Matter in Motion

UNIT 1

Student Reader

Front Cover:

The front cover shows the Hubble Space Telescope being launched into space. The telescope orbits Earth and captures images of far-away stars.

Unit 1: Matter in Motion

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1 Exploring Space with Science

Photographing Space

A telescope the size of a school bus has been circling Earth since 1990. A telescope is an instrument that helps people see objects that are too far away to see with just our eyes.

The Hubble Space Telescope gathers images of distant stars from its position above Earth.

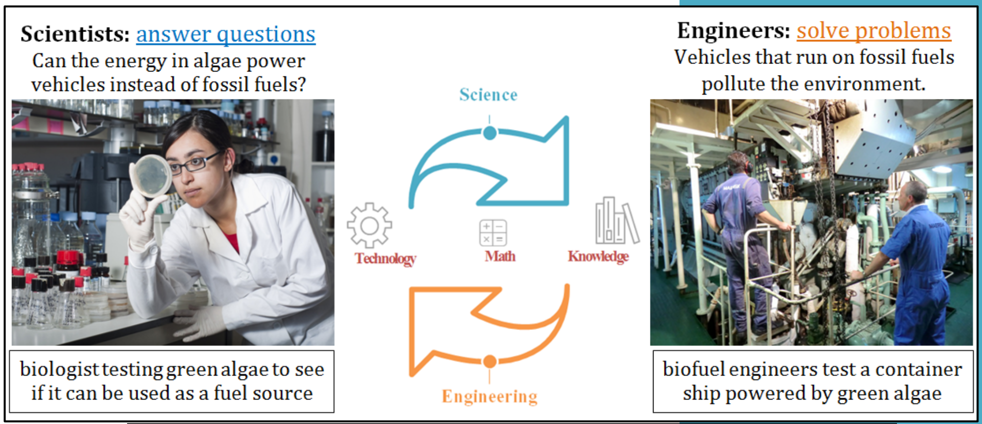
This telescope is called the Hubble Space Telescope. It circles Earth from one hundred and sixty nine kilometers (354 miles) above Earth. It has helped scientists know more about the universe.

The Hubble Space Telescope was the first telescope to ever be sent into space. Scientists have used it to observe objects in the night sky so far beyond Earth that we cannot see them from Earth. The Hubble telescope has taken many pictures of objects in space that humans had never seen before.

Following a Scientific Process

Scientists are fascinated by the universe. Earth is just one small part of the universe. The universe holds all of the matter and energy that exist. The universe is so large that it is hard to study. Scientists use instruments such as the Hubble Space Telescope to learn more about what exists beyond Earth.

Science is the search for explanations about the natural world. Because of this, asking questions is something that all scientists do. Scientists look for the causes of what they observe in the world around them. They use evidence to form conclusions that support those explanations. All knowledge learned from experiments is part of **science**.

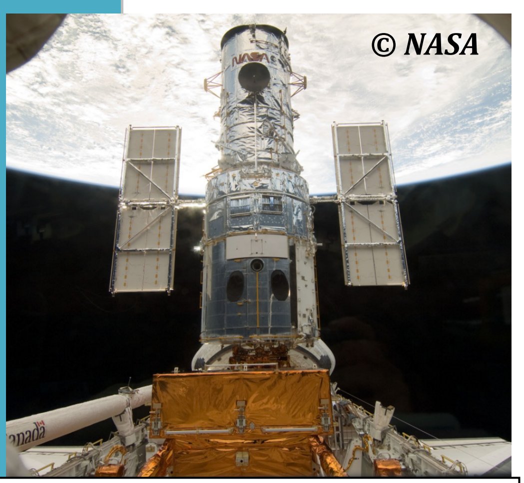


Science, technology, engineering, and math are connected in the STEM cycle.

Science is part of a larger cycle that includes engineering, math, and technology. This cycle is called the STEM cycle. Engineers apply scientific knowledge to create new technologies that solve problems. Math is a tool that both scientists and engineers use to capture results and communicate those results to others.

Scientists use a scientific process to guide them as they answer questions about the world around them. This process provides scientists with a logical framework to work from a question to a data-based conclusion.

Scientists always begin with a <u>question</u>. The question helps scientists figure out exactly what they are trying to find out. Scientists have many questions they are trying to answer. One question is: How old is the universe? In order to answer that question, scientists need to answer many smaller questions.



Scientists use the Hubble Space Telescope to learn more about what exists beyond Earth.

Scientists conduct many different experiments every year. Every year the amount of scientific knowledge grows. The Hubble Space Telescope has made more than 1 million observations since first going into space. Scientists use this existing body of knowledge to <u>research</u> their question. For example, scientists know that the universe contains all of the stars, planets, and other kinds of matter known to exist. Scientists also believe that Earth formed about 4.5 billion years ago.

After scientists have researched their question, they form a hypothesis. A hypothesis is a statement that can be proved true or false. An example of a hypothesis is: "The universe formed earlier than Earth formed."

Scientists then write a summary of the experiment they will conduct to test their hypothesis. The summary should include the basics of the data to be collected, the variables that will be tested, and the parts of the experiment that will remain constant in each test or trial.

Scientists will then list materials needed and the procedure they will follow. A procedure is like a step-by-step recipe for the experiment. A good procedure will let someone else repeat the experiment exactly. Scientists also draw a scientific diagram. They do this so anyone can use the same materials and follow the same steps to get similar results. They also want to create a record of their thinking.

Scientists then conduct an experiment. An **experiment** is a procedure designed to test whether a hypothesis is true, false, or inconclusive. As scientists conduct experiments, they gather data. Data are numbers and observations gathered from an experiment. Scientists use different tools for gathering data. The Hubble Space Telescope has mirrors, cameras, and other instruments for gathering data.

The telescope takes pictures and sends them to Earth. Scientists then download those images to study. Scientists use experiments to look for patterns in data. A **pattern** is something that happens in a regular and repeated way. A pattern sometimes tells scientists they have discovered a **cause-and-effect** relationship, where one event or thing is the result of the other.

In order to discover a cause-and-effect relationship, scientists design experiments in a way that shows how changes to one thing cause something else to change in a predictable way.

Scientists do this in a very specific way, with variables and constants. A variable is something you change. One kind of experiment is a controlled experiment. In a controlled experiment, there is usually one variable being tested. For example, when scientists built the Hubble Space Telescope, they wanted to test how the space environment would affect the materials that make up the telescope. The space environment was the variable.

The experiment also has constants. Constants are conditions that remain the same during each trial. Scientists keep certain parts of the experiment constant so they know that only the variable they are testing causes a change.

Finally, an experiment sometimes has a control. A control receives the same constants, but it is not exposed to the variable being tested. The control captures the effect of unknown variables.

For example, scientists had a control telescope on Earth. The control telescope was exposed to all of the same factors as the test telescope in the space environment. The experiment summary identifies the variables, constants, and controls.

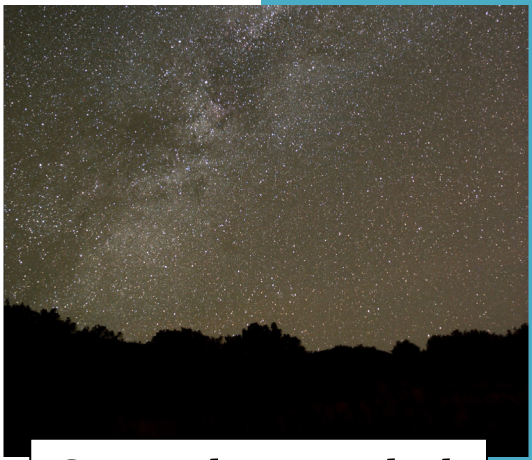
After data has been collected, scientists form a conclusion. The conclusion uses data from the experiment to explain why the hypothesis is true, false, or inconclusive. For example, data gathered from Hubble has led scientists to conclude that the universe is about 14 billion years old.

the Hubble Space Telescope's Control Center

Following a Scientific Process

1	**Question**	End with a question mark and do not include words such as "I" or "because."
2	**Research**	Include a minimum of three facts relevant to the question.
3	**Hypothesis**	Write a concise statement that answers the question and can be proved true or false.
4	**Summarize Experiment**	Describe in 2-3 sentences the experiment you will do to test whether your hypothesis is true or false. Identify the variables, constants, and controls of the experiment. Variables of the experiment are changes being tested. Constants of the experiment are conditions unchanged during each trial. A control in the experiment captures the effect of unknown variables.
5	**Materials and Procedure**	Vertically list all materials needed for your experiment with quantities. Next, vertically list the numbered steps of your procedure. Note safety precautions.
6	**Scientific Diagram**	Draw a diagram of the experiment set-up that is at least the size of your hand. Title it and include labels for all materials on the materials list.
7	**Data**	Follow your test procedure and gather data (both observations and numbers) to determine whether the hypothesis is true, false, or inconclusive. Use proper units, title data tables, and tape into lab notebooks.
8	**Conclusion**	Use the data collected in the experiment to explain why the hypothesis is true, false, or inconclusive. Every conclusion must contain a minimum of 3 elements: 1. Restate your hypothesis. 2. Make a claim (true/false/inconclusive). 3. Use key points of data as evidence to support and explain your claim.

