Eighth Grade Science Overview

	First Semester	Second Semester
Science	Controlled experiments Periodic table of the elements Mixtures and compounds Force vectors Mass, weight, and gravity Laws of motion Types of energy Student-led scientific inquiry	Properties of waves Electromagnetic spectrum Reflection, absorption, and refraction of light Electric charge and electrical current Mesuring and controlling electricity Magnetism and electromagnetism Mechanical advantage Principles of aerodynamics Student-led scientific inquiry

Grade 8
Physical Science Coursebook

Oak Meadow

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Unit III: Forces and Interactions

Unit V: Waves

Unit VI: Electricity and Magnetism

Unit VII: Engineering Design

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Introduction

Welcome to the Oak Meadow Physical Science course. In this course, you will be learning the answers to many questions we often ask about the physical world around us. Why do we see colors? How do things get hot? What forces combine to keep a heavy airplane aloft? There are many natural forces and physical properties that influence our actions every day. This year, you will be learning about some of these forces and how they work.

The secret to understanding any new subject lies in learning the language. When you learn a new game, there are usually unfamiliar words used to describe the parts of the game. The same is true of science. In this course, you may come across new words (such as *inertia*, *torque*, and *thermodynamics*) as well as words used and defined differently than you may be used to (such as *work*, *power*, and *force*). It might be helpful to keep a list of new words and their meanings handy to help you as you move through this course. You will be expected to use correct and specific terminology in your assignments.

This course was designed around Next Generation Science Standards (NGSS), which means that there are many opportunities for you to experience, explain, diagram, model, and reflect on the concepts you are learning.

Course Materials

This course uses the following materials:

- *Grade 8 Physical Science Coursebook*
- *Physical Science Lab Manual*

The coursebook in your hands is your primary resource for completing the course. The lab manual includes all the instructions for completing the lab investigations that are a required part of this course. (The lab manual is sold separately.)

In the coursebook appendix, you will find a complete list of materials for all the assignments, labs, and activities in this course. (Refer to the materials list in the coursebook appendix rather than the one in the lab manual, which only lists the lab materials.) Most assignments use ordinary household objects or items that may be recycled. You may want to get in the habit of saving certain kinds of materials, such as cardboard, glass jars, large aluminum cans, and paperboard (from cereal or shoeboxes). Glance through upcoming lessons each week so you have plenty of time to collect any necessary materials.

It is often helpful to seek out additional sources to help you better understand a topic. On the Oak Meadow website, you will find a Curriculum Resource Links page for this course at www.oakmeadow.com/curriculum-links. If you have access to the internet, take a few minutes to look it over and then bookmark the page for future reference.

How the Course Is Set Up

This course is divided into 36 lessons, and each lesson is designed to take about one week to complete. In most lessons, you will find the following sections:

An **Assignment Summary** shows at a glance what is required so you can check off assignments as you complete them.

A **Materials List** shows you what materials will be needed so you can collect your supplies (it helps to look at this ahead of time so you have everything handy when you begin the lesson).

Learning Objectives outline the main goals of the lesson and give you an idea of what to expect.

Assignments give you many ways to explore key concepts and apply your knowledge.

Lab Investigations, which are found in the lab manual, provide hands-on ways to work with the materials and practice your scientific skills. These are a required element of the course.

Optional Activities offer additional ways to explore the lesson topics. You can choose any that interest you (none are required).

Tests provide a way to assess your knowledge of the material.

Learning Checklists let you keep track of your progress and skill development.

A section **For Enrolled Students** provides reminders and information for students who are enrolled in Oak Meadow School and submitting work to their Oak Meadow teacher.

Reading Selections are found at the end of each lesson. This section contains your primary source of information for the lesson material. There are seven units in the course:

- Unit I: Scientific Habits and Properties of Matter
- Unit II: Chemical Reactions
- Unit III: Forces and Interactions
- Unit IV: Energy
- Unit V: Waves
- Unit VI: Electricity and Magnetism
- Unit VII: Engineering Design

Most units conclude with a self-designed project called Scientific Inquiry. These projects let you dive into the material in an active, creative way.

