most of the countries of the world.

Converting between Celsius and Fahrenheit temperature scales is not straightforward because they have different starting points and the degrees are different sizes. Instead, having a general idea of how they compare is usually sufficient for everyday activity.

Zero point of Fahrenheit thermometer: 0ºF = -18ºC
Freezing point of water: 32ºF = 0ºC
Room temperature: 72ºF = 22ºC
Normal body temperature: 98.6ºF = 37ºC
Boiling point of water: 212ºF = 100ºC

Bryan realized that both thermometers were giving the same reading. The one on the outside cabin wall that showed 10 degrees was measuring with the Celsius temperature scale. The thermometer on his compass that showed 50 degrees was measuring with the Fahrenheit temperature scale.

The woman named Rebecca Murphy opened the door. "Welcome to Danger Lodge!" she told the boys. "Come on in and clean up and we will have our evening meal."

Mrs. Murphy made a face as Tom started to step through the door. "Why don't you leave your raincoat with your friend's backpack?

The coat has a terrible odor!"

Bryan explained, "We helped my uncle with a sick moose at the bog. Tom's raincoat picked up the smell."

Ranger Eldridge strode up as Tom hung the coat over the rail of the porch. He took one look at Bryan's pack and said. "Looks like the bears have been at work."

"Bears?" Bryan asked.

Life Principle



"Doing the right thing helps to keep you out of hot water.

—Anonymous

Lesson 6
Light and Sound

Chapter 2

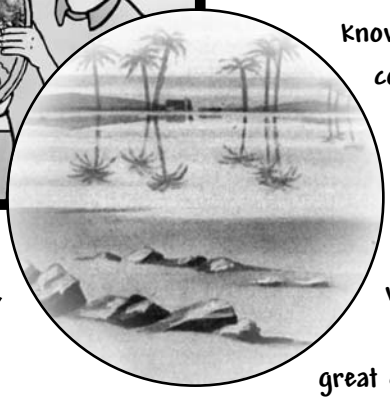
Speed, Illusions and Relationships, Discoveries of Olaus Roemer

Section 2

Lessons 6-10

LIGHT





Mrs. Murphy said, "Yes, indeed, we have bears! Del and I have to be careful about throwing out food, because bears will raid the garbage cans."

Bryan looked sharply at the girl who seemed unconcerned that his pack had been trashed. Bryan said, "You did not say anything about bears!"

Del replied, "I thought you would know to put your food in a bear-proof container and hang it from a tall limb."

Bryan's irritation at the girl was soon forgotten as Mrs. Murphy served dinner. The food was fresh, well prepared and served hot. The meal was completed with homemade apple pie.

Dinner had been served in the great dining room. Although the ceiling was illuminated by electric lights, a fire in the fireplace gave a cheery glow. In addition, Mrs. Murphy had placed an antique oil lamp on the dining table. Mrs. Murphy spoke freely about the mystery of Danger Island. She said, "The Vikings were seafaring explorers who settled Iceland and Greenland. About a thousand years ago they explored the East Coast of North America, a place they called "Vinland." Although much physical evidence of their presence is lacking, I think my father discovered something that proves the Vikings landed on this island."

Although Del's grandfather disappeared before Del was born, she knew about the mystery. She said, "He disappeared before he revealed the discovery. All he left was a plate, and what kind of clue is that?"

"What is she talking about?" Tom asked.

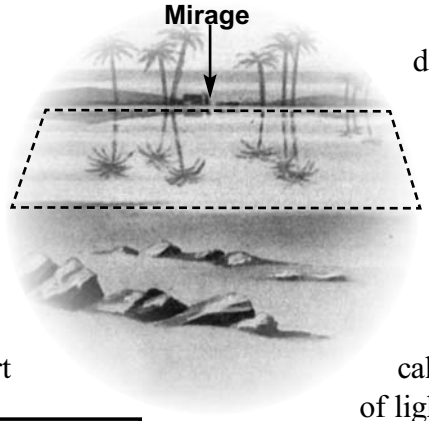
VOCABULARY

Mirage: an optical illusion due to certain light ray and temperature combinations
Olaus Roemer: Danish astronomer, 1644-1710, who made the first measurement of the speed of light. (The current accepted value for the speed of light is 186,000 miles per second or 300,000 kilometers per second)
Inverse: a relationship between two quantities in which as one increases, the other one decreases

The evening meal in the lodge was possible because of the artificial light from the electric lights, the fireplace and the antique lantern. At about the same time that they were improving thermometers, scientists were also making progress in understanding light. Scientists began to understand that air and water affect the speed of light.

The speed of light slows slightly when it enters the air from outer space. Then, when light enters water from the air, it slows again. In each transparent medium, the speed of light is different. Light travels fastest in a vacuum and slowest in a diamond. In addition, each color of light changes speed by a slightly different amount. When red, green and blue light enters a diamond, blue slows the most and red slows the least. Because of the difference in speed, if light strikes a diamond at an angle, the rays of each color separate. A diamond sparkles because it separates light into its colors better than any other gemstone.

Anytime light goes from one medium into another medium at an angle, the light beam bends. Layers of air at different temperatures can change the direction that light travels. A ***mirage*** is an illusion caused by such bending. In a desert area, the air is hotter near the ground than higher up. The paths of light rays bend as light rays enter the less dense, hot air. Thus, a distant mountain may appear to be floating upside down. Or, rays of light from a part of the blue sky may bend and appear to be a shimmering blue lake on the distant surface of the desert. Sometimes the mirage is so realistic as to fool even the most experienced desert traveler.



Light travels faster than sound. During a lightning storm, we see the flash of a lightning bolt and then a few seconds later we hear the clap of thunder. The electrical discharge from the cloud causes the air to glow and gives rise to the visible lightning bolt. At the same time hot air expands rapidly and causes the sound of thunder. For a person a mile away, the sound arrives about one second behind the lightning. Light arrives first and sound second.

To measure speed, distance and time must be known: speed is calculated as distance divided by time. Light travels very fast. Unless the distance is great, the time is too short to measure.

The first scientist to calculate a value for the speed of light was the Danish astronomer, ***Olaus Roemer***. He worked at an observatory in Paris and studied the motion of the four brightest moons of Jupiter. These moons were large and easily seen with even a small telescope. The innermost moon was named *Io*. When its orbit carried it behind the planet, Io disappeared from sight as seen from Earth. The eclipse of Io by Jupiter was


Olaus Roemer

VOCABULARY

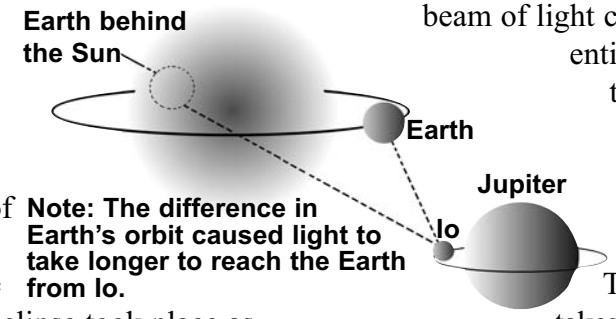
Inverse-Square Law: the scientific law that one quantity is inversely related the square of the other; the intensity of light is inversely related to the square of the distance from the source; moving three times closer to a source of light increases the intensity by nine times, $3^2 = 3 * 3 = 9$

very regular and easy to predict—every 42 hours and 28 minutes.

Olaus Roemer began observing Jupiter when it was high in the night sky. He continued to observe it as both Earth and Jupiter traveled in their orbits around the Sun. Roemer detected a slight error in the time of the predicted eclipses. After six months, Jupiter was low in the sky at sunrise. By then, the eclipses were coming about 1,000 seconds later than Roemer had predicted. That indicated an error of almost 17 minutes.

Roemer wanted to know what caused the error. Perhaps his clock was inaccurate. Clocks were not highly accurate in the 1600s. However, Roemer's clock was accurate enough for him to know that the error had some other cause. He built an improved pendulum clock that kept better time than any clock then in use. He checked his calculations. He was not making an error in his math. Maybe Io was speeding up or slowing for some undetected reason. Roemer continued his observations for four years. Io's motion appeared entirely regular.

Roemer realized the error was not in his clock, his calculations, or an imbalance in Io's orbit. Instead, the change in the time of eclipse of Jupiter's moon was due to the speed of light. The eclipse took place as predicted. Light from the event did not reach him as it should because of the changing distance between Earth and Jupiter.



The greatest error occurred when Roemer viewed Jupiter from two widely separated points. When Jupiter was high in the night sky, Earth and Jupiter were at their closest point. When Roemer saw Jupiter near the Sun, Earth was on the opposite side of its orbit around the Sun. The delay of 1,000 seconds represented the extra time light needed to cross from one side of Earth's orbit to the other.

Roemer calculated the velocity of light by dividing the diameter of the Earth's orbit by 1,000 seconds: *speed = distance/time = diameter* of Earth's orbit / 1,000 seconds. At that time, the diameter of Earth's orbit was only roughly known, so the speed he calculated was inexact. Later, astronomers learned that the distance from Earth to the Sun was 93,000,000 miles (93 million miles). The distance from one side of Earth's orbit to the other was 186,000,000 miles (186 million miles). Dividing 186,000,000 miles by 1,000 seconds set the speed of light at 186,000 miles per second.

The value of 186,000 miles per second is very close to the accepted value today. The modern value for the speed of light is 186,282 miles per second (299,792 kilometers per second). For ordinary use, these values are often rounded: 186,000 miles per second (300,000 kilometers per second).

The speed of light is very fast. A beam of light could travel across the entire United States in less than 1/50 of a second. However, distances in space are so great that even light takes time to journey among the planets. The light that the Sun emits takes about 8 1/3 minutes to reach Earth.

Suppose a person is reading a newspaper in a room that is poorly lighted. The closer a person moves to the light the greater the intensity of light that strikes the newspaper. As the distance becomes less, the intensity becomes more. Because distance and intensity change in the opposite directions, scientists say that the intensity of light is

inversely related to the distance.

Scientists also found that the intensity of light depended on the square of the distance. If you cut in half the distance from an object to the light, the intensity becomes four times as great: $2^2 = 2 * 2 = 4$. The expression 2^2 is read "2 squared." If you move so you are three times closer to the light, the intensity becomes nine times as great: $3^2 = 3 * 3 = 9$. The intensity is inversely related to the square of the distance.

In traveling from the Sun to Earth, the intensity of light grows weaker. Light rays spread out and cover a greater area. The sunlight that reaches Mercury, the planet closest to Earth, is far greater than the light that reaches Earth. Earth is three times as far from the Sun as Mercury. Each square foot of Mercury's surface receives nine times as much sunlight as does the Earth.

Jupiter is about five times as far from the Sun as is the Earth. Each square foot of Jupiter's surface receives only about 1/25 as much sunlight as Earth receives: 1/5 x 1/5 = 1/25.

Several other quantities grow weaker by the square of the distance. Electric intensity, magnetic fields and the force of gravity also decrease by the square of the distance. When a quantity decreases by the square of the distance, it is said to follow the ***Inverse-Square Law***.

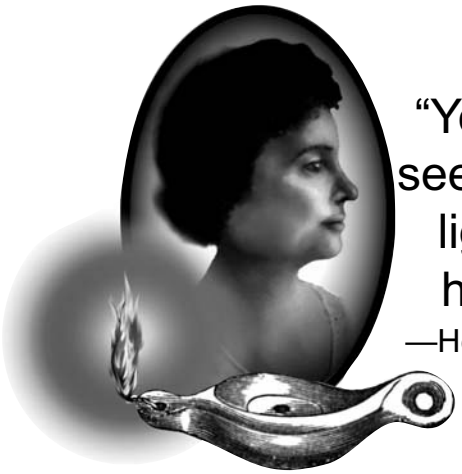
Scientists wanted to measure the intensity of sunlight. The standard for equating light was called the foot-candle. A candle of a particular composition, size and shape served as the standard. A *foot-candle* was the light received by a surface one foot from the flame of a standard candle. Today, the standard for light intensity in the metric system is called the *candela*. The light given off by an object that is heated to a specified temperature measures the candela.

A large china plate with a design in blue was on a stand under a photograph of a man. Bryan assumed the portrait was of Mr. Murphy.

Mrs. Murphy took down the plate and handed it carefully to Bryan. He and Tom studied it. The blue design was a drawing that showed the main features of the island. The plate had been broken and carefully glued back together. Tom traced his fingers lightly over the cracks. The cracks converged on a stunted, twisted tree along a rocky outcrop at the north end of the island.

The girl said, "Grandfather Murphy was working in his shop when he disappeared. He was making a gift for my mother's birthday. After he disappeared, the souvenir plate was found in the gift box. We think it is a clue."

Life Principle



"You can see by the light of hope."
—Helen Keller

Lesson 7
Light and Sound

Chapter 2

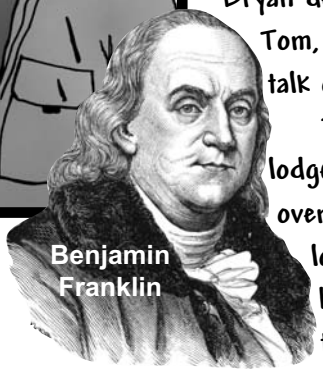
Conductors, Nonconductors, Experiments of Benjamin Franklin and Andre Ampere

Section 2

Lessons 6-10

ELECTRICITY





The next morning, Mrs. Murphy gave Tom fresh clothes to replace those stolen by James Olsen. Mrs. Murphy had washed and dried Tom's other clothes. When he separated a pair of socks, they crackled with static electricity.

Bryan learned that the clothes had belonged to the missing or dead Mr. Murphy. Bryan decided not to share that information with Tom, who was spooked enough already with the talk of wolves and bears.

Pictures posted along the walls of the lodge showed how Danger Island had changed over the years. One photo was of a man with a long flowing beard, a seaman's cap and bright, white canvas (called "duck") trousers and shirt. He stood by a waterwheel.

"That is old man Barnett at his mill," Del said. "He was the last to leave the island, except for my grandmother. Mr. Barnett lives in a home on the mainland."

Bryan marveled the man was still alive. He looked ancient in the picture, which had been made thirty years earlier.

Electricity for the lodge came from a diesel powered generator. Mrs. Murphy ran it only a few hours each day. The island had no roads, no powered vehicles, and only two main trails that connected to make a circuit of the island. One of the trails passed by the old mill, an abandoned copper mine, and then came to a bluff that overlooked a small island to the north.