Matter in Space



Stars and trees are both made up of tiny atoms.

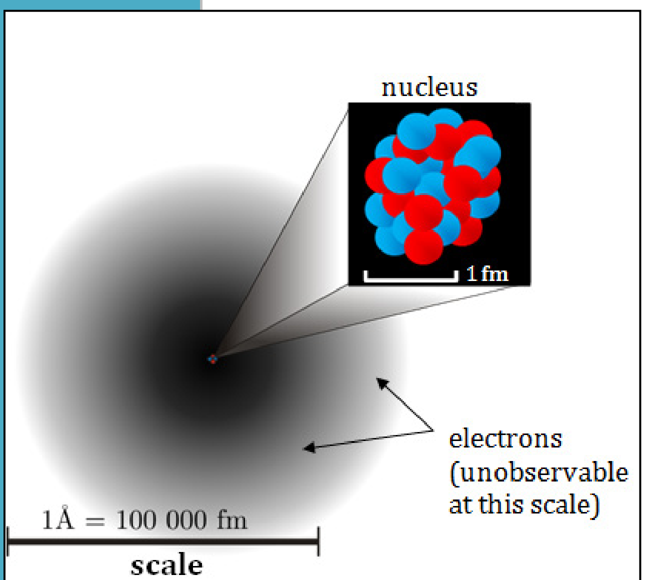
From its position above Earth, the Hubble Space Telescope makes observations of Earth, the sun, and distant stars. Earth, the sun, and stars are examples of matter. **Matter** is everything that has mass and takes up space.

All matter is made up of tiny parts that are too small to be seen. These parts are called atoms. An **atom** is the smallest piece of matter that has the properties of an element. An **element** is a substance entirely made up of one kind of atom. There are 118 different kinds of elements. All matter is made up of combinations of the 118 elements.

Both nonliving things and living things are made up of atoms. Even though atoms make up both living and nonliving things, atoms are not alive.

Atoms are so tiny that we cannot see them. Just one grain of sand is made up of many millions of atoms. Think about a grapefruit. If each atom in the grapefruit were the size of a blueberry, the grapefruit would have to be the size of Earth. There are so many atoms in just one grapefruit that they are impossible to count. Imagine having to fill up the entire planet with blueberries. That's about how many atoms are in one grapefruit.

Atoms themselves are made up of smaller particles, called protons, neutrons, and electrons. These smaller particles are much smaller than the atom itself. Because atoms are so tiny, scientists use scale to better understand the size of an atom, its smaller parts, and how it relates to everyday substances. **Scale** is the size, extent, or importance (magnitude) of something relative to something else.



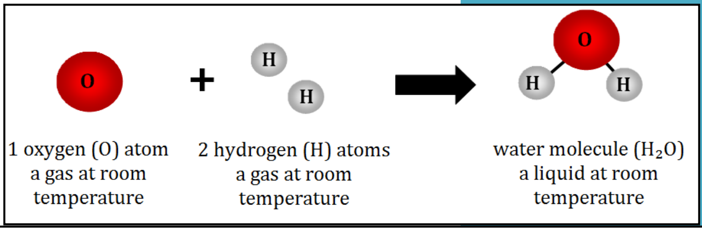
For example, the protons and neutrons group together in the atom's core, called the nucleus. If the atom is the size of a blueberry and you open the blueberry up, the nucleus would be too small to see.

If you were to make the blueberry the size of a football field, you would just be able to see the nucleus. It would be the size of a small marble. The nucleus holds all of the atom's protons and neutrons.

Most of the atom is filled with empty space. The electrons are much smaller than the protons and the neutrons. They are in constant motion around the nucleus. However, there are huge amounts of space between each of the electrons and between the electrons and the nucleus.

Forming Matter

All of the matter that exists, including stars, planets, and all the other "stuff" in the universe, is made up of combinations of the 118 different kinds of elements. There are so many different kinds of matter because atoms are like Lego blocks. They can fit together with other atoms to form bigger pieces of matter.



Atoms combine in a chemical reaction.

Whenever two or more atoms join together, they create a molecule. Molecules are formed as a result of a chemical reaction between two or more atoms.

In a **chemical reaction**, the atoms of the original substances are rearranged to form new substances that have different properties from the original substances.

Rust is the result of a chemical reaction. It forms when the element iron combines with oxygen.

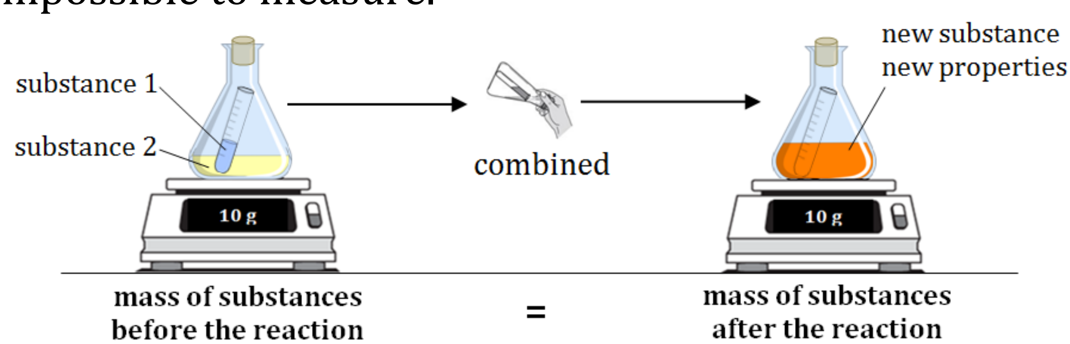
There are a couple of clues to look for to determine whether a chemical reaction has occurred. For example, a change in color or odor can be a sign that a chemical reaction has taken place. Also, if a gas forms when two different substances are mixed together, a chemical reaction has occurred.

Conserving Matter

Chemical reactions occur when two or more atoms interact. The effect of this interaction is that the atoms are rearranged to form new molecules. However, the total number of atoms does not change in a chemical reaction. The mass of any one element at the beginning of a reaction will equal the mass of that same element at the end of the reaction.

This is called the **conservation of matter**. It states that atoms are never created or destroyed during a chemical reaction. They are rearranged to form new substances.

For scientists to measure that matter has been conserved, they must conduct the chemical reaction in a closed system. In a closed system, matter is prevented from being added or removed from the system. In contrast, in an open system, some of the mass is transferred to the environment, which is impossible to measure.



chemical reaction in a closed system

Matter has different properties depending on the number and kind of atoms that make it up. A **property** is an observable or measurable characteristic of matter. Properties help scientists classify and describe different kinds of matter. Properties include texture, flexibility, color, mass, volume, temperature, and odor.

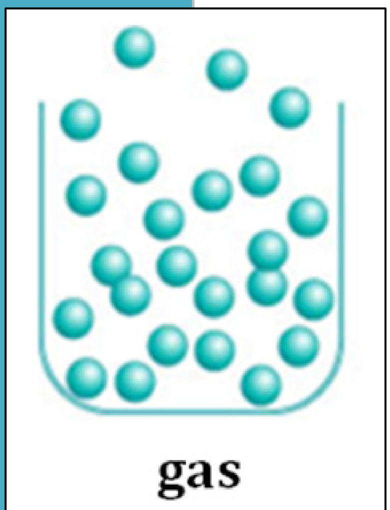
For example, scientists can use color to describe an object. Color is an observable property. From space, Earth is green and brown from the land, blue from the oceans, and white from the ice caps and clouds.