How to Get the Most Out of This Course

When you begin each lesson, scan the entire lesson first. Take a quick look at the assignments and lab description, and then look over the reading sections to get an idea of how much reading there is. It might also help to read the test questions, too, because these often highlight key concepts that you will want to pay attention to. Having a sense of the whole lesson before you begin will help you manage your time effectively.

An important element of this course is developing good scientific habits. Here are some tips:

- Take the time to explain your observations and ideas using clear, precise language.
- Use scientific terms whenever possible. These words are in italics in the lesson text; if you don't understand a term after reading the text, look it up on your own. Scientific writing requires a certain amount of precision and using the scientific terms will make your writing more exact.
- Make sure you use examples from the reading or from your observations to back up your statements.
- Assume the role of expert, and write out your ideas as though you are explaining them to someone who is just learning about science.
- When making observations, your notes should be as detailed as possible, describing what you observed with your senses. Before you begin your observations, determine whether you can organize the page in such a way to make note-taking easier. Use of a chart, data table, or a diagram can help you keep your observations organized.
- Learning to draw accurately is another important scientific skill. Artistic style is not as important as attention to detail. By studying the object carefully, you will be better able to draw an accurate representation. Make sure to label all diagrams and drawings, and add color as necessary so the drawings give clearer or more accurate information.

For Students Enrolled in Oak Meadow School

If you are enrolled in Oak Meadow School, you will submit work to your Oak Meadow teacher on a regular basis. Continue working on your next lesson while you are waiting for your teacher to send lesson comments. After you have submitted the first 18 lessons, you will receive a first-semester evaluation and grade. At the end of 36 lessons, you will receive a final evaluation and grade.

Follow the instructions in your teacher's welcome letter about how and when to submit work. Your teacher may also provide information on alternate assignments, and can help you adapt the lesson material or workload, if necessary. Contact your teacher whenever you have a question.

You are expected to submit original work, writing in your own words. When you use or quote other sources, cite them accurately following the guidelines in the appendix. Plagiarism, whether accidental or intentional, is a serious matter.

The appendix of this coursebook includes complete details on Oak Meadow's academic expectations and original work guidelines. It is your responsibility to make sure you understand these academic expectations and abide by them.

In addition to students' academic achievement in a course, Oak Meadow values student effort, attitude, and work habits. As well as content mastery, grades earned in a course will reflect how well you have demonstrated your level of engagement through consistent submission of work, ongoing communication with your teacher, and attention to detail in following directions and in the general organization of your submissions.

Please remember to stay in touch with your Oak Meadow teacher and share your comments, ideas, questions, and challenges. Your teacher is eager to help you!

The Quest for Knowledge

One important element of scientific thinking is to remember that just because someone makes a claim doesn't necessarily mean it's true. Most discoveries were made by people who asked, "Why is that true?" The many biographies included in this course will introduce you to people who continued to ask questions. You are encouraged to ask questions all the time, of the material in this course and of the world in general. The quest for knowledge never ends!

Lesson 1

Measurements and Quantitative Data

Learning Objectives

At the end of this lesson you will be able to:

- Demonstrate objective observations.
- Differentiate between subjective, objective, qualitative, and quantitative observations.
- Identify the basic components of a scientific argument.

Reading

Read the following sections (found in Reading Selections at the end of this lesson).

- The Flow of Discovery
- Scientific Inquiry
- Measurements and Quantitative Data
- Scientific Argument

Before you begin reading, glance over the length of the reading selections in this week's lesson. This is a good habit to get into—at the beginning of each lesson, scan all the work ahead of you. If you find a lot of reading material in a lesson, try to read one or two sections and then take a break before reading more. That way, you are more likely to remember what you read rather than if you had rushed through it.