Del said, "From the bluff you can see Shell Island. The name shell refers to shells fired from battleships. During World War II, the Navy used the island for target practice. No one has

VOCABULARY

Nonconductors: substances that prevent the movement of electricity; most nonmetals are nonconductors, examples include glass, mica, and rubber
Conductor: a substance that allows the movement of electricity; most metals are conductors: examples include gold, silver, copper and aluminum
Insulated: electricity kept from flowing outside a conductor by means of a nonconducting material; copperwire is insulated with rubber or plastic to prevent electrocution

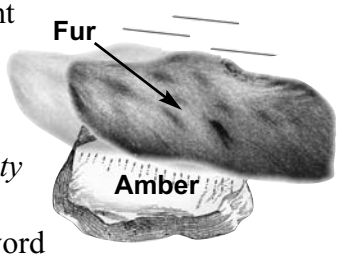
ever lived on the island. It is off limits because of the danger of unexploded shells."

Tom rolled his eyes, "Bears, wolves, unexploded shells. This is a real fun place!"

On Saturday, the boys decided to explore Danger Island. Ranger Eldridge supplied the boys with a good map. Bryan made sure he had his compass.

Ancient people had experienced static electricity such as that in Tom's socks. They also knew about magnetism that caused Bryan's compass to show directions. However, neither electricity nor magnetism was well understood. Not until the 1200s was magnetism employed in making the first compasses. The first practical electrical invention, the lightning rod, was not made until the 1750s.

Ancient Greeks were the first to describe static electricity. The Greeks discovered that rubbing amber with fur produced a static electric charge. Amber is fossilized pine tree sap with a golden color. The ancient Greeks charged amber and amused themselves by picking up lightweight objects such as feathers or bits of fabric. The words *electron* and *electricity* were made from *elektron*, the Greek word for amber.



Scientists did not study static electricity in detail until the 1500s. William Gilbert was an English physician who served as the doctor for Queen Elizabeth I and King James I. Gilbert was also a scientist who investigated the properties of magnetism and electricity. Amber was still prized for its beautiful color. It was used to make jewelry. William Gilbert wondered if other gemstones could become electrically charged. He rubbed diamonds, opals and sapphires with fur. They also gained a static electric charge, which attracted bits of paper, feathers and pieces of cork.



Other substances were found to gain a static electric charge: various gemstones, crystals, glass and the paraffin wax for making candles. These could be given the charge by being rubbed with fur, wool or silk. Because they held a charge, they were called ***nonconductors***.

The best nonconductors of electricity are nonmetals. Good nonconductors include glass, mica (a mineral) and rubber.

VOCABULARY

Neutral: a substance with as much positive electric charge as negative electric charge; overall it appears to be uncharged

Negative electric charge: a charge of the same type as that carried by an electron; an object has a negative electric charge if it has more electrons than protons; a negative charge is usually achieved by a substance gaining electrons

Positive electric charge: a charge of the same type as that carried by a proton; an object has a positive electric charge if it has more protons than electrons; a substance losing electrons usually gains a positive charge

Electrons: small, subatomic particles that circle the nucleus of the atom and carry a negative charge; electrons move about easily in metals

Protons: small, subatomic particles found in the nucleus of the atom along with neutrons; protons carry a positive charge

Leyden jar: an early device for storing a static electric charge; a modern form of the Leyden jar is a capacitor

Ampere: the metric unit for measuring electric current

Additional experiments showed that electricity could travel from one substance to another. When a hard rubber rod was rubbed with fur, the rod would take a static charge. If the rubber rod were touched to a metal post, the electricity left the rubber rod. The metal post was called a ***conductor***.

The best conductors of electricity are metals. Good conductors include gold, silver and copper.

Some nonconductors could be made to conduct electricity by soaking them in salt water. For example, a dry silk ribbon does not conduct electricity. It can touch a charged glass rod and the rod keep its charge. Scientists experimented by soaking silk ribbon in salt water and then touching it to a charged glass rod. The static charge left the rod through the wet ribbon. The human body also conducts electricity. Touching a charged glass rod with your hands discharges the rod.

A conductor retained a charge if it was ***insulated*** from its surroundings by nonconductors. Suppose a metal plate was placed on a wax surface and stroked with silk. Providing the air was dry and no body touched the metal plate, it would hold a charge because it was insulated from other conductors.

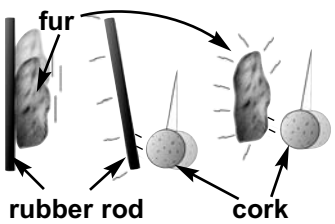
The American publisher, statesman and inventor, Benjamin Franklin, was credited with making the breakthrough in understanding static electricity. In 1747, he began a series of experiments that revealed the true nature of static electricity. He stroked a rubber rod with fur and brought the rod near a piece of cork hanging from a thread. The rubber rod attracted the cork. Franklin then brought the fur near the cork. The fur also attracted the small ball of cork.

This experiment convinced Benjamin Franklin that friction generated by rubbing actually transferred charged particles from one body to another. Before they were rubbed together, the rod and the fur had no charge. They were ***neutral***. When Franklin rubbed the rod with fur, each substance gained a static electric charge. However, the charges were opposite one another. He called the charge on the rod a ***negative electric charge***. He called the charge on the fur a ***positive electric charge***.

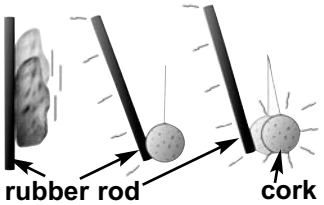
Scientists later learned that ***electrons*** and ***protons*** cause the static electric charge of a body. Electrons and protons are two of the building blocks of atoms. They are extremely tiny. An electron has a negative charge. A proton has a positive charge. Electrons and protons have opposite electric charges.

An object with a negative charge has more electrons than protons. An object with a positive charge has more protons than electrons. A neutral body has an equal number of protons and neutrons. Usually, an object becomes charged because the electrons enter or leave the object. For instance, when Franklin stroked a rubber rod with fur, the rod gained electrons from the fur. The rod became negatively charged and the fur became positively charged.

Franklin then touched the cork with the rubber rod. This transferred some of the static charge to the cork. The cork carried the same amount of electric charge as the rubber rod. Then Franklin brought the rod near the cork again. This time the rod pushed away the cork ball. Although the cork and the rod had the same charge, they repelled one another. Benjamin Franklin concluded that like static electric charges repel one another.

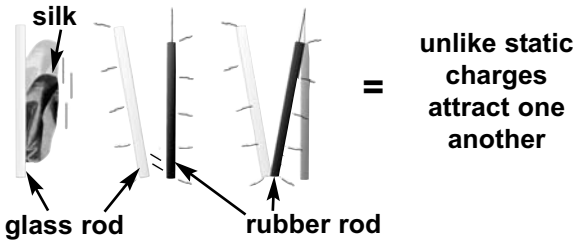


= friction transfers charged particles from one body to another

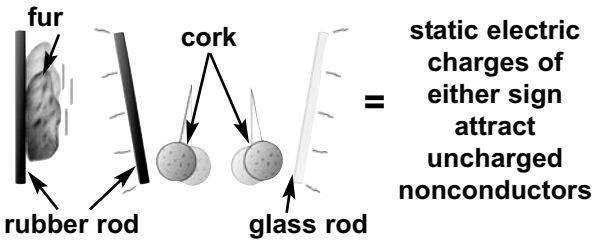


= like static electric charges repel one another

Mr. Franklin then tested a glass rod stroked with silk. The glass rod received a positive charge. He brought a charged glass rod near a charged rubber rod suspended by a thread. The rubber rod had a negative charge but the glass rod had a positive charge. They attracted one another. Benjamin Franklin concluded that unlike static electric charges attract one another. Unlike static charges are also known as opposite static charges.



The colonial scientist conducted another experiment by suspending a piece of uncharged cork from a thread. Although a charged rubber rod and a charged glass rod had opposite charges, they each attracted the cork. Benjamin Franklin concluded that static electric charges of either sign, positive or negative, attract uncharged nonconductors.



Benjamin Franklin could discharge a charged object by touching his finger to it. Sometimes before he touched the object, the static electricity jumped from the nonconductor to his finger. He saw a tiny sparkle of light and heard a faint pop. It reminded him of lightning in a thunderstorm. First came the brilliant streak of lightning and then a few minutes later the loud rumble of the thunder. Mr. Franklin's inquisitive mind predicted a connection between lightning and static electricity.

Benjamin Franklin did an amazing and very dangerous experiment. In June 1752, he flew a kite during an electrical storm. He tied a metal rod to the top of the kite. A wet cord connected the rod to a key on the ground near where Franklin stood. The key then connected to a device called a ***Leyden jar*** that could store electricity. Franklin predicted that the rod would attract electricity from the cloud, conduct it down the wet cord to the key, and then into the Leyden jar.

Benjamin Franklin knew the experiment was dangerous. If a bolt of lightning came down the cord, he could be killed. Franklin took the precaution of standing inside the doorway of a shed while he flew the kite. He held the wet string by a dry silk ribbon. Lightning struck the kite and traveled down the string. Franklin touched the key and felt a shock. He could have been electrocuted! Instead, electricity was captured in the Leyden jar. After it filled with electricity from the lightning, the jar was taken inside. Further experiments showed that the captured lightning had all the same properties of static electricity. Lightning was a static discharge like that from a rubber rod, but on a much grander scale.

In the 1800s, the French scientist Andre Ampere made the surprising discovery that a conducting wire charged with an electric current has a magnetic field around it. In one experiment, Ampere sent an electric current down two wires that ran parallel to one another. If the current traveled in the same direction in both wires, the magnetic fields produced attracted one another. When the current traveled in opposite directions, the magnetic field they produced repelled one another. The stronger the current, the stronger the magnetic fields. This gave scientists a way to measure the strength of an electric current.

Ampere's discovery caused scientists to want to set a standard for measuring electric current. In the metric system the standard

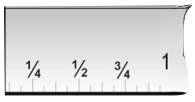
unit for measuring electric current is the ***ampere***, named in honor of Andre Ampere. An ampere is defined as the amount of current that would produce a particular force for every meter along two long parallel wires that are one meter apart. The force is very tiny. About 20 million amperes are needed to produce a force of one pound.

On his map, Bryan traced out the trail that would take the boys around the island and to the bluff at the opposite end of the island. Then Bryan said, "The cracks in the plate left behind by Mr. Murphy come together at the bluff. That's where the twisted tree grows. Maybe we can solve the mystery of what Mr. Murphy found on Danger Island!"

"Wise people learn not to repeat previous mistakes"

—Anonymous





Lesson 8
Measurement

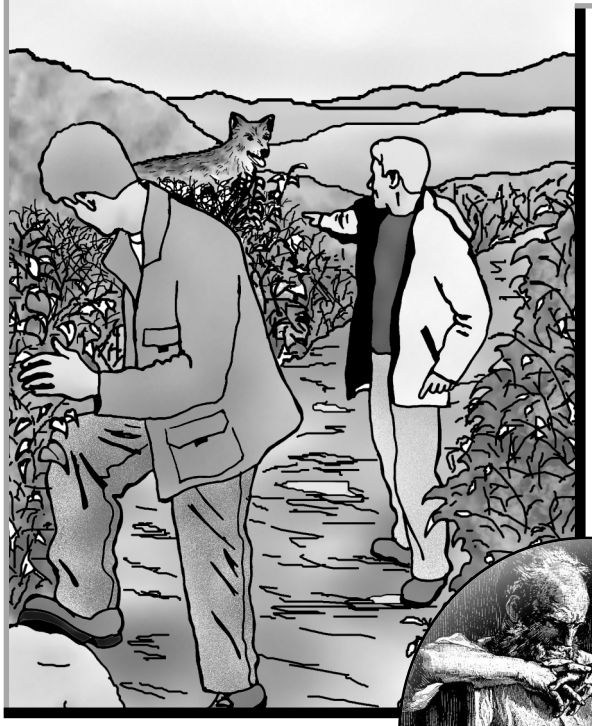
Chapter 2

Place Values, Advent of Zero, Exponents and Applications in Science

Section 2

Lessons 6-10

LARGE NUMBERS AND THE MOLE



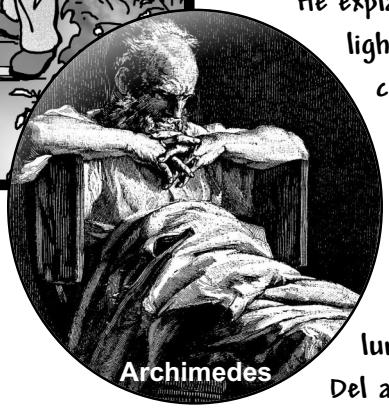
The girl, Del, learned of the boys' plans to hike around the island. She was full of information about things to see and do. She said, "The Island is 12 miles long and three to four miles wide. That trail runs along the eastern side near the shore. I can go with you and show you things you probably would miss on your own."

Tom disagreed. He said, "We're big guys. We have long legs and travel fast. You would not be able to keep up."

Bryan could see that she was disappointed. He explained to her, "We're going to travel light, walk fast and make the complete circuit in one day. We'll have 15 hours of daylight to cover 24 miles."

The girl asked, "So you'll be at the bluff overlooking Shell Island a little after noon?"

Bryan nodded. "We plan to eat lunch there."



Del always had something to say. This time she was strangely silent. Bryan had the clear impression that she was planning something. But what?

As the boys left the lodge, Bryan noticed a date carved in the cornerstone of the lodge. The date was in Roman numerals and gave the year work started on the building: MCMXXIII. Bryan translated that as 1923.

One of the challenges scientists face is to summarize statistics and data collected from observation or experiments. Del said Danger Island was about 12 miles long and three to four miles wide. Bryan said the boys had 15 hours of daylight

VOCABULARY

Place value: a numbering system in which the position of a number gives its value; the decimal numbering system that we use is a place value system

Exponent: a number placed to the right of and above another number showing how many times it is multiplied; in 10^6, the *6* is the exponent, also called *power*

to hike 24 miles. The cornerstone showed that construction began in 1923. These are small numbers. Often scientists must deal with extremely large numbers. The speed of light, stated as 186,000 miles per second, is one example of a large number. It is far smaller than some other numbers that scientists use. The number of air molecules in a small room extends to trillions.

The ancient Greeks and Romans used letters to stand for numbers. In the Roman system, I stood for one, V for five, X for ten, L for fifty, C for one hundred and M for one thousand. The Romans wrote the number 1,358 as MCCCLVIII. Multiplying and dividing with Roman numerals were especially difficult. To show numbers much beyond one thousand, M, was not easily done.

The location of the symbol did not change its value. The Roman number XXIII was 10 + 10 + 1 + 1 + 1 = 23. If scientists wrote a number as IIIXX, it was still 1 + 1 + 1 + 10 + 10 = 23. Later, a slight change was made in Roman numerals so that a smaller number before a larger number was subtracted from the larger number. For instance, VI was 5 + 1 = 6, but IV was 5 - 1 = 4. This made Roman numerals even more confusing.