Earth's colors are a result of the matter that makes it up.

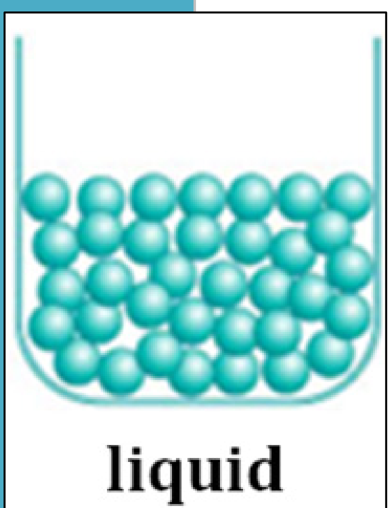
Properties can also be measurable. Measurements are an important part of science. Scientists use the metric system, which communicates measurements of mass and distance in units such as grams and meters.

Mass is an example of a measurable property. **Mass** is a measure of the amount of matter that makes up an object. It increases as the number and size of atoms increase in an object. It is measured in grams (g).

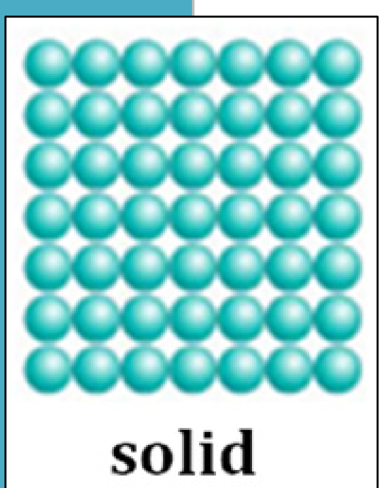
Whether or not a substance is a solid, liquid, or gas is another property of matter. This is called state of matter.



Earth's atmosphere is made up of a mixture of gases. Gases are different from solids or liquids because of the amount of heat present. The atoms in gases are far apart and move with a lot of energy. As a result, a gas takes the shape of whatever it is in. It will spread out to fill all of the space it is in, no matter how big the space is.

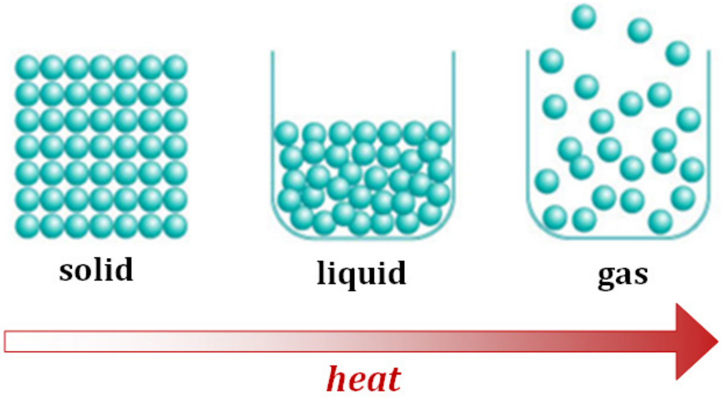


In liquids, there is less available heat than in gases. The atoms in a liquid are close together but can slide past one another. This is why liquids flow, taking the shape of their container. The water in oceans is an example of liquid water.

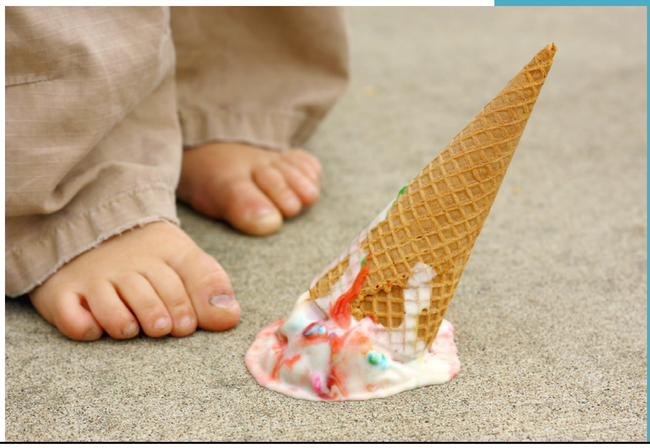


Solids have the least amount of heat. They do not have enough energy to move past one another. As a result, solids hold their shape because the atoms that make them up are packed tightly together. They hold their own shape until something changes them by force. Earth's land is an example of a solid.

Remember that cause and effect describes the relationship between events or things, where one is the result of the other. For example, when the right amount of heat is added or taken away, it causes a substance to change state.

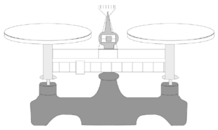
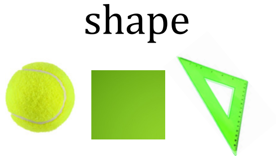
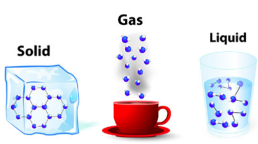
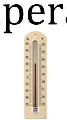
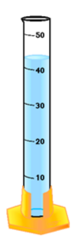


When a substance changes from one state to another, it is a physical change. In a **physical change**, the atoms and molecules that make up the substance do not change.


Melting ice cream is a physical change.

For example, if you leave an ice cream cone outside on a hot summer day, it will melt. The solid ice cream will gain heat, causing it to turn into a liquid. However, the ice cream will not change its chemical structure. It will still have the same properties. It can also turn back into a solid when enough heat is removed.

Identifying Properties of Matter

Property	What It Is	Observable or Measurable
color 	how matter reflects or absorbs light (e.g., red, yellow, blue)	observable (*qualitative**)
mass 	a measure of the amount of matter that makes up an object	measurable in grams (g) or kilograms (kg) with a scale (*quantitative**)
shape 	the form of an object (e.g., circle, square, rectangle)	observable (*qualitative**)
state of matter 	the different forms of matter depending on the amount of heat present (e.g., solid, liquid, or gas)	observable (*qualitative**)
temperature 	a measure of how fast molecules are moving	measurable in degrees Celsius (C) with a thermometer (*quantitative**)
texture 	the feel of a substance (e.g., rough, smooth, soft, hard)	observable (*qualitative**)
volume 	a measure of how much space an object or substance takes up	measurable in cubic meters (m^3) for solids with a ruler; liters (L) or milliliters (mL) for liquids (*quantitative**)

** Qualitative properties are those that can be observed and described. Quantitative properties are those that can be measured.*

Section 1 Review

Reading Comprehension Questions:

1. Find a specific quote from the text that explains why scientists ask questions.

2. The text provides several reasons why scientists are so careful in how they set up experiments. What does the text say specifically about these reasons? What can you infer about why this is so important?

3. What is the relationship between telescopes, stars, and bicycles?

4. How does the text use evidence to support the point that solids, liquids, and gases are different because of the amount of heat present?

5. Why do different kinds of matter have different properties?

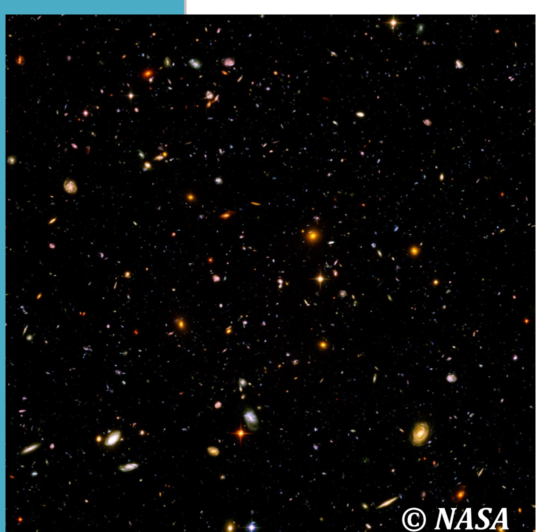
6. How do chemical reactions cause matter to change?