In addition to the reading selections in this coursebook, you are encouraged to learn more about topics you are interested in by visiting the library, reading newspapers and scientific journals, and doing research online. You'll find a list of online resources at www.oakmeadow.com/curriculum-links. You can use these links to learn more about lesson topics.

ASSIGNMENT SUMMARY

- ☐ Complete the reading selections.
- ☐ Reflect on how knowledge is built on the work of others.
- ☐ Identify objective and subjective observations.
- ☐ Record qualitative and quantitative observations.
- ☐ Measure and describe household objects.
- ☐ Optional Activity: Scientists and Scientific Discoveries
- ☐ Complete lesson 1 test.

MATERIALS

metric ruler or tape measure

Assignments

At the beginning of each lesson, read the assignments, lab investigations, and activities to see what you'll be doing that week. Yes, this will take a little time, but it will help you get a good sense of how long things will take so you can manage your time better. You have a full week to complete each lesson, so there's no rush.

1. Think of a time when you have built on the knowledge of someone who came before you, and consciously taken it to the next step. Was this next step an improvement or a better design? Perhaps an activity you do is now more efficient. Write about one or two of your experiences.
2. Identify which of the following observations are objective and which are subjective.

Statement	Objective	Subjective
The cat is 20 inches long.		
Its tail is striped orange and white.		
It is friendly.		
The cat is fat.		
It weighs 20 pounds.		
Its whiskers are white.		
The fur on its paws is orange.		
It enjoys lying in the sun.		

3. Practice careful and objective observation. Choose something to observe, either outdoors or indoors. Consider what you might need to do for the observation to be repeatable. If you're observing your dog playing in your backyard, you need to record the dog's actions as well as the time of day, the weather, the sounds around you, who else is there, etc. All these things are important and helpful information. For example, if you don't note that a thunderstorm comes up, and you just say, "The dog suddenly stopped chasing the stick and hid under a bush," we're not getting the full picture. You will need to use all your senses and record your data carefully and thoroughly. Be sure to be objective. Instead of saying, "My dog kept jumping up happily," you should say, "My dog jumped two feet off the ground six times in ten seconds while wagging his tail." That way the reader decides if the dog seems happy or not. Use clear and precise language when describing your observations. Make sure to include both qualitative and quantitative data.
4. Find five objects in your house that are rectangular or square. The objects should be different sizes. At least one should be smaller than your hand, and at least one should be larger than a chair (such as an appliance). Take careful measurements using a metric ruler or tape measure and complete the table below. After measuring the item (quantitative data), write down one objective qualitative observation.

Object	Dimensions (length, height, and width)	Volume (length × height × width)	Qualitative observation

Activities

All the activities in this course are optional. Although these activities are not required, you are encouraged to choose any that interest you to help you gain a better understanding of the course material.

Activity: Scientists and Scientific Discoveries

In this lesson, you've been introduced to a few scientists whose work changed the world. Find a scientist or a scientific discovery that interests you. Do a little research, and write a paragraph highlighting the work of this scientist or the significance of the discovery.

Test

Answer the following questions using the knowledge you have gained in this lesson. Use correct terminology and refer to scientific concepts to support your answer whenever possible.

1. Explain the difference between an objective observation and a subjective observation.
2. Give three examples of quantitative observations.
3. Give three examples of qualitative observations.
4. List and define the steps of a scientific argument.

Learning Checklist

This learning checklist can be filled out by either you or the adult who is supervising your work. This checklist will help you keep track of how your skills are progressing and what you need to work on. You or your home teacher can also add notes about where you'd like help.

Here is what the different headings mean:

Developing: You still need to work on this skill.

Consistent: You use this skill correctly most of the time.

Competent: You show mastery of this skill.

Please remember that these skills continue to develop over time so you aren't expected to be able to do all of them yet. The main goal is to be aware of which skills you need to focus on.