VOCABULARY

Mole: in chemistry is the very large number $6.022 * 10^{23}$, the number of carbon atoms needed to weigh 12 grams; a mole of particles has the same weight in grams as the atomic weight of an individual particle; a mole is the metric standard unit for measuring large numbers of particles

Atomic weight: the weight of an atom compared to the weight of a carbon atom; a carbon atom is given an atomic weight of 12

One of the great scientists of the ancient world was Archimedes. He believed Roman numerals were not adequate for representing large numbers. He once heard a person use the expression "As countless as the grains of sand on the seashore." As Archimedes thought about this statement, he realized that it was incorrect. The number of grains of sand was not infinite. However, the number was so great that it could not be written using Roman numerals.



Archimedes developed his own numbering system to count large quantities. He invented the name *myriad* for 10,000. It was ten multiplied by itself four times: 10 * 10 * 10 * 10 = 10,000. He made a still larger number as a myriad myriad, or one hundred million (100,000,000). He called this number an *octad*. It was ten multiplied by itself eight times. Octad meant eight. A still larger number was an octad octad (10,000,000,000,000,000).

Although the number of grains of sand was immense, Archimedes could name their number with his counting system. However, his superior method of using powers of 10 to represent numbers was not immediately accepted.

The Romans gained control of the Greek Empire, but the Romans, who did not make as many scientific discoveries as did the Greeks, did not appreciate Archimedes' numbering system. Romans did, however, build roads for their chariots and construct aqueducts for carrying water. The improved water supply system made cities healthier places in which to live.

In the 400s, the Roman Empire began to collapse. Governments worldwide crumbled.

Learning went into decline. Education became of little importance. Few people could read or write. Most people in Europe lived as farmers and worked on land owned by wealthy families. Trade between countries all but disappeared.

During the 1100s, a group of merchants from cities such as Venice and Genoa, Italy began to trade in sugar, spices and silk carried by Arab caravans that followed the historic Silk Road from China.

The merchants had to convert weights and measures from one system to another. Businessmen calculated the rate of exchange for money and divided profit and expenses among partners. Merchants calculated the percentages of taxes and figured interest. Doing this with Roman numerals was a real headache.

The Arabs had a better method of writing numbers. Italian merchants learned the Arabic counting system and were astonished at the ease of doing math with the new system. It was superior to Roman numerals due to two key features. First, a ***place value*** system allowed a symbol to change in value depending on where the symbol was located in a number. For instance, 5,358 has two 5s in it. The 5 on the left stands for 5,000. The 5 in the middle stands for 50. The value given by the 5 depends on its place in the sequence of digits.

The second key feature was the use of a new numeral. The invention of zero (0) made place value possible. Suppose the number was three hundred and three. Without a zero, it would be written as 33, which was incorrect. But with the zero, three hundred and three could be correctly written as 303.

All of mathematics changed with invention of the numeral 0. With just ten digits—0, 1, 2, 3, 4, 5, 6, 7, 8, 9—a person could easily write numbers from 0 to far beyond the myriad myriad developed by Archimedes.

For large numbers, considerable simplicity is gained by using powers of ten. The numbers are more compact and require less space to write. Moreover, large numbers are more easily grasped and compared. For example, one million (1,000,000) can be written as 10^6. The superscript "6" is the ***exponent***. It tells how many times 10 is multiplied to indicate a quantity. For one million, ten is multiplied six times: 10 * 10 * 10 * 10 * 10 * 10 = 1,000,000. The exponent is also called the *power*.

Notice that the exponent is not the number of zeros in a number. The speed of light, 186,000 miles per second, can be written as $1.86 * 10^5$. The number 186,000 has three zeros, but the exponent for the power of ten is 5. The exponent is the number of 10s that 1.86 must be multiplied by to give the number. Multiply 1.86 by 10 five times: 1.86 * 10 * 10 * 10 * 10 * 10 = 186,000. By definition, 10^0 is set equal to one: $10^0 = 1$.

In the metric system the most common prefixes for large numbers are:

10^6	mega	million	1,000,000
10^3	kilo	thousand	1,000
10^2	hecto	hundred	100
10^1	deca	ten	10
10^0	unit	one	1

These units can be put together with any of the metric units for length or weight. One kilometer is 1,000 meters. One kilogram is 1,000 grams. A watt is a measure of electrical power. One megawatt is one million watts.

One of the large numbers that is used in science is the ***mole***. In chemistry, a mole is not an animal. Instead, it is a metric unit for measuring a large number of very small particles such as atoms or molecules. A mole is $6.022 * 10^{23}$ particles.

Chemists weigh atoms in two different ways. Sometimes they use the metric unit for weight (grams). At other times, they compare the atomic weights. A carbon atom is used as a standard and set equal to 12. Other atoms are weighed by comparing them to the carbon atom. This weight is known as ***atomic weight***. For instance, a helium atom has an atomic weight of 4. Three helium atoms weigh as much as a carbon atom: 4 * 3 = 12.

Chemists found that if a sample of an element contained $6.022 * 10^{23}$ atoms, then its weight in grams equaled its atomic weight. Scientists call this number a mole.

A helium atom has an atomic weight of 4, and $6.022 * 10^{23}$ helium atoms weigh 4.0 grams. An oxygen atom has an atomic weight of 16. A mole of oxygen atoms ($6.022 * 10^{23}$ oxygen atoms), has a weight of 16 grams. So important is the mole ($6.022 * 10^{23}$) that it is the standard in the metric unit for measuring large numbers of particles.

You can easily see that adoption of Arabic numbering advanced the calculation of scientific data and statistics. Continued use of Roman numerals would have severely hampered scientific calculations.

The next morning the boys were out before sun-up. Bryan breathed in deeply, using the cool island air to wake-up. Tom again wore the yellow raincoat. Although he had rinsed it off, the smell of the moose still clung to the coat.

By midmorning the boys were almost to the abandoned mine. Because the rough trail took all of their attention, Bryan and Tom had lapsed into silence. They hardly said a word. Suddenly, they heard a sound behind them. Bryan turned and saw an animal trotting across the trail. It had yellow-gray fur with black patches on its side and white on its chest.

"Wolf!" Tom cried. The wolf walked with a curious sideways trot. The animal stopped. He looked at them and sniffed the air as if confused.

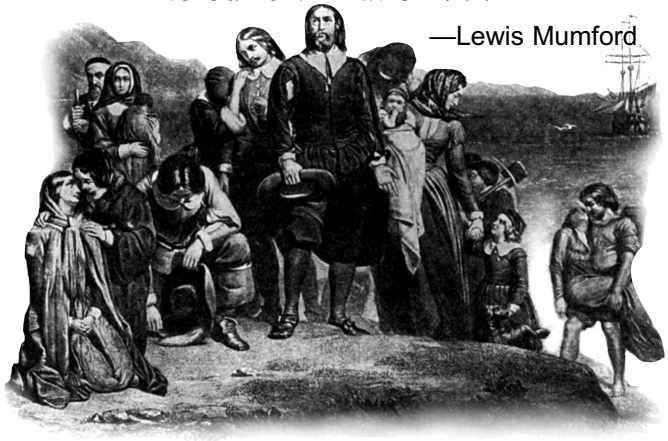
"Don't panic," Bryan cautioned. "He saw us; but remember, they avoid humans."

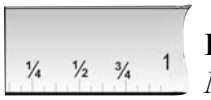
The wolf, however, seemed definitely interested in the two boys.

Life Principle

"Man's chief purpose . . . is the . . . preservation of values; (which) gives meaning to our civilization . . ."

—Lewis Mumford





Lesson 9
Measurement

Chapter 2

Surface Area, Negative Exponents and Base Units

Section 2

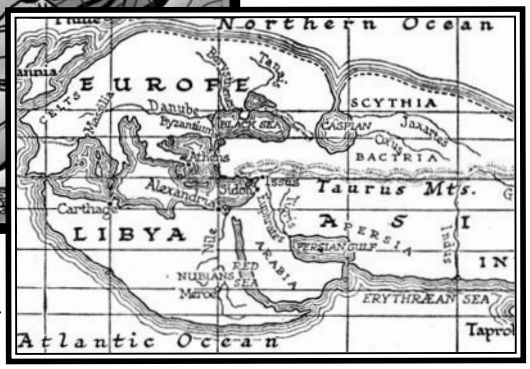
Lessons 6-10

DERIVED UNITS AND SMALL NUMBERS



As the wolf looked at the boys, Bryan remembered what his uncle had said; "Danger Island covers 42 square miles. Normally, wolves stay in remote areas where humans seldom go. However, this winter was particularly difficult for wolves. They are becoming more bold." This was a huge animal, six feet long, counting the bushy tail. The wolf looked underfed; but even so, it probably weighed a hundred and fifty pounds.

The boys backed along the trail to a higher viewpoint. The wolf watched them but did not move. Silently, two smaller wolves appeared from behind the trees. Then others came into view. Suddenly, the one on the trail bounded into an opening in the woods. Then, as quickly as they had appeared, all the wolves faded from sight.



"It's the whole pack!" Tom gasped. "Are they gone? Or are they secretly watching?"

Bryan admitted that he did not know. "The copper mine is only a few hundred yards on up the trail. I think they will avoid an area where humans once worked. Let's go!"

The boys kept a watchful eye over their shoulders as they strode purposely along the trail. The wolves did not reappear. Tom picked up a greenish colored stone the size of his fist. He ran his fingers over the rough surface. Light reflected from little bits of green crystals.

"Copper ore," Bryan commented. "We must be near the abandoned mine; but where is it?"

VOCABULARY

Surface area: the amount of two-dimensional space that a figure occupies; area is expressed as the square of a unit for measuring length

Derived unit: a unit of measure derived from base units; surface area is a derived unit because it can be expressed as the product of length and width

Ranger Eldridge had described the island as having a ***surface area*** of 42 square miles. Surface area is an example of a ***derived unit***. Surface area can be stated by combining distance measured in two dimensions. An area measurement has length and width. Because it can be stated in terms of another unit, surface area is a derived unit.

Area of a rectangle is found by multiplying the length times the width: $A = l * w$ (with l the length and w the width). Length and width are measured using units of length such as feet, yards and miles or meters and kilometers.

In the United States, one common way of measuring small areas is by ***square feet***. If a room is 12 feet by 14 feet, then the surface area is 168 square feet: 12 ft * 14 ft = 168 sq. ft or 168 ft^2. The letters *sq. ft.* are the abbreviation for *square feet*. The symbol ft^2 is read as square feet or feet squared. The *square foot* is a *unit of area*.

For larger areas, *square yards* may be used. For instance, a large flag flew over Fort McHenry near Baltimore, Maryland on September 13, 1814. The fort was under attack by the British during the War of 1812. Because this flag still flew after a night of bombardment, Francis Scott Key was inspired to write "The Star Spangled Banner." The flag still exists. It is a large one, 10 yards high by 14 yards long. The total area is 10 yards times 14 yards, or 140 square yards. The area, 140 square yards, can be written as *140 sq. yd.* or *140* yd^2. The original size of the flag may have been larger, about 10 yards by 19 yards. The size of the complete flag would have an area of 10 yards * 19 yards = 190 sq. yd.


Francis Scott Key

A still larger unit of area is the ***square mile***. A surface area of one square mile is equal to a square field that is one mile on each side. A square mile can be written as *sq. mi.* or mi^2.

One of the largest national parks in North America is Denali National Park in Alaska. Within the park is Mount McKinley, the highest mountain in North America. The park is a protected area for forests, tundra, brown and black bears, wolves, caribou and mountain goats as well as other wildlife. Denali National Park has an area of 7,812 square miles. Contrast it with Gran Pardiso in Italy, one of the larger parks in Europe. Gran Pardiso contains 220 square miles.

Yellowstone National Park in Wyoming is home to Old Faithful, the geyser that erupts into a plume of boiling water at a predictable time of about once every hour. Yellowstone Park is roughly rectangular. It is 55 miles long in the east-west direction and 63 miles long in the north-south direction. The total area is about 55 miles * 63 miles = 3,465 square miles.


Old Faithful geyser


55 mi. * 63 mi. = 3,465 mi^2

VOCABULARY

Square feet: an English unit for measuring surface area, equal to a square one foot on each side; abbreviated *sq. ft* or ft^2

Square mile: an English unit for measuring surface area, equal to a square one mile on each side; abbreviated *sq. mi.* or mi^2

Base unit: a standard unit of measure from which any other unit of measure is derived; the metric system has seven base units

When measuring area, both dimensions must be in the same unit. For instance, suppose the width of a hall is measured as 5 feet but the length of the hall is measured as 6 yards. To calculate area, the units both need to be in either feet or yards. In this example, first convert 6 yards to 18 feet (6 yards * 3 feet/yard = 18 feet). Then calculate the area of the hall as 5 feet * 18 feet = 90 sq. ft. or 90 ft^2.

Scientists must also deal with extremely small numbers. One example is the diameter of an atom which, stated in meters, is about 0.0000000001 meters.

Using the same idea of powers of 10, a very small number can be written with negative exponents. A number such as one-ten thousandth, 1/10,000 (0.0001) can be written as 1/10 * 1/10* 1/10 * 1/10 = $(1/10)^4$. Multiplying by one-tenth, 1/10, is the same as dividing by 10. Rather than showing 1/10,000 or 0.0001 as $(1/10)^4$, the larger number can be written with a negative exponent as 10^{-4}. The negative exponent shows that 10 is a divisor four times.

Negative exponents represent one tenth, 1/10, as 10^{-1}. One-hundredth is 1/100 = 1/10 * 1/10 = 10^{-2}. One-thousandth is 1/1,000 = 0.001 = 1/10 * 1/10 * 1/10 = 10^{-3}. The diameter of an atom, about 0.0000000001 meters, can be written as 10^{-10} meters.

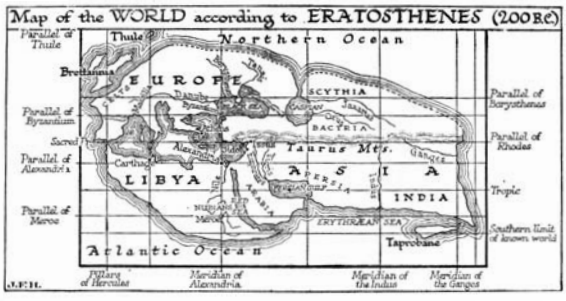
In the metric system some prefixes for small numbers are:

unit	1	10^0	one
deci	0.1	10^{-1}	tenth
centi	0.01	10^{-2}	hundredth
milli	0.001	10^{-3}	thousandth
micro	0.00001	10^{-6}	millionth

These units can be put together with any of the metric units for length or weight. One centimeter is 0.01 meter, or 1/100 of a meter. One milligram is 0.001 grams or 1/1000 grams. A *curie* is a measure of exposure to atomic radiation. One microcurie is 0.00001 curie or 1/1,000,000 (one millionth) of a curie.