2 Scale in the Universe

Looking Back in Time

The Hubble Space Telescope allows scientists to look back in time. This means they can study the history of the universe. This is possible because when you look at the stars in the night sky, you are seeing light that is thousands or millions of years old. This light has travelled billions of miles through space to reach your eyes.

The farther away an object is, the longer its light takes to reach you. When you look at an object across the room, you actually see it as it was a few billionths of a second ago. Stars are so far away that it takes a very long time for their light to reach us.



Images from the Hubble telescope show very distant stars.

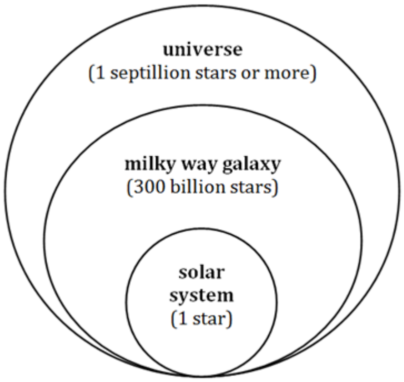
For example, the Hubble Space Telescope has taken pictures of a large cluster of stars that is 100 million light years away. The distant stars are so far away that the images are actually from 100 million years ago. At the time that light left those stars, dinosaurs still roamed Earth.

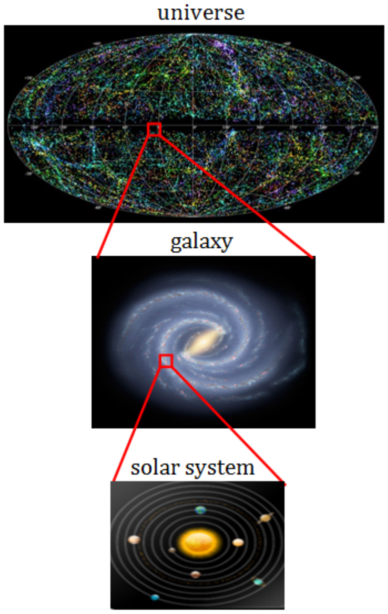
Scaling the Universe

The universe is full of mostly empty space. Millions of miles separate Earth from other objects in the universe. The universe is so immense that when scientists talk about distances, they often use scale models. Scale models are useful for scientists who want to understand how the various parts of the universe interact.

For example, scientists can use a scale model to observe the different parts that make up the universe.

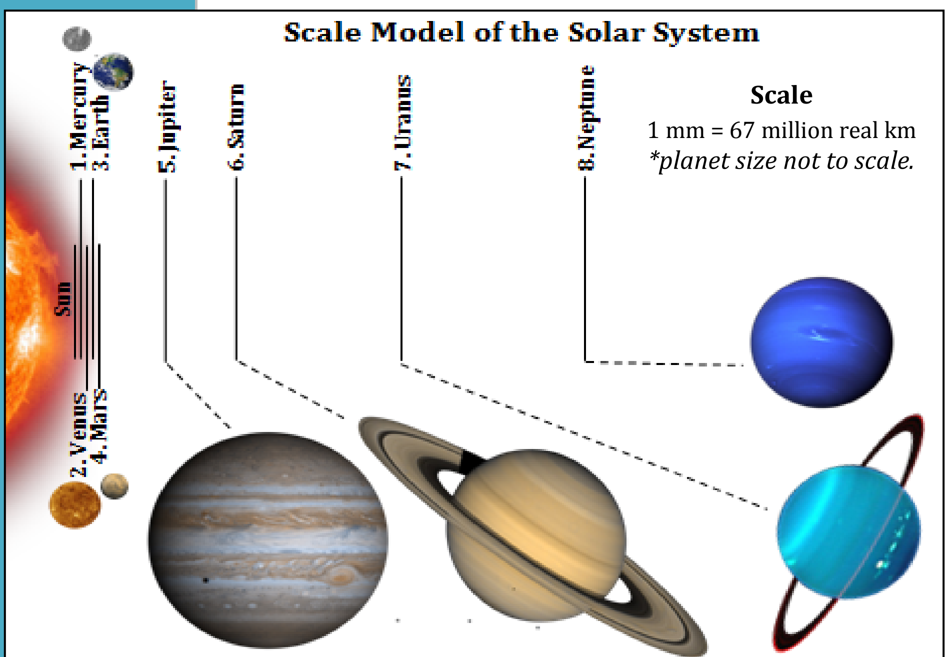
Earth is part of the Milky Way Galaxy. A galaxy is a large cluster of stars. The Milky Way Galaxy is shaped like a thick pancake. It contains billions of stars. There are hundreds of billions of galaxies in the universe.





Scaling Distance

Earth is part of a solar system in the Milky Way Galaxy. A **solar system** is a collection of planets and other objects that orbit a star. A planet is a body that orbits (travels in a circle around) the sun, is massive enough for its own gravity to make it round, and has cleared out smaller objects around its orbit.



The sun is the center of our solar system. The sun is a star orbited by planets. There are eight known planets in our solar system.

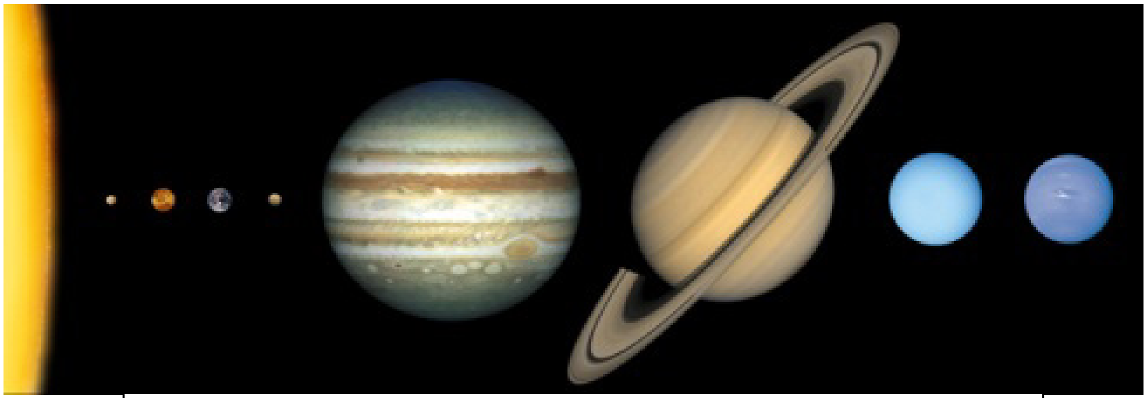
Our sun is much closer to Earth than any other star. In Earth terms, however, it is still very far away. It is 150 million kilometers (93 million miles) away from Earth. At this distance, it takes sunlight eight minutes to travel from the sun's surface to Earth. Neptune, the farthest planet from the sun, is much farther than Earth. It is 4.5 billion kilometers (2.8 billion miles) from the sun.

Scaling Size

Scale is also important for understanding how the masses of different objects in the universe compare to each other. For example, as far as stars go, our sun is an average-sized star. Other stars are much more massive than our sun. However, it seems so much larger and brighter than any other star because it is so much closer to Earth than any other star.

The sun is the most massive object in our solar system. It is so massive that more than one million Earths could fit inside the sun. Its diameter is 1.4 million kilometers (865,000 miles) wide. In comparison, Earth's diameter is 12,742 kilometers (7,918 miles).

In other words, if the sun were the size of a typical front door, Earth would be about the size of a nickel. Jupiter, the largest planet in our solar system, would be the size of a basketball. Mercury, the smallest planet, would be the size of a pea.

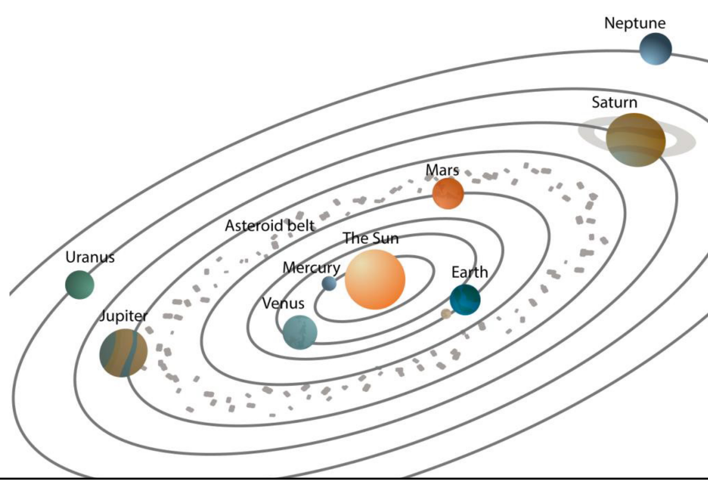


A model shows the relative sizes of the eight planets.