SKILLS	Developing	Consistent	Competent	Notes
Differentiate between subjective and objective observations				
Define quantitative and qualitative data				
Record accurate measurements				
Use scientific terminology in explanations				

FOR ENROLLED STUDENTS

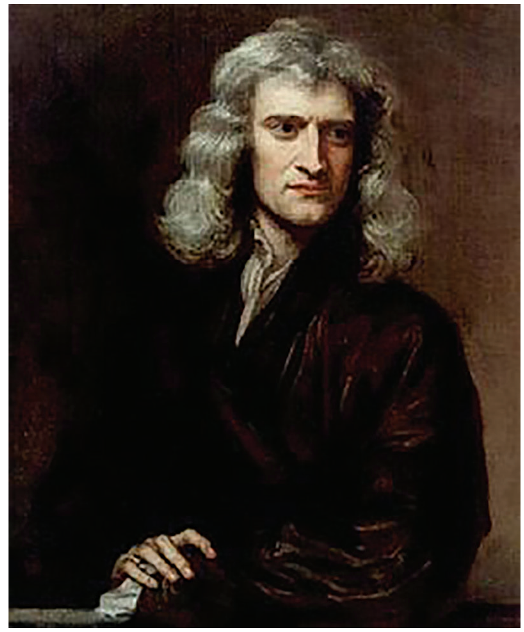
You will be sending your work from this lesson to your Oak Meadow teacher at the end of lesson 2. In the meantime, feel free to contact your teacher if you have any questions about the assignments or the submission process.

Reading Selections

The Flow of Discovery

Roughly 2,500 years ago, two Greeks, Aristotle and (a hundred years later) Archimedes, made discoveries because they were curious about why certain things in their world behaved as they did. Aristotle observed natural phenomena and tried to come up with logical explanations about them, testing his observations through organized scientific inquiry. This changed everything! Until then, people had explained natural phenomena through myths and stories. Archimedes was a noted mathematician who introduced mathematical reasoning into scientific inquiry.

Like Aristotle and Archimedes, Isaac Newton (1642–1727) challenged ideas that had dominated scientific thinking for thousands of years. Newton developed the laws of motion of bodies, and the laws of gravitation and optics. Much of what we'll be learning about in this physical science course is what is known as "Newtonian physics."



Portrait of Isaac Newton,
Godfrey Kneller (1689)

Some 300 years later, *Time* magazine chose German-born physicist Albert Einstein as "the most important person of the twentieth century." When Einstein published his Theories of Relativity in 1905 and 1915, he dramatically altered the way we understood the world. Throughout his life, Einstein acknowledged his debt to scientists who had gone before him. Though it was their individual brilliance that led to scientific breakthroughs, both Newton and Einstein saw themselves as part of a flow of discovery.

When Einstein advanced his Theory of Relativity, it overturned Newton's idea of absolute space and time. About the same time, Max Planck introduced the basis for the Quantum Theory. These two concepts—Relativity Theory and Quantum Theory—have provided the foundation for most of modern physics, which includes ideas such as the big bang, black holes, antimatter, and quarks.

However, scientific theories often come into question as new theories are advanced. That is what science is all about! It's all about hypothesizing, testing theories, making mistakes, adjusting your hypothesis, and trying again.

Many scientists today are deeply involved in developing a Unified Field Theory, also known as the Theory of Everything. It ties together all known phenomena to explain the nature of all energy and matter in existence. So far it has defied expression; there are some things that just don't fit into the equation. The current search for a Unified Field Theory has led to the Superstring Theory, which says that all matter and energy in the universe is composed of incredibly tiny vibrating "strings." This idea offers a lot of promise.

Perhaps during your lifetime an entirely new concept of space and time will emerge, rendering what we know today obsolete. We hope this course will make it easier for you to accept new ideas. Perhaps, one day, you will help discover one of those new ideas.

Throughout the course, you'll find short biographies of notable people in the scientific world. Each one has made a significant contribution and helps us remember that science is about people. It's easy to forget that! The biographies highlight people who devoted their lives to searching for answers to scientific questions, and to those who stumbled on a scientific discovery by accident.