Exchanging information among scientists depends on a system of consistent measurements. Often, work on the same problem is done in different countries. Sometimes the work is done years apart. For instance, the movement of the Earth's crust in predicting earthquakes or volcanic eruptions will require years of monitoring. Scientists throughout the Earth must be able to compare their discoveries and research statistics.

An ancient Greek scientist named Eratosthenes made a map of the world. He showed the locations of important cities. The distances between cities were given in stadia.



The *stadia* was a unit of length. It was the length of a straight track in a sports stadium. However, the sizes of stadiums in different cities in Greece were not the same. Scientists believe the stadia could vary from 505 feet to 705 feet. No one knows which stadia Eratosthenes used when he gave his distances. In one experiment, he calculated distance around the Earth and stated it as 250,000 stadia. Scientists still argue about how accurate Eratosthenes was because they cannot agree on the stadia he used.

Since the start of the 1800s, most scientific measurements have been made in the metric system. The system came into use after the French revolution. In 1791, the French government gave the French Academy of Sciences the job of developing a new system of weights and measures. The goal was to select a system that was logical and simple. It

would have to serve the needs of a variety of individuals, including bankers, businessmen, farmers, soldiers, sailors and scientists. The result was the metric system.

Scientists decided to agree on a standard unit for length. It would need to be one that was based on some physical property that could be measured. They decided to define the unit of length as 1/10,000,000 (one ten-millionth) of the distance from the equator to the North Pole. That distance was one-fourth the way around the Earth.

Rather than traveling the full distance from the equator to the North Pole, surveyors made a very accurate measurement of a portion of the total arc from the equator to the North Pole. Scientists measured the exact distance from Barcelona in Spain to Dunkirk in France. The survey took six years. From this smaller arc, scientists calculated that the new standard for length had a value of about 39.37 inches. It was a little longer than a yard. They gave the unit the name *meter*, from the Greek word *metron* that means *measure*.

Later, scientists found that the measure of the size of the arc could be improved. However, this would change the size of the meter. Rather than doing that, scientists set the length of the meter equal to the distance between two parallel lines engraved on a metal bar. The bar was made of an alloy of the two metals platinum and iridium. The alloy was known to resist changes in length because of changes in temperature. Even so, the alloy bar was kept in an air-conditioned vault in France as a caution to preserve an exact meter for establishing accurate measurements of the globe.

Over the years the way of measuring a meter changed several times. Today, the meter is defined as the distance light travels in a vacuum in 1/299,792,456 of a second.

The meter is a fundamental or ***base unit*** for length or distance. The other metric base units are: the kilogram (for mass), the second (for time), the Celsius degree (for temperature), the ampere (for electric current), the candela (for measuring the intensity of light) and the mole (as a standard number of atomic particles). All other metric units are derived from the seven metric base units.

The two boys nearly missed the entrance to the mine. Tom noticed miniature iron rails for ore cars. The track ran out of the mouth of the horizontal shaft. The entrance was moss covered and overgrown with weeds.

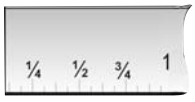
Bryan retrieved a flashlight from his day pack and shined the beam into the mine. Two metal doors had been fitted across the entrance, but they were partially open. Beyond the doors, Bryan saw an ore car with its wheels still resting on the track. A old and rusted sign read, "Danger—Keep Out. Mine Shaft is Unstable."

Life Principle

"Kindness is derived from love."



—Anonymous



Lesson 10
Measurement

Chapter 2

Acres, Hectares, Volume, Base and Derived Units

Section 2

Lessons 6-10

AREA AND DENSITY





Tom was not looking at the mine. His gaze was upon a small hill beyond the entrance. "We have visitors again!" As silently as shadows, the wolf pack had closed in on the boys. The lead wolf they had seen on the trail had taken up a position at the top of the hill.

Tom spoke loudly, "Listen up, you guys! We're humans. We're healthy. You're supposed to hide when you see us coming! You've got 42 square miles to lose yourselves in!" As he spoke, the lead wolf hopped down and circled around to draw closer.

"Let's get in the mine!" Bryan urged.

"That mine shaft is a hundred years old!" Tom protested, "It's not safe in there!"

"Well, it is surely not safe out here!" Bryan countered.

The boys squeezed past the sheets of iron that served as doors. Once inside, they put their shoulders against the metal. With a screech of protest, the doors closed. The boys pushed the ore car against the doors and set stones behind the wheels to secure the car against the iron doors.

The lead wolf eyed the mine entrance and began sniffing around it. The ground at the bottom in one corner had washed out. The wolf began digging to enlarge the opening. Bryan yelled, "We've got to fill in that hole!"

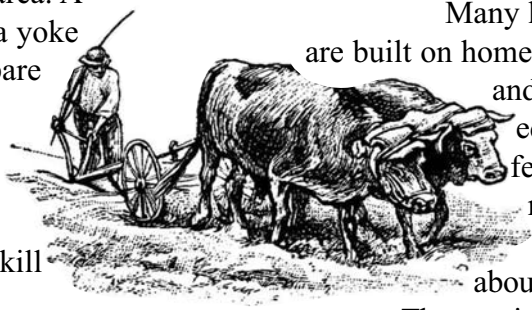
Tom yanked off his yellow raincoat and spread it out on the floor. Bryan helped him load it with loose stones. Tom rolled

VOCABULARY

Acre: a common land surface area measurement equal to 43,560 square feet or 4,047 square meters
Hectare: metric unit of area equal to 10,000 square meters
Are: a seldom-used metric unit for area equal to 100 square meters
Volume: amount or quantity; the liter is the metric unit for measuring volume or capacity

it into a bundle, and with Bryan's help stuffed the load into the opening. The action seemed to enrage the wolves. They attacked the raincoat as if determined to rip it loose!

Danger Island has an area of 42 square miles. However, the most common unit for measuring ground surface area is the ***acre***. The word *acre* comes from a Latin word meaning *pastureland*. As one would expect, it is used to measure the size of fields. The acre was an area that a yoke of oxen could plow in one morning. When farmers depended on the muscles of animals to do work, the oxen-acre ratio was a good unit for area. A six-acre field would take a yoke of oxen three days to prepare for planting.



Of course, the actual surface area plowed depended on the strength of the oxen, the skill of the ox driver, the type of soil, and so on. To give a standard to the acre, the English set an acre equal to a square field that was about 209 feet on a side.

In the 1800s, the United States government encouraged people to move west and settle land. The government gave the homesteaders a plot of land one-quarter mile on a side. A field this size contains 40 acres. A square, one mile on a side, has 640 acres, 1 mi^2 = 640 acres. A square mile was also known as a section of land. Danger Island with an area of 42 square miles has an area in acres of 42 mi^2 * 640 acres/mi^2 = 26,880 acres.

Many homes in the United States are built on home sites of 1/4 acre. The house and yard have a total area equal to a square about 105 feet on a side. The home itself may be 1,500 to 2,000 sq. ft, while the plot of ground is about 11,025 sq. ft.

The metric unit for area is the ***hectare***. Hectare is made from the prefix *hecto,* (meaning *100)*, and ***are***, a metric word for *100 square meters*. However, *are* has disappeared in use in favor of the *hectare*. A hectare is equal to 10,000 square meters, or about 2.47 acres.

As a general rule, in converting hectares and acres, the conversion factor is 2.5 acres per hectare. In making conversions from one unit of measure to another, as a first step decide whether the final answer should be larger or smaller than the beginning number. Knowing this outcome helps you decide whether to multiply or divide by the conversion factor. A hectare is larger than an acre. To convert from hectare to acres, multiply hectare by 2.5. For instance, we know a 40-hectare field contains about 100 acres because: 40 hectare * 2.5 acre per hectare = 100 acres.

If you begin with acres and need to get hectares, the number for the final answer will be smaller than the starting value. To

VOCABULARY

Cube: a geometric figure of three dimensions in which all sides are equal in length and all angles are right angles; the three-dimensional equivalent of a two-dimensional square

Rectangular solid: a geometric figure of three dimensions in which all sides are rectangles and all angles are right angles; the three-dimensional equivalent of a two-dimensional rectangle

Capacity: the maximum volume of a container

Liter: the metric unit of volume or capacity, equal to the capacity of a cube 10 centimeters on a side

Density: the mass of an object compared to its volume; density = mass/volume, the density of water is 1.00 g/cm^3

change 640 acres to hectares, divide by 2.5: 640 acres / 2.5 hectare per acre = 256 hectare.

Because it can be stated as square meters, hectare is a derived unit. The meter is the standard base unit for length.

The standard for length can also be used to specify ***volume***. For a regular three-dimensional solid such as a ***cube*** or ***rectangular solid***, volume is equal to the product of the length, width and height. If a room is 12 feet wide by 14 feet long and 10 feet high, then the volume is 12 ft * 14 ft * 10 ft = 1680 ft^3. The symbol ft^3 is read as cubic feet or feet cubed. The cubic foot is a measure of volume.



The English system measures volume by fluid ounces, cups, pints, quarts, gallons and barrels. Most of these units are for liquid measure. Crude oil is priced by the barrel. Gasoline is sold by the gallon. Milk is sold by the gallon, quart or pint. A fluid ounce is a unit of volume, not weight. Liquids such as soda and juice are often sold by the fluid ounce.

Liquid Measure

1 cup	=	8 fl oz		
1 pint	=	16 fl oz	=	2 cups
1 quart	=	32 fl oz	=	2 pints
1 gallon	=	128 fl oz	=	4 quarts

Volume is also known as ***capacity***. A barrel used for measuring petroleum has a volume or capacity of 42 gallons. Other liquids are measured in barrels, but they are not standard. Some barrels hold only 32 gallons. A container that has a volume of 1 cubic foot has a capacity of 7.5 gallons.

For dry measure, the English system uses bushels, pecks, dry quarts and dry pints. Potatoes and grains are sold by the bushels. Berries such as strawberries, are sold by the dry quart. The pint and quart used in dry measure are not the same as the pint and quart used in liquid measure. The dry measures are larger than the liquid measures. A dry quart is about 1.164 times larger than a liquid quart.

Scientists certainly find all of these different units for volume confusing and awkward. That is why they prefer the metric system as a worldwide standard.

The French Academy of Science defined a ***liter*** as a measure of volume. A liter was set equal to the volume of a cube 10 centimeters on a side. Ten centimeters is about four inches. In the metric system, both liquid and dry capacities are measured in liters.

As a general rule for converting from the English system to the metric system, one liter is slightly larger than a quart.

Mass, length and volume are related in the metric system. A kilogram (mass) of water has a volume of one liter (capacity) and can be contained in a cube 1/10 of a meter (length) on a side. Stating this in smaller units: 1,000 grams of water has a volume of 1,000 milliliters and would fill 1,000 cubic centimeters. Stated in smaller units, 1 gram of water has a volume of 1 milliliter and would fill a cubic container 1 centimeter on a side. The relationships are not exact because as time passed, the units were redefined and today they differ slightly from the original definitions.

A *derived* unit is one that is stated in terms of some other unit. Both the hectare and liter are *derived* units because they are defined in terms of the meter. The hectare is defined as 10,000 square meters. A liter is 1/100 cubic meter. The meter, on the other hand, is a *base* unit. Other measures such as length and width are derived from it.

Mass in the metric system was at first defined as the weight of one liter of water. If a cubic container 10 centimeters on a side were filled with water, it would have a weight of 1.0 kilogram. However, because of the difficulty of repeating this measurement, the kilogram was defined by a standard mass of a bar of metal. Many of the other standards such as length and time have been redefined in terms of scientific constants such as the speed of light or events that take place in atoms. However, the kilogram is still defined as the mass of a bar of metal. The standard for mass is kept in a vault in France.

Like the meter, the kilogram is a base unit. Other units of measure are made from it. One of the most common derived units is ***density***. Density is defined as the mass of an object compared to its volume. In the metric system, density is measured in grams per cubic centimeter, g/cm^3. Water has a density of 1.0 g/cm^3.

People often speak of weight when they mean density. For instance, you would not be correct to say that lead is heavier than feathers. Either one could be heavier than the other one. The comparison depends upon the size of each sample. A truckload of feathers is heavier than a lump of lead. The correct statement is that lead is heavier than an equal volume of feathers. Another way of expressing this is that lead is denser than feathers. Feathers have a density of about 0.01 g/cm^3. Lead has a density of 11.34 g/cm^3.

One cubic centimeter of water has a mass of one gram. Its density = mass/volume = 1.0 g / 1.0 cm^3 = 1.0 g/cm^3. Rock is denser than water. A rock such as granite has a density of about 2.75 g/cm^3.

Solid objects sink in water if the density of the solid is greater than the density of water. A granite stone will sink in water because its density of 2.75 g/cm^3 is greater than the density of water, 1.0 g/cm^3. Any object with a density less than the density of water will float. Most types of wood have a density of about 0.65 g/cm^3, so most woods will float in water.

In the English system, density is measured in pounds per cubic foot, lbs/ft^3.

Within seconds the powerful jaws had grasped the rubber-coated fabric of the yellow raincoat and ripped it to shreds. The rocks tumbled out of the coat. But rather than working to clear the opening, a fight ensued among the wolves for possession of the raincoat. The leader snarled menacingly, and the other wolves backed away. The leader held the raincoat as if it were a prized possession and trotted away. The other wolves followed, and the animals soon disappeared from sight.

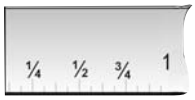
Tom breathed a sigh of relief. "If the raincoat was all they wanted, I would have been happy to have donated it to them when they first appeared!"

Life Principle



"Whatever you measure out to others will be measured back to you."