Mass and Gravity

The sun is made up mostly of the elements hydrogen and helium. It is a hot ball of gas that produces its own light through chemical reactions. It is so massive compared to the other objects in our solar system that its gravity holds the entire system in place. **Gravity** is a force of attraction between all matter. Gravity is what keeps you on Earth. It is also what holds the solar system together. Gravity is a result of an object's mass. The more massive an object is, the more its gravity will pull on other objects.

The sun is so massive that its gravity reaches beyond the eight planets of our solar system, pulling every planet toward it. When an object is much more massive than any other object near it, its gravity will pull on the other objects and cause them to move. This gravitational pull is why the planets orbit the sun.



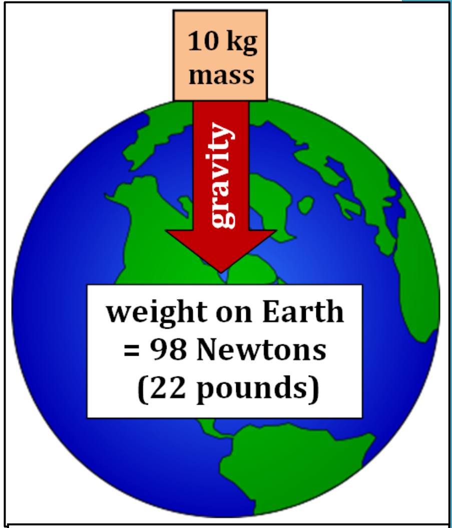
The sun's gravity holds the eight planets in orbit.

Earth's Gravity

The force of gravity becomes weaker as the distance between two objects increases. The sun is much more massive than Earth, but it is also much farther away. This is why here on Earth, you always experience the pull of Earth's gravity. All matter has gravity, even the matter that makes up people. The reason a person doesn't noticeably attract nearby objects is because more massive objects have more gravity. Earth's gravity pulls on all objects on or near Earth's surface because Earth is so massive.

Earth's gravity keeps you from floating off into space. It is also why things thrown in the air fall back to the ground. Earth's gravity pulls all objects near Earth's surface downward.

The gravitational force exerted on an object by a planet or moon is called **weight**. It is measured in newtons (N). Here on Earth, weight is calculated by multiplying the object's mass by the force of Earth's gravity. The pull of gravity is nearly identical everywhere on Earth.



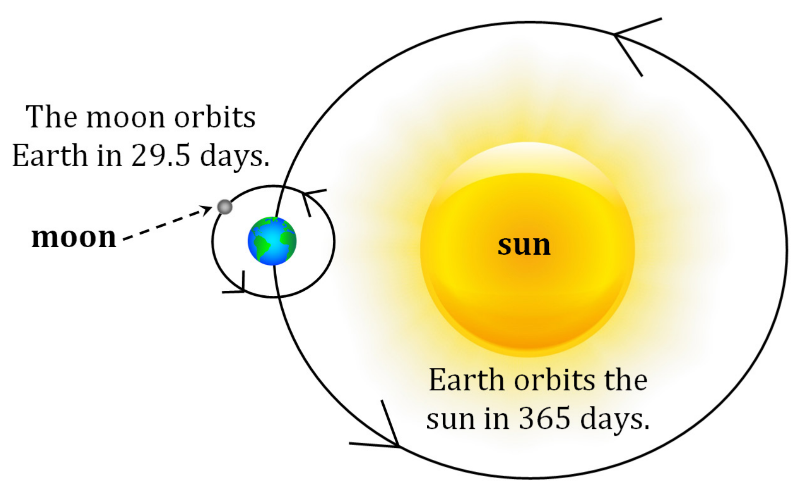
Weight depends on an object's mass and the force of gravity.

Non-scientists often think that an object's weight is the same as its mass. The two are related because an object's weight depends on its mass. However, weight also depends on the force of gravity.

When astronauts travel to the moon, their mass doesn't change, but their weight does. This is because the moon is much less massive than Earth is, so its gravitational force isn't as strong as Earth's.

The moon has a diameter of 3,476 kilometers (2,159 miles). It is about one-quarter the size of Earth. If Earth were the size of a basketball, the moon would be roughly the size of a tennis ball.

The moon orbits Earth for the same reason that Earth orbits the sun. The pull of Earth's gravity keeps it, along with the Hubble Space Telescope, in orbit around it.



The Metric System

The metric system is the world's most widely used measurement system. This system is built on different types of *base units* that measure physical properties such as length, volume, and mass.

Table 1: Common Base Units		
Base Quantity	**Name**	**Symbol**
	Base Unit	
length	meter	m
volume	liter	l
mass	gram	g

All metric units are expressed in multiples of 10. This makes it easy to change from one unit to another. Prefixes are used to express metric units that are larger or smaller than base units. For example, *kilo*- means 1,000 times, and *milli*- indicates 1/1,000 times. One kilometer equals 1,000 meters and one millimeter equals one thousandth of a meter. These units prefixes are helpful in science when measuring something as small as an atom or as large as the moon.

Table 2: Common Unit Conversions		
	Units	**Conversions**
Length	**meter (m)**	
	kilometer (km)	1 km = 1,000 m
	decimeter (dm)	1 dm = 0.1 m
	centimeter (cm)	1 cm = 0.01 m
	millimeter (mm)	1 mm = 0.001 m
Volume	**Liter (l)**	
	cubic centimeter (cm^3)	1 cm^3 = 1 mL
	milliliter (mL)	1 mL = .0001 L
Mass	**gram (g)**	
	kilogram (kg)	1 g = 0.001 kg

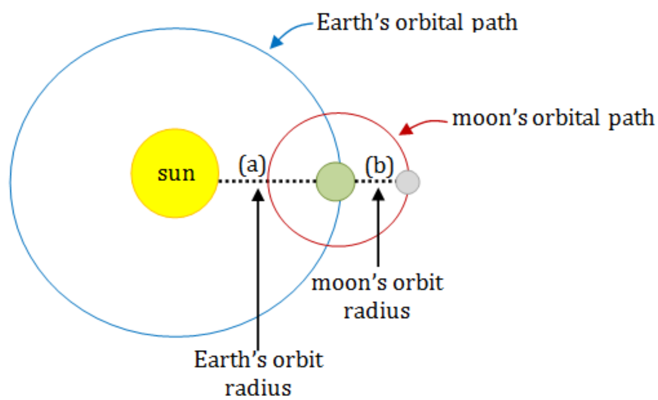
Name: ______________________________Date: ________________

Gravity and Stars Investigation

How does gravity influence the motion and position of the sun-Earth-moon system? How does the sun's relative size and distance from Earth affect how we observe it? Use the procedure to create a model, and then use the model to investigate the questions that follow.

A. Scaled Sun-Earth-Moon System Data

1. The diagram on the right illustrates the average orbit radius of (a) the Earth around the sun and (b) the moon around the Earth (not to scale).

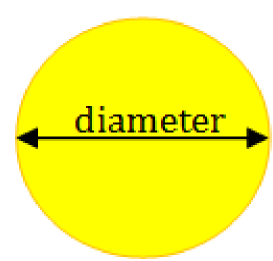


2. The actual Earth and moon orbit radii are shown in the second column of Table 1 in kilometers. Those values have been scaled down to one ten-billionth (1/10,000,000,000) of their actual size in the third column.

a) Convert the scaled orbit radius in kilometers to centimeters in the fourth column of Table 1. (There are 100,000 centimeters in a kilometer.)