—Jesus of Nazareth



Lesson 11
Measurement

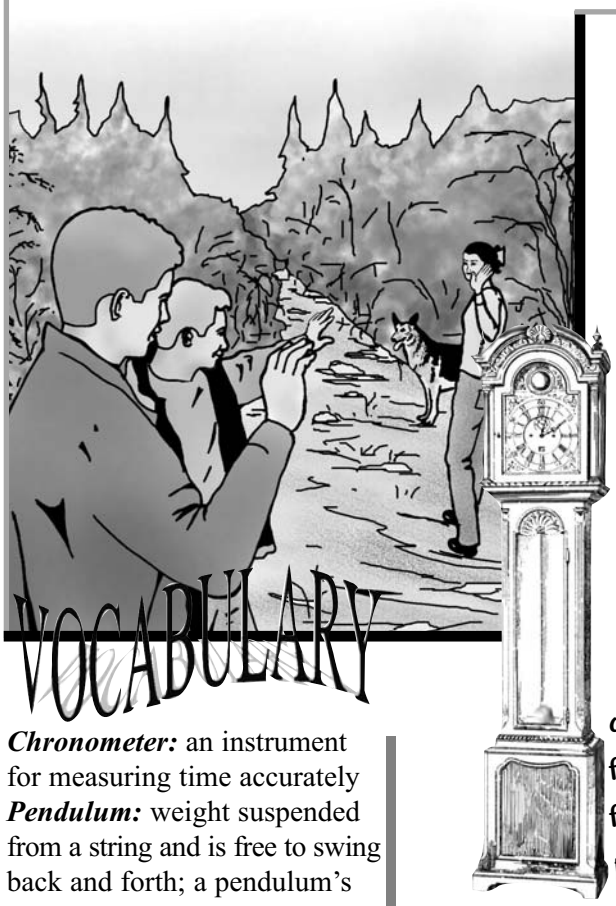
Chapter 2

Digital, Crystal and Atomic Clocks; Types of Scales

Section 3

Lessons 11-15

TOOLS FOR MEASURING TIME, MASS AND WEIGHT



Because of their hurry to leave the wolf area, Bryan and Tom made good time to the north bluff. In the distance, they saw the ancient tree with its gnarled limbs and twisted trunk. Bryan checked his watch. It gave the time of day as 1:30 p.m. The watch had a built-in timer that Bryan had started when the boys first stepped on the trail that morning. Bryan pushed the pause button. It showed the boys had been on the trail for 7 hours, 12 minutes and 53 seconds.

Tom squinted to discern a form. "Someone is sitting under that tree!"

Astonished, Bryan said, "It's the girl!"

Del had spread out a checkered tablecloth on the flat stone. She set out potato salad, slaw and fried chicken that was still warm. Del even had fresh, cold milk. She smiled, "See, I've brought a picnic lunch for you!"

"How did you get here before us?" Tom questioned. She refused to explain. Instead, she pointed and exclaimed, "Oh, look! There's a fog bank hiding Shell Island!"

"Forget the island! Did you see the wolves?" Bryan demanded. "They stalked us!"

"Not possible!" she retorted. "I spend my summer vacations here. I've never even seen a wolf! They avoid humans."

Tom persisted, "I guess that means they confused us with something inhuman!"

VOCABULARY

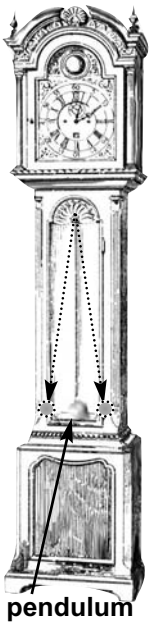
Chronometer: an instrument for measuring time accurately
Pendulum: weight suspended from a string and is free to swing back and forth; a pendulum's motion is regular and can be used for measuring time
Balance wheel: a small wheel that is made to rotate back and forth to measure time; a balance wheel made possible the first accurate watches
Hairspring: a fine, coiled spring that is mounted in a balance wheel to give it a regular back and forth motion

Modern digital watches, such as the one Bryan wore, provide a variety of information. The watch can display the time of day, date and day of the week. Many watches can be set to sound an alarm at one or more times during the day. Some can show time for cities in other time zones. Sports watches are capable of recording elapsed time. Because modern watches are crystal-controlled, they are far more accurate than the best mechanical watches made less than fifty years ago.



Scientists have a variety of devices available to them to measure time. A clock capable of keeping accurate time is known as a ***chronometer***. The word is made of *chrono*, meaning *time*, and *meter*, meaning *measure*.

A clock measures time by counting regularly occurring events. The first clocks used the regular back and forth motion of a pendulum to measure time. A ***pendulum*** has the property of swinging in a small arc in the same period of time as in a large arc. The regular back and forth motion made possible clocks so accurate that time to the nearest second could be measured. The pendulum clocks were large, however. They were mounted in cabinets and were known as grandfather clocks.


pendulum

Although not as accurate at first, watches did take up less space. A watch measured time by the regular back and forth motion of a ***balance wheel***. This wheel had a tiny coiled spring, a ***hairspring***, attached to it. The hairspring coiled and uncoiled at regular intervals. The coiling and uncoiling wheel was attached to gears to turn the hands of the watch. A main spring was wound up to provide the power to run the watch.

Most watches today are highly accurate. They use quartz crystals to control their movements. Late in the 1800s, the French scientist Pierre Curie discovered that when a quartz crystal was squeezed, it released a tiny spark of electricity. When the pressure was released, the crystal emitted another spark of electricity.

Experiments showed that the crystal reacted to electricity. If an electric spark passed through the quartz crystal, it expanded and contracted. The expansion and contraction, or vibration was predictably regular. Its rate depended on the size and shape of the crystal. When put in an electronic circuit, the quartz crystal vibrated at an absolute and very precise rate. In the 1940s, clocks controlled by quartz crystals became the ones to use when very accurate time measurements or absolute predictions were needed.

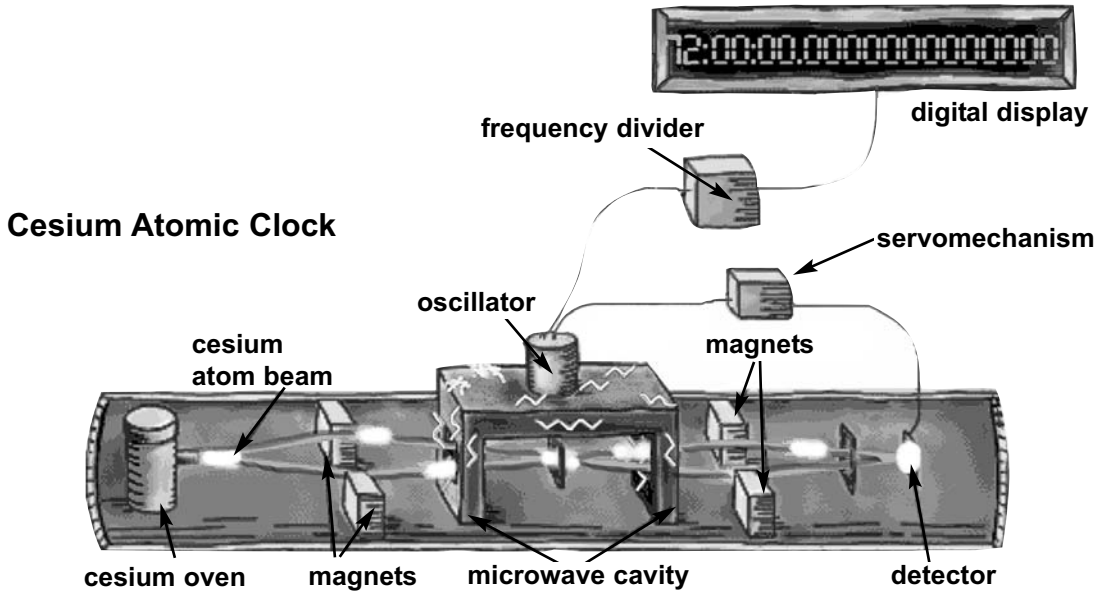
Today, the ***atomic clock*** is the most accurate way to measure time. When microwaves strike an atom, the waves are absorbed and then released. The cycle is regular and occurs very rapidly. The microwaves emitted carry the information about how quickly the atom is vibrating. A counter in the atomic clock reads the

VOCABULARY

Atomic clock: the most accurate type of clock; uses the very brief but highly regular events that take place inside an atom to measure time

Mass: the quantity of matter an object contains; the mass of the body is not dependent on gravity and therefore does not change when an object is weightless

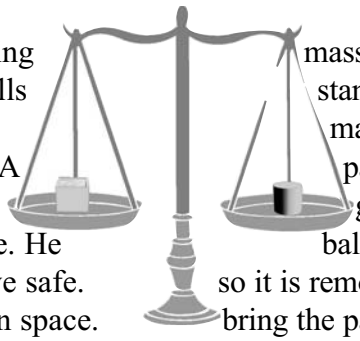
Weight: the force of gravity acting on an object



microwaves and keeps track of each cycle. The metal *cesium* is used to make atomic clocks. In the cesium atom, the cycles occur about nine billion times each second. A cesium clock can keep time accurate to about one second every million years. This discovery enables scientists to assume that some events or occurrences can be absolutely predictable.

Scientists know that ***mass*** and ***weight*** are not the same quantities. Mass is the amount of matter an object contains. Weight is the pull of gravity upon an object.

To illustrate the difference between mass and weight, suppose movers want to unload a safe from the back or a truck and roll it down an unloading ramp. The safe gets away and rolls down the ramp. The street is sloping and the safe gains speed. A pedestrian unfortunate enough to be in its way knows to dive aside. He knows he cannot stop the massive safe.



Suppose an astronaut is in space. Coming toward him is a runaway satellite with the same mass and speed as the runaway safe. The runaway satellite is weightless, but it is not without mass. Like a pedestrian on the street, the astronaut is wise enough to get out of the way. A weightless object still has its full mass and can still do damage during a collision.

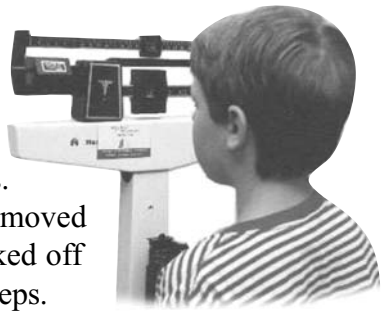
In the same gravity field, two objects that have the same mass will have the same weight. This fact is used to measure the mass of objects. The simplest scale for weighing an object is a *pan balance*. A pan balance is similar to a seesaw. In the simplest of the pan balances, each pan is the same distance from the center of the beam. Samples of known mass are added to one pan until they equal the unknown mass in the other pan. When the pans are in balance, each one holds the same mass.

Suppose an object of unknown mass is put in one pan. In the other pan, standard weights are added. A known mass of 100 grams is put in the other pan. It does not balance and a 20-gram mass is added. It still does not balance. A 5-gram mass is too much, so it is removed and three 1-gram masses bring the pans in balance. The mass of the unknown object is 100 g + 20 g + 3 g = 123 g.

A *beam balance* is a modified version of the pan balance. It makes use of the laws of levers to weigh an object. Rather than adding more weights on one side, the weight is moved farther from the pivot point. As the weight is

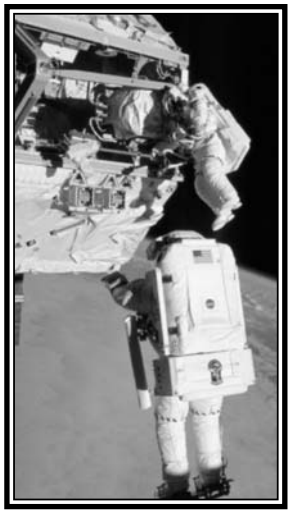
moved farther from the pivot point, greater will be the effect of the standard weight. A one-gram mass ten times farther along the beam has the same effect as a 10-gram mass. The standard weight is moved along the beam until it matches the unknown weight. The beam is marked off in grams. A triple beam balance has three standard weights that are moved along beams marked in 1.0 gram, 10.0 gram and 100.0 gram.

Perhaps you have weighed on a scale at a clinic or hospital. In one form of these scales, a weight is moved along a beam marked off in steps of 50 pounds. Another weight is moved along a beam marked off in quarter pound steps. When the beams are brought in balance, the position of the weights on the beam reveals your weight.



Most scales in grocery stores use a stretched spring to measure the weight of the product being sold. Metal springs and elastic substances, such as rubber bands, stretch in proportion to the weight they are holding. For instance, suppose a rubber band stretches one inch when a one-ounce weight is hung from it. Then it will stretch five inches when a five-ounce weight is hung from it. By marking off a scale, an unknown mass can be weighed by hanging it from the rubber band. If the rubber band stretches to 3.5 inches, then the unknown mass has a weight of 3.5 ounces.

Doctors were concerned that astronauts who spent long periods of time in space might lose weight. Because a spaceship is freely falling without resisting the pull of gravity, objects appear to be weightless. Objects, including astronauts, float around. Doctors wanted to make sure astronauts would be safe while experiencing weightlessness in space. Scales were created to weigh astronauts in space-like conditions. You can get an idea of the scales by conducting a simple experiment:



Hold a ruler so it projects over the side of a table. Hold it firmly against the table and then thump the other end. The ruler will vibrate up and down. This vibration depends on the ruler's mass. If you tape several coins to the end and thump it again, the ruler will not vibrate as rapidly.

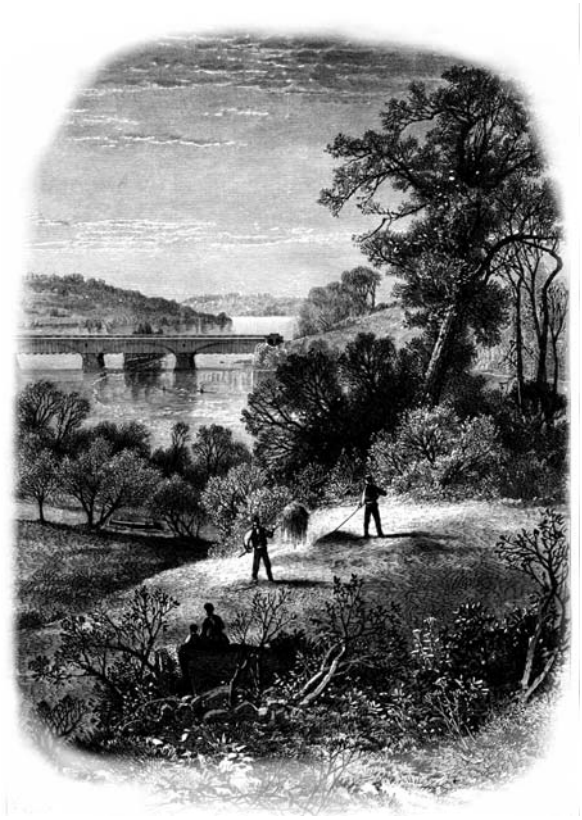
Scales used to weigh astronauts follow this principle for measuring the mass of objects in weightless conditions. Each scale has a coiled spring that vibrates back and forth when it is released. An object to be weighted is placed in a container at the end of the spring. When the spring is released it pushes out and then recoils back. The vibrations slowly cease. The rate of vibration gives the mass in the container. The spring vibrates more slowly if the object it carries is massive.

Another way of measuring mass is to compare how quickly a coiled spring puts a body in motion. An astronaut aboard a space station sits in a special chair that has a coiled spring at the back. A spring is released that shoves the chair forward. The speed that the spring gives the astronaut depends on his or her weight. A person of slight mass gains speed faster than a person of greater mass.

After the young people ate their meal, Del packed the basket and said good-bye to the boys. She strolled away with her dog, Sam, unconcerned about wolves or the twelve-mile hike. The boys waved and thanked her for bringing the lunch.

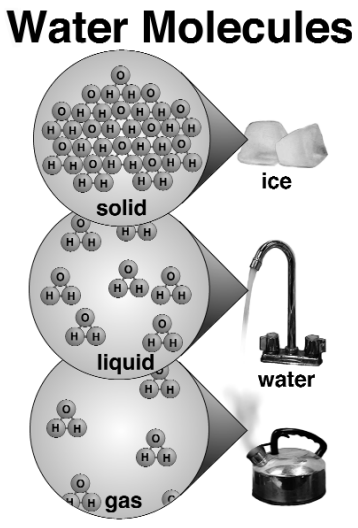
Bryan and Tom stayed a few minutes longer to explore the rocky cliffs around the ancient tree. Ocean waves made a hollow, drumming sound against the base of the cliff. The tree grew from what appeared to be solid rock without a grain of soil. At first, Bryan thought the tree was dead. He looked more closely and saw a few buds. Storms had twisted the tree's limbs; but, despite the harsh conditions, it had thrived for centuries in its exposed location.

Life Principle



"Duty is the course of action that frees the mind of uncertainty."

—Anonymous


Water Molecules
ice
solid
liquid
water
gas



Lesson 12
Physics

Chapter 2

States of Matter;
Fahrenheit and Kelvin Scales

Section 3

Lessons 11-15

HEAT AND TEMPERATURE



The boys found nothing around the ancient, twisted tree that looked out of the ordinary. As Bryan turned to leave, Tom hollered, "Look!" The wind had swept the fog away from Shell Island. "I see a town!"

"Don't be silly! The place has never been inhabited—," Bryan began, as he turned to look where Tom pointed. Bryan blinked his eyes—once, twice and a third time. A shaft of sunlight revealed a row of stone buildings with roofs covered by straw. The buildings looked vaguely new, as if they had been constructed recently but made to look old. The town stood near a steep bluff on Shell Island. Waves crashed against the bluff.

Bryan commented, "That is a strange place for a town! There is no sheltered harbor. How do they land a boat safely to go ashore?"

Tom ventured, "Maybe that is why it is abandoned!" As they strained their eyes to make out details, a rain cloud moved between them and the island. A sheet of rain changed the town into a misty vision in the distance.

Bryan turned and said, "Let's go! I've had enough mysteries for one day!"

The boys made a special effort to overtake the girl, but she succeeded in arriving at the lodge before them. By the time the boys arrived, Del was helping her grandmother set the table for the evening meal.

VOCABULARY

States of matter: the physical conditions of a substance as a solid, liquid or gas
Solid: a state of matter with definite volume and shape
Liquid: a state of matter with definite volume but not shape
Gas: a state of matter without definite volume or shape
Melting temperature: the temperature at which a solid becomes a liquid; also known as the melting point
Boiling temperature: the temperature at which a liquid becomes a gas; also known as the boiling point

The three ***states of matter*** are ***solid***, ***liquid*** and ***gas***. As Bryan and Tom looked at the mystery village on Shell Island, they saw water in two of its forms. Liquid that filled the oceans and fell as rain and gaseous water that formed the clouds from which the rain fell. The third form of water is ice. Ice is water in the solid state. Water at a temperature below 0ºC (32ºF) is in the solid state.

When ice is heated above 0ºC (32ºF), it changes into a liquid. The temperature of 0ºC is the ***melting temperature*** of water. The melting temperature is sometimes called the *melting point*. Water at a temperature between 0ºC and 100ºC is in the liquid state.

The gaseous state of water is steam. When water is heated above 100ºC (212ºF), it changes into a gas. The temperature, 100ºC, is the ***boiling temperature*** of water. The boiling temperature is sometimes called the *boiling point*. Water above 100ºC is in the gaseous state.



A gas has neither a definite shape nor a definite volume. A gas changes shape readily and expands to fill its container. When you blow up an air mattress, the air expands to fill the shape of the air mattress.

A gas has low density. The individual particles that make a gas are so far apart they take up a large amount of space without providing much mass. Because of the empty space between air ***molecules***, a gas is easy to compress. Air added to an air mattress will compress to make the mattress firmer.

The bonds that hold molecules together are electrical in nature. Water molecules have areas with a weak negative charge and other areas with a weak positive charge. As water molecules come close to one another, the unlike regions attract one another. If steam is kept at a temperature greater than 100ºC, the water molecules travel so fast they do not stick together. They rush about at great speed. They hit each other and the walls of the container. They bounce away and continue flying about freely.

When steam is cooled, it becomes a liquid. The temperature at which a gas becomes a liquid is called the ***condensation temperature*** or *condensation point*. As the temperature is lowered, water molecules travel less quickly. When they collide, they do not bounce away as readily. When the temperature falls below the condensation temperature, weak electrical forces hold the water molecules together and the vapor changes into a liquid.

A liquid does not have a definite shape but it does have a definite volume. In a liquid, the molecules can still move. They slide around and over one another. The liquid is able to flow.

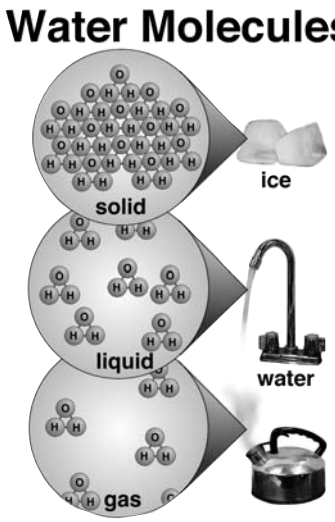
VOCABULARY

Molecules: the smallest particles that have the properties of a substance
Condensation temperature: temperature at which a gas becomes a liquid; also known as the condensation point
Freezing temperature: the temperature at which a liquid becomes a solid; also known as the freezing point
Evaporates: changes from liquid or solid into a gaseous state
Absolute zero: the temperature at which all motion in any substance ceases; the coldest temperature possible, -273ºC
Kelvin temperature scale: a temperature scale that has its zero point at absolute zero; a temperature change of one Kelvin degree is equal to a temperature change of one Celsius degrees

When milk is poured into a glass, it takes the shape of the glass. A liquid flows in and around obstacles. Water is said to seek its own level. Under the influence of gravity, liquid fills the bottom of the container. Regardless of the shape of the container a liquid takes up the same volume as the container.

Unlike a gas, a liquid is difficult to compress. The molecules are close together with little empty space. They resist being squeezed closer together. When you press the plunger of a water gun, the water squirts out because it resists the action of the plunger to compress the water.

Liquid that is chilled can change into a solid. When liquid water is cooled, it becomes a solid at 0ºC (32ºF.) The temperature, 0ºC, is the ***freezing temperature*** or *freezing point* of water. The atoms and molecules hold more firmly to one another in a frozen state than in a liquid state. They are not free to move about, so they stay in the same place.



A solid has a definite shape and volume. A solid is able to stand on its own without a container. It retains its shape and does not flow.

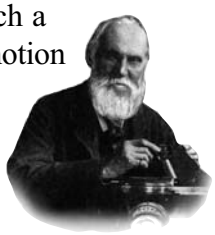
In a solid, the atoms are locked in position, but they are not motionless. The atoms vibrate around a central location. Atomic motion gives the body heat and temperature. When heat is added, atoms and molecules vibrate faster and faster until finally, the electrical bonds that hold the molecules in place are broken. Molecules then are free to slide past one another. The solid changes into a liquid. If more heat is added, then the temperature increases still more. The atoms move about more vigorously. Finally, they move so fast that they can escape from the surface of the liquid. Boiling begins. The liquid ***evaporates***, or changes into a gas.

We normally say that oxygen is a gas, mercury is a liquid and iron is a solid. However, we understand that those descriptions are true only at room temperature. When a scientist describes a substance as a gas, we understand that he means at room temperature and normal atmospheric pressure. Each can be changed into another state by being heated or cooled or by being put under pressure.

For instance, iron is a solid at room temperature. However, it becomes molten (liquid) at 1,535ºC. If heated to 2,750ºC (almost 5,000ºF) iron changes into a gas. Mercury is a liquid at room temperature. In some places on Earth such as the North Pole or South Pole, mercury thermometers cease to work because the mercury freezes solid at -40ºC. (That temperature is also -40ºF.) In 1983, a scientific research station on Antarctica recorded a temperature of -82.2ºC (-128ºF), the coldest temperature ever recorded on Earth. For these very cold temperatures, special purpose thermometers were required. One type made use of the fact that a wire does not conduct electricity well under extremely cold conditions. A drop in temperature reduces the flow of electricity. Scientists used a type of thermometer with a solid (wire) rather than a liquid (mercury) to measure cold, arctic temperatures.

A gas such as oxygen can also be changed to a liquid or solid, provided the temperature is cold enough. Oxygen becomes a liquid at -183ºC (-297ºF) and a solid at -218ºC (-360ºF). Neither of these temperatures ever occurs naturally on Earth. However, scientists using special equipment can change oxygen into a liquid and into a solid.

As the temperature becomes colder, molecules move more slowly. About 150 years ago, the Scottish scientist, William Thomson, wondered if he could identify the very coldest temperature on Earth. At such a temperature, all molecular motion would cease. Thompson's calculations showed that at -273ºC (-459ºF) atoms and molecules lost all of their motion. This, then, was recorded as the coldest possible temperature. William Thomson called -273ºC ***absolute zero***.



William Thomson

Water, oxygen, mercury, iron and all the other substances have their own condensation and freezing temperatures. Usually, the temperatures required for changing the state (liquid, solid, gas) of substances vary. Oxygen becomes solid at a far colder temperature than water. However, all substances have the same absolute zero temperature. At -273ºC the motion of molecules in all substances stop.

Scientists found that many of the laws of nature could be more easily expressed if scientists began measuring temperature from absolute zero. William Thomson received the title of Lord Kelvin in recognition of his contributions to science. The temperature scale that begins at absolute zero became known as the ***Kelvin temperature scale***. The Kelvin scale has been adopted as the international standard for scientific temperature measurement. A temperature change of one Kelvin degree is the same as a temperature change of one Celsius degree. However, the two scales have different zero points. The Celsius zero point is the freezing point of water, 0ºC. The Kelvin zero point is absolute zero, 0ºK. The temperature 273ºK is the same as 0ºC or 32ºF.

During the dinner, Bryan's uncle asked about the boys' day. "Did you see the twisted tree? Native Americans, European fur trappers, miners and explorers all have noticed that remarkable tree. If the Vikings explored the coast, they probably saw it, too."

"When was the town on the Shell Island built?" Tom asked.

Uncle Eldridge and the others stopped eating. They looked at the boys as if they had lost their senses. "There is no town on the island," said Bryan's uncle. "But—" Tom began.

"Perhaps we were mistaken," Bryan interrupted quickly. He shook his head slightly so Tom would not say any more.

Life Principle



"Our 'states of mind,' like states of matter, fluctuate with the 'temperature' of our surroundings."

—Anonymous



Lesson 13
Meteorology

Chapter 2

Historical Aspects, Sources of Atmospheric Carbon Dioxide

Section 3

Lessons 11-15

CLIMATE



Later that night in their cabin, Bryan explained. "Until we have some logical explanations, we should not mention the town or the wolves. My uncle will think we are unreliable and send us home!"

"All right," Tom agreed, "But why did the wolves attack? We barely escaped with our skin intact!"

Bryan reasoned, "I'm sure there is a simple explanation."

Tom exploded. "Simple or complex, I don't care! Just give me a reason before I decide I've slipped off the Earth and fallen into an alternate universe where nothing makes sense!"

"What kind of *weather* can we expect tomorrow?" Bryan wondered, changing the subject.

Tom recovered his composure and read from a guidebook about the ***climate***. "During summer the average temperature ranges from 17° to 21°C." He looked at Bryan for an explanation.

Bryan explained, "Between 62° and 70°F means the average temperature includes nighttime temperatures."

Tom read further. "The daytime temperature may reach 33°C."

"In the 90s," Bryan said.

Tom continued reading; "Yearly precipitation averages 40 inches. More than 250 days out of the year have cloud cover. The first killing frost occurs in late September."

The boys laid out their clothes for the next day and soon fell asleep, exhausted. At three o'clock in the morning, Bryan suddenly woke up and shouted, "I've got it! I know why the wolves attacked!"

VOCABULARY

Weather: the specific state of the atmosphere with regards to temperature, humidity, precipitation, air pressure, wind speed and wind direction that is experienced at a given location at a particular time

Climate: the general weather conditions that prevail in a particular region for a long period of time

Ice Age: the period in which glaciers covered a large part of Earth's surface

The information from Tom's guidebook described the climate the boys could expect on Danger Island. *Climate* is the general *weather* conditions that a region experiences over a long period of time. For instance, people in Forks, Washington near the Hoh rain forest expect rain almost every day of the year. The climate is rainy. On the other hand, residents of Timbuktu in Africa live in the middle of the Sahara desert. They expect sunny and dry conditions most of the year. A person in Minnesota can expect cold winters and mild summers. A resident of Phoenix, Arizona can expect hot summers and mild winters. Other regions can be cold or hot, wet or dry, windy or calm.

The conditions found in one year are likely to repeat the next year. Climate is the average weather conditions that have existed in an area over a long period of time. Weather forecasters cannot predict the exact temperature a year in advance. However, they can say that the average temperature for one summer in a particular city is likely to be similar the next year. By carefully keeping records over several decades, scientists can learn whether the climate is changing in a particular location.

A change in climate usually takes 30 years or more. Native Americans known as the Anasazi lived in the desert southwest in New Mexico, Colorado, Arizona and Utah. Anasazis survived because the weather conditions gave them enough rain for game to flourish and crops to grow. However, starting about 1225 A.D., the climate became dryer. Harsher conditions caused the Anasazi population to decrease, which resulted in abandoned communities.

One of the most dramatic changes in climate is estimated to have occurred several thousand years ago during the ***Ice Age***. During that time, ice covered about a third of the Earth's surface. Some areas of the world, such as Greenland and Antarctica, are still covered with vast sheets of ice. ***Glaciers*** are found in high mountains on most continents of Earth. The only exception is Australia. It has no ice sheets. About seven percent of all the water on Earth is found in a frozen state, mostly in Antarctica at the South Pole.



The North Pole also has a large blanket of ice. The north polar ice cap does not rest on land. Instead, it floats on top of

VOCABULARY

Glaciers: slow-moving, thick rivers of ice that form over land; move about one foot per day; produced by deep layers of snow that press down and change the lower snow crystals to ice

Transparent: a medium that allows light to pass unhindered; the air is transparent to sunlight

Greenhouse effect: gradual heating caused by Earth's atmosphere trapping solar radiation, carbon dioxide, other gases and dust; allows incoming sunlight to reach the surface of the Earth but prevents heat from radiating back into space

Algae: plant-like organisms that live in water; algae may be one-celled and appear as pond scum or may be much bigger in the form of seaweed; algae carry out photosynthesis and remove carbon dioxide from the atmosphere

the Arctic Ocean. For 50 years, scientists have been studying the arctic ice cap and measuring its thickness. Some scientists believe the cap is melting. The total surface area is becoming less, at the rate of about three percent a year. Since the late 1950s, nuclear powered submarines have traveled under the ice cap. Occasionally, they break through the ice and come to the surface. Readings taken by the submarines indicate that the ice cap at the North Pole is also getting thinner.