	Table 1: Comparing Earth and Moon Orbit Radii Scaled to One Ten-Billionth (1/10,000,000,000) of their actual size		
	Column 2	**Column 3**	**Column 4**
	Actual Orbit Radius (km)	**Scaled Orbit Radius (km)**	**Scaled Orbit Radius (cm)**
Earth's Orbit Radius (a)	149,570,000	**.014957**	
Moon's Orbit Radius (b)	384,400	**.00003844**	

3. The diagram on the right shows where the diameter of a sphere is measured.



4. The actual body diameter of the sun, Earth, and moon are listed in the second column of Table 2 in kilometers. Those values have been scaled down to one ten-billionth (1/10,000,000,000) of their actual size in the third column. The scaled diameter in the third column has been converted to meters in the fourth column.

a) Convert the scaled diameter of the sun, Earth, and moon in meters to millimeters in the fifth column of Table 2. (There are 1,000 millimeters in a meter.)

	Table 2: Comparing Sun and Planet Body Diameters Scaled to One Ten-Billionth (1/10,000,000,000) of their actual size			
	Column 2	**Column 3**	**Column 4**	**Column 5**
	Actual Body Diameter (km)	**Scaled Body Diameter (km)**	**Scaled Body Diameter (m)**	**Scaled Body Diameter (mm)**
Sun	1,391,900	**.000139**	**.13919**	
Earth	12,742	**.0000012742**	**.0012742**	
Moon	3,474	**.0000003474**	**.0003474**	

B. Use the data to create a scaled model of the sun-Earth-moon system

Model Set-Up Procedure

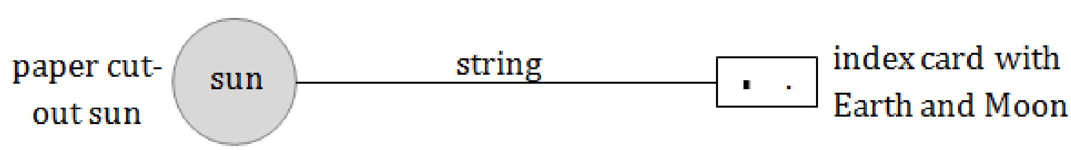
Step 1: Use a ruler, scissors, and the data from Table 2 to draw and cut out a circle that is equal to sun's scaled body diameter in millimeters on a sheet of yellow paper.

Step 2: Use a ruler and the data from Table 2 to draw a circle that is equal to Earth's scaled body diameter in millimeters on the index card.

Step 3: Use the scaled orbit radius and scaled body diameter from Table 1 and Table 2 to determine the moon's size and distance from Earth. Use a ruler to draw a circle to represent the moon on the index card with Earth.

Step 4: Measure and cut one length of string that is equal to Earth's scaled orbit radius from the sun in centimeters. Attach one end of this string to the yellow paper that represents the sun.

Step 5: Stretch the string attached to the sun to its full length. Tape the index card with the Earth and moon circles to the opposite end of the string.



C. Analyze the Model

1. Use information from your physical sun-Earth-moon model to draw a visual model that shows the orbital paths of the moon and Earth in the system. Use the space below to draw your model.

2. How do your physical and visual models of the Earth-sun-moon system provide evidence that the more massive an object is, the more its gravity will pull on other objects?

3. On Earth, the sun appears to be very small in the sky. However, more than one million planet Earths could fit inside the sun. How does your physical model help to explain why the sun appears so small in the sky when viewed from Earth?

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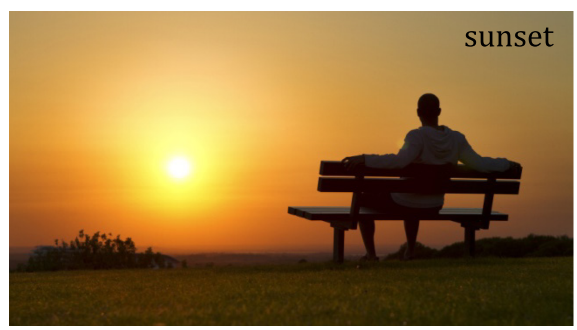
4. Sirius is one of the brightest stars in the night sky. It is nearly twice the mass and diameter of the sun. It is also 62 thousand times farther from Earth than the sun. On Earth, the sun is 11 billion times brighter than Sirius.



How does your physical sun-Earth-moon model help to explain why the sun is so much brighter than Sirius, even though Sirius is a more massive star?

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Section 2 Review

<u>Reading Comprehension Questions</u>:

1. Quote accurately from the text to describe the relationship between Earth, a galaxy, and the universe.

2. If you compare the size and brightness of the sun in the sky with the size and brightness of another star, the sun appears much larger and brighter than any other star. Why is this?

3. How does the text explain the relationship between the sun, the moon, and Earth? Why does the moon orbit Earth, and Earth orbit the sun?

4. How does the text explain the cause-and-effect relationship between Earth's orbit around the sun and the sun's gravity?

Patterns on Earth 3

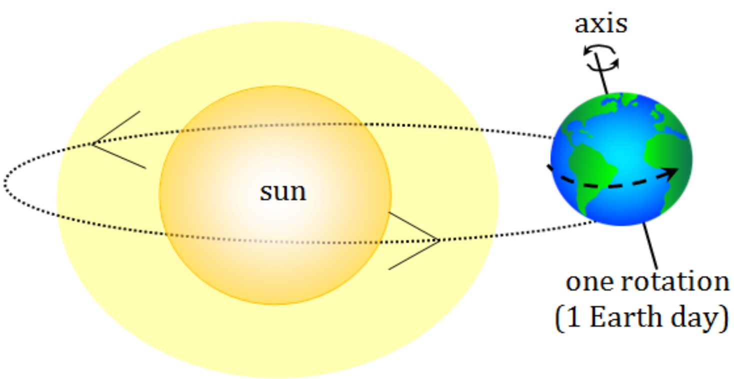
Gazing into Space

The movement of the sun across the sky marked the passage of time.

Long before the Hubble Space Telescope was launched into space, people used to watch the sky. They noticed patterns in how the sun, stars, planets and moon moved across the sky over a day, a month, and a year.

From Earth, it appears as though our planet stays still, while the sun, moon, and stars travel around it. The sun appears to rise in the east and set in the west. The moon seems to travel across the night sky. And the stars appear in different places in the night sky depending on the time of year.

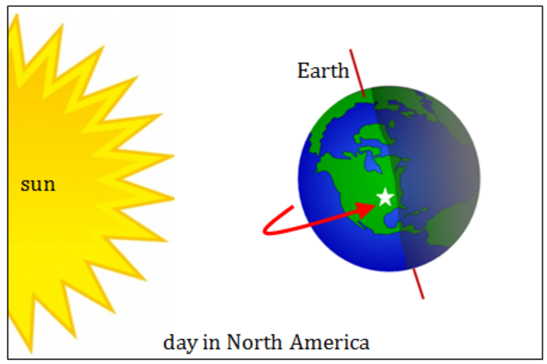
Scientists now know that Earth is in constant motion. Earth and the other planets orbit the sun, while the moon orbits Earth. At the same time, Earth is also rotating. This means it spins like a top.

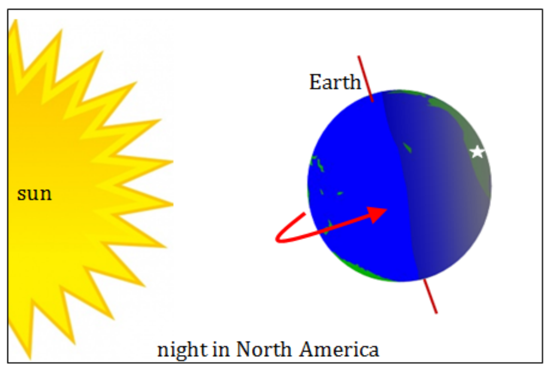


Earth's movement in the solar system

Day and Night

Earth rotates on an imaginary line that goes from the North Pole to the South Pole. This imaginary line is called an axis. Earth rotates very quickly. Earth completely rotates around its axis about once every 23 hours and 56 minutes (one Earth day).





The reason we don't feel like we're speeding through air is similar to how it can feel in an airplane like the plane isn't moving. Gravity holds us all onto the planet, and so we rotate with it.