Some scientists believe that the reduction in size of the ice cap is proof that the Earth is going through a period of global warming. The average temperature of Earth's atmosphere is increasing in certain regions of the world. Scientists want to know what causes the atmosphere to become warmer, and what is the source of extra heat, which affects portions of the globe.

The primary source of Earth's heat is the Sun. Sunlight is radiant energy that can travel through a vacuum. Once sunlight strikes Earth's surface, the radiant waves change into other forms of energy. If the Sun were to put out more radiant energy, this would cause the Earth to grow warmer. However, sensitive instruments have been put in orbit around Earth to measure the Sun's energy, and they measure a constant release of heat from the Sun. Since heat from the Sun is constant, then the cause of warming must be within Earth's atmosphere.

An object grows warmer when it absorbs more heat than it releases. Some scientists believe the Earth is absorbing more heat from the Sun than it is radiating back into space. The atmosphere is ***transparent*** to visible light. Sunlight enters the atmosphere and passes through it. The visible sunlight reaches Earth's surface and heats the land and oceans. Part of the energy is radiated by Earth's surface. However, the rays are not visible light. They are *infrared* radiation, or heat rays. The human eyes cannot see infrared radiation. Humans can detect heat through senses other than the eyes. When you hold your hands next to a warm stove, your hands feel the infrared radiation.

Earth's atmosphere has carbon dioxide in it. Carbon dioxide absorbs the infrared rays and prevents their escape into space. Because of carbon dioxide, the atmosphere is not as transparent to infrared radiation as it is to visible light.

The action of carbon dioxide is the ***greenhouse effect***. Sunlight enters the panes of glass in a greenhouse and strikes the plants and soil. The light changes into heat energy and infrared rays. Air in the greenhouse becomes warm and cannot escape. In addition, the infrared rays do not pass through the glass as easily as visible light. Thus, energy is trapped in the greenhouse. The interior of the building stays warm, even in cold weather.

Think of a car with its windows rolled up and left in bright sunlight during summer. The inside of the car can reach temperatures of more than 60ºC (140ºF), hot enough to burn passengers who press against hot metal on the inside. A pet or child can be killed if left unattended for even a few minutes in a closed car.

Earth, however, benefits from the greenhouse effect. The amount of carbon dioxide in the atmosphere is small, composing only 0.03 percent by volume. Only about 3 molecules out of every 10,000 are carbon dioxide molecules. This small amount serves a huge role in keeping the Earth warm. Without

carbon dioxide, Earth would release so much heat into space that the average temperature would fall to about -73ºC(-99ºF). This would cause the oceans of the world to freeze solid.

On the other hand, the planet Venus appears to be suffering from a runaway greenhouse effect. If Earth were to be subjected to the same atmospheric effects on Venus, average surface temperatures on earth would soar to 500ºC (932ºF).

The amount of carbon dioxide in the atmosphere is increasing. Since about 1850, the amount of carbon dioxide has increased from 0.022 percent to 0.030 percent. At the same time, scientists estimate that the average global temperature of the Earth has risen about 1ºC (1.8ºF). Some scientists think the rise in Earth's temperature is because of an increase of carbon dioxide in the atmosphere. Other scientists believe temperature changes are confined to certain regions and are only temporary changes.

As part of their life activities, plants and ***algae*** in the sea remove carbon dioxide from the air. Scientists believe that until about 1850, plants kept the amount of carbon dioxide in the air at a steady level. However, the amount of carbon dioxide in the atmosphere has increased in the past 150 years.



One source of carbon dioxide is volcanoes. Volcanoes have been especially active in the past 25 years. In 1980, Mount St. Helen's in Washington State erupted. The volcano Mauna Loa in Hawaii began erupting in 1984 and is still active. In 1991, Mount Pinatubo in the Philippines erupted several times. Volcanoes far north in Alaska and far south in the Antarctic have been active.

When volcanoes erupt, they send dust, ash, carbon dioxide and other greenhouse gases into the upper atmosphere. Mount Pinatubo was one of the most massive eruptions in recent history. It tossed millions of tons of ash more than eight miles into the atmosphere. Much of the volcanic material spread around the world. Air that carries fine dust particles absorbs heat better than clean air. Some scientists credit volcanoes as being one cause of global warming.

Another source of carbon dioxide is human activities. Carbon dioxide produced by humans comes primarily from the combustion, or burning, of fuels. Combustion combines oxygen with carbon to produce carbon dioxide. Fuels are burned in factories to produce goods such as steel, to run automobiles and to heat homes and offices. Burning of fuels releases carbon dioxide into the air.

Scientists have not been able to determine the true effect of human activity in adding carbon dioxide to the atmosphere. Some scientists do not think global warming is caused by human activity. These scientists point to the fact that only since the start of the Industrial Revolution, about 1760, have humans produced enough carbon dioxide by their factories to make a difference in the atmosphere or worldwide temperatures.

Tom awoke with a moan. "Why must you have your bright ideas in the middle of the night?"

Bryan expounded his theory. "Wolves prey on weak animals. They eliminate the sick ones and keep the herd healthy. It's their natural function!"

"But we weren't sick!" Tom mumbled.

Bryan agreed. He said, "The wolves did not think we were human. Did you notice the peculiar odor in the mine? Like something sick and decayed?"

Tom complained, "I've been smelling it ever since I helped your uncle with the sick moose. The whole side of that animal was one disgusting infection! The stuff got on the coat. I scrubbed the coat but the odor never came out!"

Bryan reasoned, "The wolves were confused by the smell. That is why they followed us to the mine. They smelled a sick moose! Once they had the raincoat, they were satisfied!"

Life Principle

"A TRUE FRIEND STICKS BY YOU IN ANY KIND OF WEATHER."

—Old proverb





Lesson 14
Meteorology

Chapter 2

Factors that Affect Change:
Sun, Water and Wind Currents

Section 3

Lessons 11-14

WEATHER



The next morning, the weather that greeted the boys was far cooler than Tom's guidebook had predicted. A steady rain fell. Bryan said, "This rain shower shows that climate and weather are not the same!" The boys put on their rain gear. Tom wore a plastic poncho to replace the raincoat ripped apart by the wolves.

Tom agreed that Bryan had given the correct explanation for the unusual behavior of the wolves. "There is another mystery," he said. "How did Del travel to the north end of the island so quickly? The milk was still cold and the cooked food still warm!"

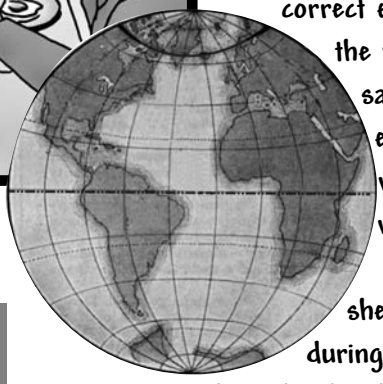
Bryan said, "The girl knows how she did it. We'll get an answer out of her during breakfast."

Tom shook his head. "No. Let's figure it out ourselves!"

Breakfast was turkey ham and eggs with a tall stack of hotcakes and maple syrup poured from a pitcher.

Ranger Eldridge gave the boys their instructions for the day: "We have a weather data collection station on the island. The station is powered by electricity from a battery that is charged by solar cells. The station automatically records temperature, wind speed, wind direction, air pressure, rainfall and humidity every six hours. The data is then radioed to a data collection station on the mainland. The station is in a clearing on the highest point of the island just off the ridge trail. Your job today is to replace the battery."

"Sure," Tom said. Then he said casually, "I haven't noticed any vehicles around here——."



VOCABULARY

Puerto Rico: a small, self-governing territory (island) in the Caribbean Sea, associated with the United States

Trade winds: winds that blow at a constant speed and in the same direction; trade winds are found over the ocean, between 30º north latitude and 30º south latitude

Triangular trade routes: trade routes between the Old World and the New World in days of sailing ships, somewhat triangle-shaped

Cuba: a large island in the Caribbean Sea about 90 miles from Florida; ruled by a communist dictator

"No roads for them," Mrs. Murphy interjected.

"What about motorbikes, or terrain vehicles, or ——."

"Ranger Eldridge said, "All powered vehicles are banned from the island. The only moving thing with a motor is the park service powerboat."

"Where was the powerboat yesterday?" Tom asked.

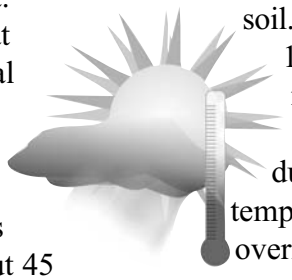
The girl grinned suddenly. She said, "These big guys with their long legs. They can travel so-o-o fast that I can't keep up."

Mrs. Murphy looked at her granddaughter. "What are you talking about?"

"It's nothing," Bryan said quickly. He and Tom agreed to learn how the girl could be so speedy, without asking her outright. Right now, he did not have a clue as to how to solve that particular mystery.

Weather is the specific state of the atmosphere. An automatic weather station like the one described by Ranger Eldridge records the conditions of the atmosphere. Such stations measure temperature, humidity, precipitation, air pressure, wind speed and wind direction. One day can be warm and cloudy. The next day, a cold front moves through, and rain falls. Then after the cold front passes, the weather becomes clear and dry. We expect weather to change from one day to the next and from one season to the next.

All weather is due to heat energy from the Sun. Of the total sunlight that strikes the outer reaches of Earth's atmosphere, about 35 percent is reflected back into space. The air absorbs about 20 percent. The rest, about 45 percent, reaches Earth's surface.



This last percentage of sunlight is the primary cause of weather because the heat of the Sun does not fall with equal intensity over the Earth. Earth is unequally heated because it rotates on its axis. During the daylight hours, sunlight warms the land, which in turn raises the air temperature. Daily temperatures are usually warmest in mid-afternoon at about 2:00 o'clock. At night, the heat radiates back into space. The land cools and so does the air. The daily temperature is usually coldest just at sunrise.

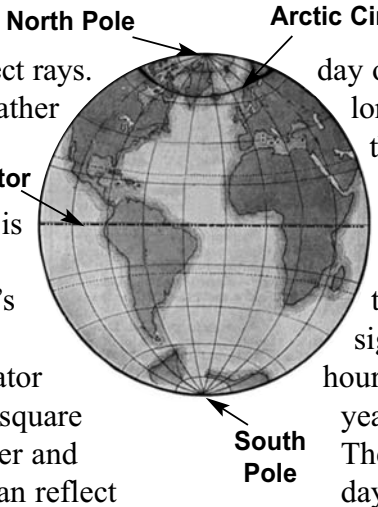
Large bodies of water and clouds moderate the heating effect of the Sun's rays. A seacoast city such as Fort Lauderdale, Florida has milder temperatures than a city located away from the ocean. Water has a greater heat capacity than most other substances. When water absorbs heat, its temperature does not change as much as other substances would after absorbing the same amount of heat. Water keeps the temperature from rising or falling quickly.

At night, clouds hold in heat rays so they do not escape into space. A cloudy night is generally warmer than a clear night. A city that is cooled by the ocean by day and kept warm by clouds by night may have only a slight change in temperature. The Hawaiian Islands, for instance are surrounded by the warm waters of the Pacific Ocean. The temperature during the day seldom exceeds 85ºF, and at night it seldom falls below 65ºF.

Deserts, on the other hand, have little water in the soil and the nights are usually clear. During the day, the Sun heats the desert soil. Daytime temperature may soar to 110ºF or higher. At night, the heat is radiated back into the clear, dark desert sky as fast as it was absorbed during the day. Therefore, the temperature may plunge to 40ºF or lower overnight.

Temperatures also vary depending on how far the region is located from the equator. Near the North Pole, rays of sunlight strike

Earth at a slant. Each square foot of Earth's surface there presents a smaller area to the direct rays. In addition, ice and snow reflect rather than absorb the Sun's rays. About 80 percent of the sunlight that falls on snow or ice is reflected back into space.



Near the equator, the Sun's rays are more direct. Each square foot of Earth's surface at the equator receives more Sun energy than a square foot at the poles. In addition, water and land tend to absorb rays rather than reflect them. About 80 percent of the sunlight that falls on water or land is absorbed. Only 20 percent is reflected. The equator receives more sunlight and absorbs more of the sunlight that it receives. As you would expect, the equator is warmer than the North and South Poles.

The heating effect of sunlight also changes from one season to another. Earth tilts on its axis at an angle of about 23 degrees. As Earth revolves around the Sun, the tilt presents more of the Northern Hemisphere to the Sun for part of the year and more of the Southern Hemisphere to the Sun during the rest of the year.

The tropics are those regions of Earth that lie within 23 degrees of latitude from the equator. For comparison, the distance from the equator to the North Pole is 90 degrees. For people who live in the tropics, the Sun is generally overhead at noon throughout the entire year. Earth's tilt does not have much effect in causing seasons in the tropics. There, the longest day and the shortest day do not differ much in length.

For instance, San Juan, ***Puerto Rico*** in the tropics is at about 18.5º north latitude.

The first day of summer in Puerto Rico is the longest day of the year and is only 2.5 hours longer than the first day of winter, the shortest day of the year. Contrast that with Fairbanks, Alaska located at 65º north latitude. On the longest day of the year, the Sun drops out of sight below the horizon for two hours. On the shortest day of the year, the Sun shines for two hours. The amount of sunlight for the first day of winter compared to the first day of summer varies by 20 hours.

Just north of Fairbanks, Alaska is the line that marks the Arctic Circle. At any point between that circle and the North Pole, a person can expect the Sun to be above the horizon for 24 hours or more during summer. During winter, a person in the Arctic region can expect the Sun to be below the horizon for 24 hours or more. At the pole during summer, the Sun is above the eastern horizon in the morning, above the southern horizon at noon and above the western horizon at evening. But the Sun does not "set." At midnight, the Sun shines above the northern horizon. For six months, the Sun is above the horizon. Finally, it does disappear below the horizon and then remains hidden from view for six months.



As a person travels farther north from the equator, the effect of seasons is amplified. In the tropics, climates and hours of darkness vary only slightly among summer, fall, winter and spring. Farther north, the seasons are more pronounced. Tropical summer temperatures are warmer than arctic summer temperatures.