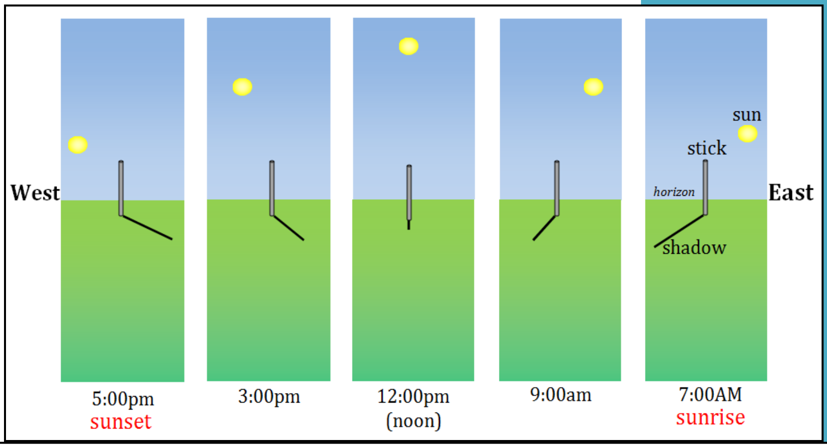
As Earth rotates, part of the planet gets light, and then dark. The sun always shines, but its light only hits one half of Earth at a time. This is why we have day and night.

The patterns in how the sun, stars, planets and moon move across the sky are caused by Earth's movement. All of these bodies appear to rise in the east and set in the west over one day because of Earth's rotation.

Telling Time with Shadows

During the day, the sun appears to move across the sky. At dawn, the sun appears close to the ground in the east. As hours pass, it moves upward. By noon, the sun appears directly overhead. In the evening, the sun appears close to the ground again, this time in the west. At night, the sun appears to disappear.

Long ago, people noticed that as the sun rises in the east, it casts shadows that change throughout a day. **Shadows** are dark shapes created when an object blocks light.



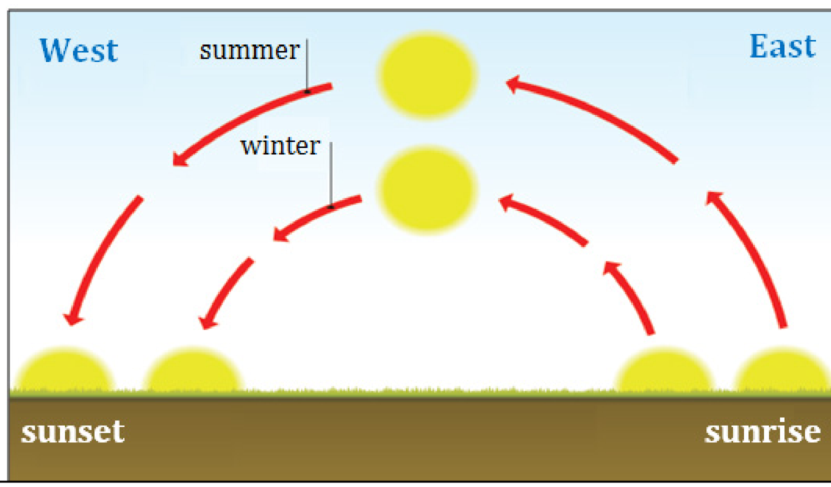
Shadows change over the course of a day as the sun moves from east to west across the sky.

The length and direction of the shadow depend on how low or high the sun is in the sky. When the sun shines down from directly above you, your head is the only part of your body blocking the sunlight. As a result, there is very little shadow. In the middle of the day, around lunchtime, your shadow will become very small. It might even disappear. In contrast, your shadow will be the largest when the sun is near the horizon. This is because your body blocks more light.

Changing Seasons

Shadows also change throughout the year. Shadows are much longer during the winter months than during the summer months.

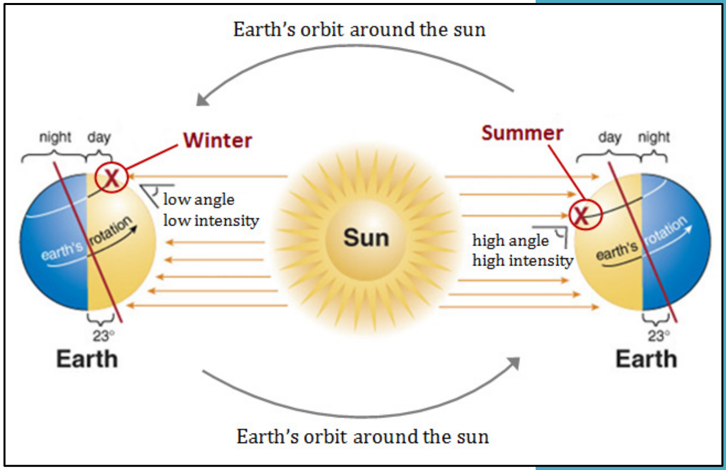
Shadows change throughout the year because the sun appears in the sky at different heights depending on the season. A **season** is a period of time characterized by specific weather patterns and by the length of day and night. In the summer, the sun appears high in the sky. In the winter, the sun appears much lower in the sky.

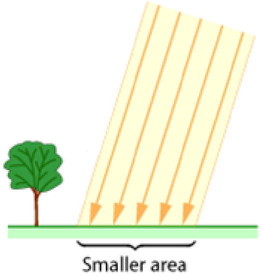


In the summer, the sun appears high in the sky. In the winter, the sun appears much lower in the sky.

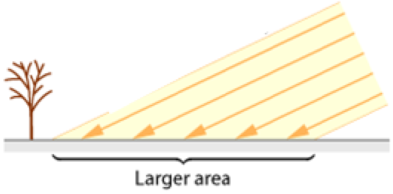
We now know that the sun appears to be in different locations throughout the year because of Earth's position in the solar system relative to the sun. As Earth moves around the sun, it is tilted 23.5 degrees on its axis.

Because of Earth's tilt, the northern and southern hemispheres each receive different amounts of sunlight throughout the year. For half of the year, the northern hemisphere is tilted toward the sun. The sun appears to be high in the sky, so the sun's rays shine more directly onto Earth, at a higher angle. When this happens, shadows are smaller and temperatures are warmer.





summer sun rays (high angle and high intensity)



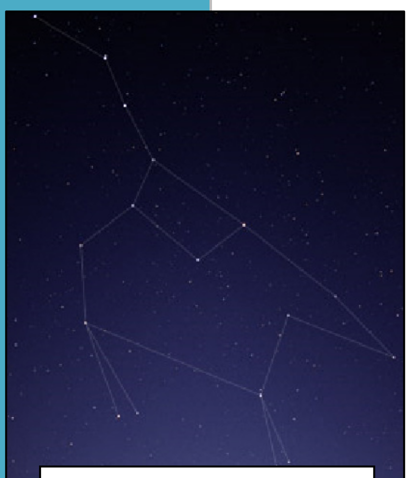
winter sun rays (low angle and low intensity)

At the same time that it is summer in the northern hemisphere, it is winter in the southern hemisphere. This is because the southern hemisphere is tilted away from the sun. The sun is lower in the sky, causing the sun's rays to hit Earth at a lower angle. This causes the sun's rays to spread out over more space, causing longer shadows. It also makes temperatures cooler.

For the other half of the year, the northern hemisphere is tilted away from the sun and the southern hemisphere is tilted toward the sun. Now it is winter in the north and summer in the south.

Changing Constellations

The sun is not the only object that appears to move in the sky. Long before we had calendars and clocks, the movement of the stars was another important sign of the changing seasons. Each night, a few stars appear in the east that weren't there the night before because Earth has moved slightly in its orbit.



Ursa Major and the Big Dipper

People named patterns in stars based on famous animals, objects, or people. These patterns are called constellations. Perhaps the best-known constellation is Ursa Major, which looks like a big bear. The tail and back of the bear are also the seven bright stars that make up the Big Dipper. Other constellations include the Summer Triangle and Orion.

When the Summer Triangle is visible, spring and summer are near. When the constellation Orion is fully visible, the cold of winter is coming.

Unlike constellations such as the Summer Triangle and Orion, some stars can be seen in the sky all year. For example, Polaris, or the North Star, is an example of a star that doesn't appear to move from the Northern Hemisphere because it lies almost exactly above Earth's northern axis.

Why Does the Moon Change?

The moon appears to change shape because of the changing positions of the moon, Earth, and the sun as the moon orbits Earth.

People have long used the movement of the moon to mark the passage of time. Within a month, the part of the moon that we see from Earth changes from a full, white disc in the sky to a small sliver and then back to a full white disc.

These changes are called phases. They occur because of the changing positions of the moon, Earth, and the sun as the moon orbits Earth. It takes the moon 29.5 days to completely orbit Earth once, about equal to one month on Earth.

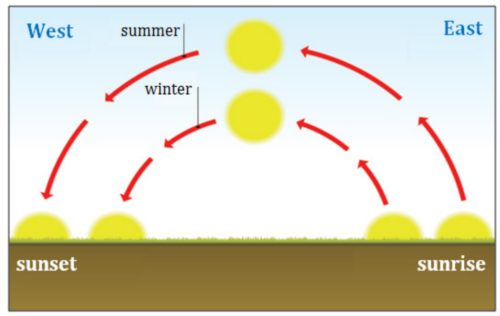
The moon doesn't emit its own light. Instead, we see the moon because the sun shines on it, lighting it up for us. Exactly half of the moon is always in sunlight, in the same way that half of Earth is always in sunlight. The same side of the moon always faces Earth, but the part of the moon that we see depends on where the moon is in its orbit around Earth. Sometimes we see parts of both the sunlit portion and the shadowed portion.

Name: ________________________________ Date: ________________

Patterns Investigation

Question
How does the position of the sun in the sky affect the length of shadows and the length of daylight hours in the winter and summer seasons?

Research
1. Use the diagram to describe how the sun's position in the sky is different in the winter compared to the summer.



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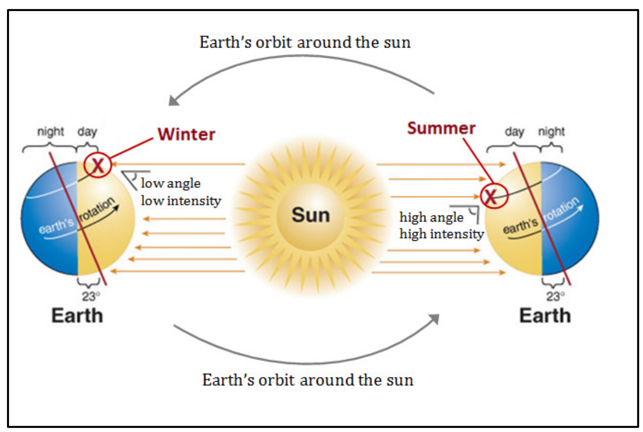
2. How does Earth's tilt explain why the sun's position in the sky changes in the summer compared to the winter? Use the diagram to help explain your answer.



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Hypothesis
Form a hypothesis for the investigation question, using what you know about Earth's tilt, its rotation on its axis, and its orbit around the sun.

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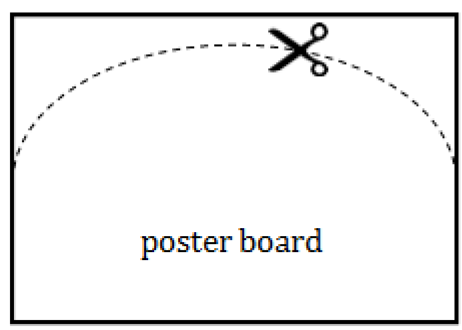
Investigation Summary
Your team will use a shadow stick and a flashlight to observe the length of shadows when the sun (flashlight) rises and sets in the winter compared to the summer. Your team will analyze sunrise and sunset times in Table 2 to compare the day length during the winter and summer.

Materials

- 1 ruler
- 1 shadow template
- 1 poster board
- 1 pair of scissors
- 1 flashlight
- 1 piece of non-drying clay
- duct tape (4-6 pieces)

Procedures
Set-Up:



1. Trim the long edge of the poster paper into a curved arc, like the diagram on the right. Tape the cut poster paper to the side of a desk or table so the curved portion extends above the edge vertically.
2. Tape the long edge of the shadow template so that its center lines up with the center of the curved poster paper 10 centimeters away.
3. Stick a 4-centimeter vertical piece of clay on the shadow template in the labeled area.

Testing Procedure:

1. To simulate the position of the sun in the summer, turn on the flashlight and position it against the lowest eastern edge of the curved poster paper so the rim of the flashlight extends 2 centimeters beyond the paper. Shine the light onto the shadow template directly on the base of the clay shadow stick.
2. Slowly move the flashlight up the curved poster paper from east to west, keeping the light directly on the shadow stick and the flashlight rim 2 centimeters beyond the poster paper. Mark and measure the length of the shadows formed by the flashlight at each time interval on the shadow template. Some of the shadows may extend beyond the shadow template.
3. Repeat steps 1-2, this time repositioning the curved poster paper so it is 5 centimeters lower to simulate the position of the sun in the winter.

Scientific Diagram

Diagram the investigation set-up. Title the diagram and label the materials used.

Data

Record data in Table 1 as the investigation progresses. Use the sunrise and sunset data in Table 2 to calculate and average day lengths for seven days in June and seven days in December.

Table 1: Comparing Summer and Winter Shadow Lengths Model			
Times	Summer Season Shadows (cm)	Winter Season Shadows (cm)	Difference (winter shadow – summer shadow) (cm)
9AM			
10AM			
11AM			
12PM			
1PM			
2PM			
3PM			

Table 2: Sunrise and Sunset Times in Boston, MA for one week in June (summer) and December (winter)			
June (day)	Sunrise (time)	Sunset (time)	Day Length (hours : minutes)
1	5:10 AM	8:15 PM	
2	5:10 AM	8:15 PM	
3	5:09 AM	8:16 PM	
4	5:08 AM	8:17 PM	
5	5:08 AM	8:17 PM	
6	5:08 AM	8:18 PM	
7	5:08 AM	8:19 PM	
Average Day Length in June			
Dec (day)	Sunrise (time)	Sunset (time)	Day Length (hours : minutes)
1	6:54 AM	4:13 PM	
2	6:55 AM	4:12 PM	
3	6:56 AM	4:12 PM	
4	6:57 AM	4:12 PM	
5	6:58 AM	4:12 PM	

6	6:59 AM	4:12 PM	
7	7:00 AM	4:12 PM	
Average Day Length in December			

Conclusion

Use the data you gathered in Tables 1 and 2 to write a conclusion for the investigation. The conclusion should summarize your findings and explain how the data did or did not support your hypothesis.

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Section 3 Review

<u>Reading Comprehension Questions</u>:

1. Accurately quote the text to explain why people used to think that the sun, the moon, and the stars moved, and Earth stayed still.

2. What can you infer from the text about how well people used to understand Earth's place and movement in the solar system?

3. What evidence does the text use to explain the relationship between Earth's motion and day and night?

4. Why are shadows longer during the winter than during the summer?

Science Words to Know

atom – the smallest piece of matter that has the properties of an element; a combination of three subatomic particles: protons, neutrons, and electrons

cause and effect – a relationship between events or things, where one is the result of the other

chemical reaction – a change that rearranges the atoms of the original substances into a new substance that has different properties from the original substances

conservation of matter – a theory that states atoms are not created or destroyed during a chemical reaction; they are rearranged to form new substances

element – a substance entirely made up of one kind of atom

experiment – a procedure designed to test whether a hypothesis is true, false, or inconclusive

gravity – a force of attraction between all matter

mass – a measure of the amount of matter that makes up an object; measured in grams (g)

matter – everything that has mass and takes up space

pattern – something that happens in a regular and repeated way

physical change – a change that does not affect the chemical structure of a substance

property – an observable or measurable characteristic of matter

scale – the size, extent, or importance of something relative to something else

science – all knowledge gained from experiments

season – a period of time characterized by specific weather patterns and by the length of day and night

shadows – dark shapes created when an object blocks light

solar system – a collection of planets and other objects that orbit a star

weight – the gravitational force exerted on an object by a planet or moon; measured in newtons (N)