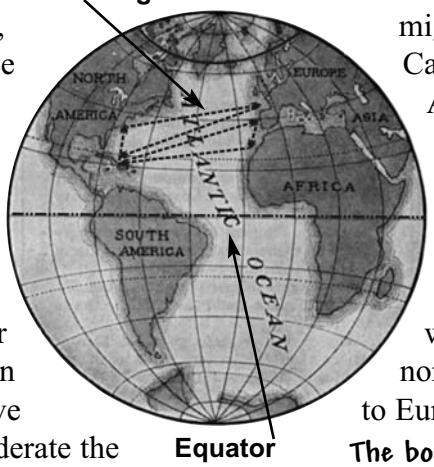
The record high temperature in the United States was recorded at Death Valley in southern California. The temperature rose to 56.7ºC (134ºF.) The record low temperature in the United States was recorded at Tanana, Alaska at -76ºF.

Despite uneven heating, the range of temperatures over the entire Earth is not as great as for some other objects in the solar system. For instance, the Moon is at the same distance from the Sun as is Earth. When the Sun is directly overhead, the Moon's surface is heated to 127ºC (261ºF), far hotter than any location on Earth. At night the temperature plunges to -173ºC (-279ºF), far colder than any temperature on Earth. The Moon does not have large amounts of water to moderate the temperature nor an atmosphere or winds to carry the heat from one place to another.

Sunlight, winds and moisture are the three main factors that cause weather. The Sun heats the Earth, water stores the heat, and winds distribute the heat.

Wind is the movement of Earth's atmosphere. Two forces cause wind. One is uneven heating. Hot air rises but cool air falls. Along the seacoast, the oceans maintain a more constant temperature. The land along the beach heats up more than does the water during the day. Air rises above the land and cooler air from the ocean sweeps in toward the shore. At night, the land cools faster than the ocean water. Then the airflow reverses, and air flows from the land to replace the air rising over the warmer oceans.

The second cause for wind is Earth's rotation. Earth, spinning on its axis, sets up a series of winds that have a dependable pattern, especially over the ocean. From about 30º north or south of the equator, the winds blow in a westerly direction toward the equator. In the Northern Hemisphere, the winds blow toward the southwest. In the Southern Hemisphere, the winds blow toward the northwest. Early sailors called these ***trade winds***, which enabled merchants to establish "***triangular trade routes***" to and from the New World. For example, to sail from Europe to America, the ships might first sail south to the Canary Islands off the coast of Africa. Then the ships would catch the dependable trade winds to take them to ***Cuba*** or other islands in the Caribbean. Ships could then sail north and catch the opposite trade winds, blowing toward the northeast, to take the ships back to Europe.



The boys started to trek up the ridge trail. Tom ventured, "Maybe Del had a mountain bicycle! Let's examine the trail and see if we can find her tracks."

Life Principle



"Blowing-off" good advice often results in shipwrecked lives."

—Nancy Johnson



Lesson 15
Physics

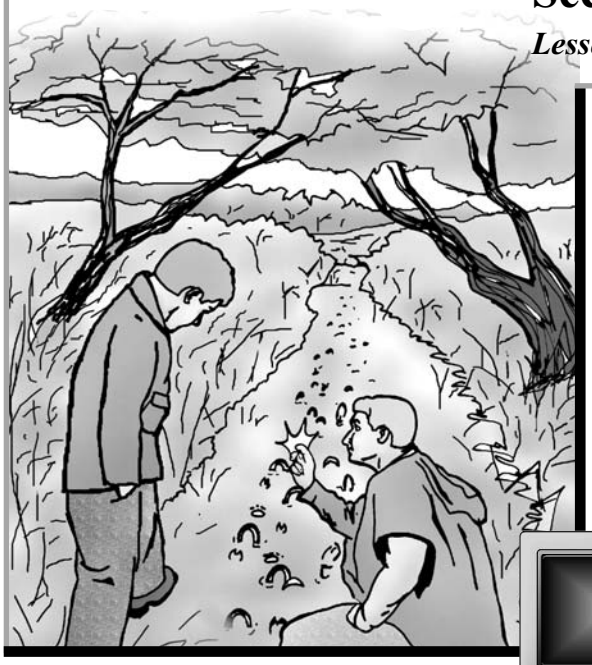
Chapter 2

Logic Verses Experiments; Scientific Methodology

Section 3

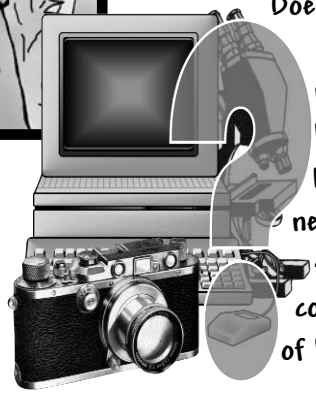
Lessons 11-15

EXPERIMENTAL SCIENCE



As the boys hiked the ridge trail to the weather station, Bryan commented, "I talked with my uncle and he said the powerboat has a key lock and no one used it yesterday. Besides, I've looked at the chart and there is not a good place to land the boat by the bluff. The waves would have dashed it to pieces!"

Tom concluded: "All right, Del didn't come by boat. All terrain vehicles are out. What is left? Does she have a bicycle?"



Bryan stated, "The trail is really rough. Even an expert could not have gone much faster than we did. I don't think that is the answer. We need to approach this with the scientific method. We need to start by collecting more information. Your idea of looking for tracks is a sound idea!"

Unfortunately, the ridge trail was rocky and didn't take tracks well. Soon, the boys came to a place where the soil was soft enough for imprints; but the morning shower had washed out any evidence. The boys kept walking. Trees sheltered a stretch of the trail and had preserved the tracks.

Tom shook his head. "Tracks of all kinds. Every animal on the island appears to have left its imprint! Here are our tracks. I recognize the sole imprint of *my* shoes. What kind of shoes was *she* wearing?"

Bryan admitted, "I didn't notice."

Tom continued to study the ground. Suddenly, he snapped

VOCABULARY

Experiments: controlled observations; the purpose of an experiment is to develop new facts or to choose the correct answer to a scientific question
Precipitation: any form of water such as rain, sleet, hail or snow that falls to the Earth's surface; precipitation is caused by falling temperatures
Hypothesis: an explanation or answer to a scientific question that can be tested by experiments

his fingers. "She was wearing western-style boots. I have a theory that may prove true! If I am right you won't find any prints left by her boots, but you will find tracks left by a — — - !"

In gathering information about tracks on the trail, the boys were taking the first step of the scientific method. Science is a way of learning about the living and nonliving physical world. Great advances in science began in the 1600s. This period is when Galileo, Kepler and Isaac Newton lived. They introduced the idea of experimental science. Scientists who relied on ***experiments*** to gain new information began the scientific revolution.

Until the 1600s, experiments were not used to gain knowledge. Scholars would read, observe and think. Suppose one scholar believed falling temperature caused rain to fall. Another scholar believed changes in air pressure caused clouds to give up their rain. The scholars would read what the ancient Greeks philosophers had said about weather. They would observe rain clouds. They would think and argue with one another. They would apply logic to what they knew. However, if they could not agree, they would never consider performing an experiment.

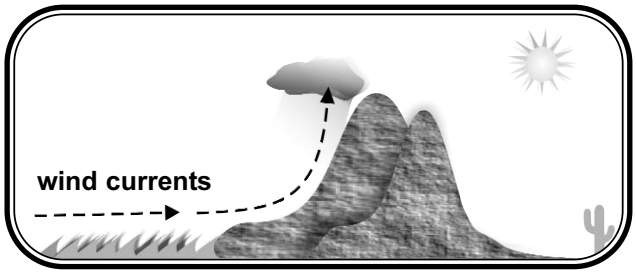
Galileo lived in the early 1600s. He proposed that scientific questions could be answered by carefully controlled observations. Experiments are controlled observations.

VOCABULARY

Theory: a hypothesis that has withstood tests by experiments and predicts facts not yet known

Scientific law: a well-established theory that has withstood many tests over a long period of time

Wind which blows across the ocean, picks up moisture that evaporates from the surface of the sea. Wind that crosses onto land frequently encounters a ridge of mountains. The prevailing winds from the west enter the United States from the Pacific Ocean. The moisture-laden air then hits the Rocky Mountains. The wind climbs up the sides of the mountains. Clouds form and rain falls. The western side of the Rocky Mountains receives far more rain than the eastern side. By the time the wind crosses the summit, the moisture has fallen as rain or snow and the air is dry. East of the Rocky Mountains are the deserts of California and Nevada, including Death Valley.



As wind rises along the West Side of the mountains, two changes take place. The rising air expands and grows less dense. The air pressure falls. At the same time, the air cools and the temperature drops. The clouds release the moisture as rain.

Scientists of the 1600s did not know by observation what caused rain. Experiments in laboratories could have provided additional information to solve the mystery. Researchers could have filled a container with saturated air and varied the air pressure but kept the temperature constant. Saturated air has as much moisture as it can hold. The researcher next could have held the air pressure constant but lowered the temperature. Both of these experiments would have revealed knowledge about rainfall.

As it turns out, meteorologists (scientists who study weather) have learned that falling temperature, not reduction in air

pressure, is the primary factor that causes moisture to condense from the air and fall as rain or other ***precipitation***.

The government, universities and corporations employ scientists. Some scientists have important but routine jobs. One such job may be to test a city's water supply each day for harmful chemicals or bacteria. A university may provide research funds to a scientist to learn the cause for an inherited disease. An aircraft company may assign a team of scientists and engineers to develop an aircraft that accelerates speed more quietly.

In each case, scientific work begins with asking questions. The city engineer would ask, "Does the water have harmful chemicals in it?" A professor of biology might ask, "Is this defective gene the cause of the inherited disease?" An aircraft engineer would ask, "What design will dampen the sound an engine makes?" The first step of problem solving is to ask questions.



The second step is to collect information. Scientists use tools to extend the five senses of sight, hearing, touch, smell and taste to collect data. The telescope and microscope extend the sense of vision. A microscope makes small objects appear larger. A telescope reveals distant objects. A camera freezes a moment in time that happens faster than the blink of an eye. Electronic equipment can record, amplify, and analyze sound. A computer records massive amounts of information. Software programs read the information and summarize it.

Other tools can detect differences in quantities that are too small for our senses to compare. A test tube may get hotter by one degree Celsius because of a chemical reaction inside it. Feeling of the test tube with the hands would not reveal the change in temperature. A thermometer can measure the temperature to tenths of degrees Celsius. Suppose two objects together weigh about five kilograms, but one is 25 grams heavier than the other. Simply lifting the objects would not indicate which was the heavier; however, a precision balance can measure their weight to the nearest hundredth of a gram. Scientific instruments take the guesswork out of measurement.

Instruments measure other quantities that are not normally detected by human senses. For instance, most people cannot sense a slow change in air pressure. A barometer is the scientific instrument that measures air pressure. As another example, polarized light can reveal strain in glass that is invisible to the human eyes. X-rays and sonograms reveal information about bones that cannot be seen with visible light. Doppler radar can show winds inside of storm systems.

By collecting the data and analyzing it, scientists narrow down the range of possible answers to two or three options, then pick the most likely answer. A ***hypothesis*** is a first explanation for a set of facts that can be tested by experiments. It may not be the final answer. After stating a hypothesis, scientists design an experiment that will either confirm that choice or reject it.

A hypothesis must be capable of being tested; otherwise, it is not considered a scientific hypothesis. Suppose a person claims that cats can talk but that they speak only when they are not being heard or recorded. This claim cannot be tested; therefore scientists do not take seriously such a claim.

Suppose you and a friend wonder whether the fender of a new car is made of steel or fiberglass. Your friend claims the fender is steel and you say it is fiberglass. A good experiment is one that reveals the true

contents of the two possibilities. Steel will attract a magnet but fiberglass will not. The experiment of testing the automobile's construction with a magnet chooses between the two possibilities. Suppose the fender does not respond to the magnet. It does not contain steel.

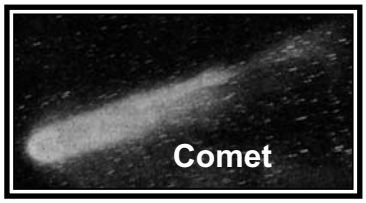
Moreover, the magnet test does not prove that the fender contains fiberglass. The fender could be made of some other nonmagnetic material such as epoxy. Neither fiberglass nor epoxy will attract a magnet. Some other test will have to be designed to determine the exact material used to make the fender.

Sometimes experiments show that the first hypothesis is in error. In that case, scientists discard the hypothesis or modify it. They design a new experiment to test the new hypothesis. In the case of a fiberglass or epoxy fender, an experiment may require a sensitive chemical test of a sample from the fender. Epoxy contains carbon while fiberglass contains silicon.

A hypothesis is a first attempt to explain a set of facts. A hypothesis is made stronger by experiments that eliminate other possibilities and generate new facts that fit the hypothesis. If a hypothesis survives a series of experiments, then it may be described as a ***theory***. A theory explains all of the known facts and predicts new facts. Bryan and Tom had eliminated several possibilities to explain how the girl had traveled so quickly across the island. Tom proposed another explanation. His theory, if it were true, predicted that he and Bryan would not find any boot prints on the trail, but that they would find horse prints.

When Isaac Newton announced his equation for measuring the force of gravity in 1686, he explained the motions of the planets that had been observed up until that point in history. Newton claimed that his equation for the force of gravity would explain the motion of other bodies, including comets.

Astronomers did not understand the orbits of comets and did not think their motions could be predicted. However, Edmund Halley, one of Newton's friends, successfully used the Law of Gravity to predict the return of a known comet. The fact that Halley's comet followed Newton's equation for the force of gravity gave Newton's hypothesis a stronger foundation. Newton's discovery was now no longer a hypothesis. It had become a theory.



Today, Newton's discovery is so well established it is called the Law of Gravity. A ***scientific law*** is a hypothesis that has stood the test of time, explains all known observations, and predicts new facts that can be tested by experiments.

Even the best scientific law is subject to change. Usually, the change does not destroy the law but merely modifies it for certain conditions. For instance, Albert Einstein and other scientists, who lived in the early 1900s, found that Newton's Laws of Motion had to be modified for objects traveling near the speed of light. All scientific laws can be modified as new discoveries are made.

That night, Tom casually asked Mrs. Murphy if Del had a horse.

"Yes, his name is Major."

Ranger Eldridge added, "She can ride him like the wind! She is a very talented horse person. I tease her by saying she could ride Major up a tree!"

Del came in with a big serving of fresh baked rolls. She asked, "Who are you talking about?"

Tom looked at her with newfound appreciation. He said simply, "We were admiring your skill with Major."

"Thank you," Del said. She smiled and tried not to appear too pleased at the compliment.

LIFE PRINCIPLE



"What is new is not always true, and what is true is not always new."

—Anonymous