Keep in mind, as you move through this course, that *people* accomplished all the great achievements you will read about. People who had homes and families, hopes and ideals. They got sick, got angry, felt frustrated, and lived from day to day, just like everyone else does. For many scientists, it is their passionate curiosity that spurs them to action.

Scientific Inquiry

Science focuses on observing, understanding, and explaining the world around us. Scientific inquiry attempts to gather information that is free of opinion or bias. In order to do that, scientific explorations have three particular things: ***measurable observation***, ***repeatable results***, and ***objective analysis***.

Every scientific observation that is made must be measurable. The ancient Greeks explained observations with myths. If there was a thunderstorm, it was assumed that the god Zeus was causing the lightning because of his anger. That's not a scientific explanation—there is no way to measure or test that assumption. We now know, through observation and measurements, that atmospheric conditions create the static charge that we know as lightning.

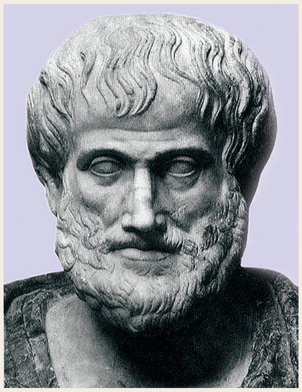
Let's say you notice that when you wake at 7:30 each morning, the day seems a little darker than it did the day before. This is a measurable observation. You can record the time the sun comes up each day for two weeks and note that the sun really does come up later each day. Your measurable observations are the specific time measurements you made for 14 days. With this specific data, other people can verify your results by repeating what you did.

The basis of scientific inquiry is careful observation. This means being aware of the world around us. ***Objectivity*** is the desire to observe things as they are, without personal opinions or feelings influencing the observation. Sometimes we really want a process to turn out a certain way, and we'll want to adjust our way of looking at it (or worse yet, adjust the results themselves) to mesh with our desire. This is not science!

En Hedu'anna (circa 2354 BCE)
Sumerian Astronomer

En Hedu'anna lived in Sumeria over 4,000 years ago. She was the daughter of the ruler Sargon, who established the Argonian Dynasty in Babylon. As Priestess of the Moon Goddess, her position was very powerful. She was the head of a sacred temple where priests and priestesses monitored the movements of the stars from a network of observatories. They created a calendar that is still in use for determining religious holy days.

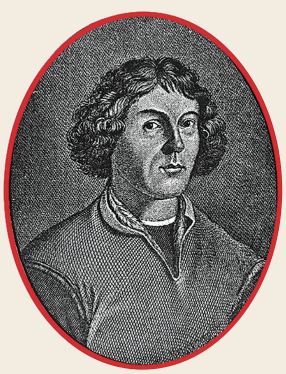
Aristotle (384–322 BCE)
Greek Philosopher



Aristotle was a Greek philosopher who founded the science of logic. Both of Aristotle's parents died when he was a boy. When he was 18, he began studying at the Academy of Plato in Athens, where he stayed for 20 years. Plato called him the "intelligence of the school." Aristotle later formed his own school in Athens, the Lyceum (335 BCE). He was known for walking around with his students while teaching them. In his writings, Aristotle covered almost every area of human knowledge. He emphasized that rationality was essential in politics and thinking. He adhered to a strict moral code, believing if a man practiced behaving morally and ethically, it would soon become his natural behavior.

Nicolaus Copernicus (1473–1543)
Polish Astronomer

Considered the founder of modern astronomy, Copernicus challenged the ancient yet popular ideas of a Greek astronomer and geographer named Ptolemy who believed the sun, moon, and planets circled around Earth. Because Ptolemy's work was so respected, for almost 1,500 years astronomers believed this was true. However, Copernicus set out to prove how Earth's movements explained the movement of other heavenly bodies with the sun as the center of the universe. Copernicus's theory laid the foundation for Johannes Kepler to use mathematics to develop the three laws of planetary motion. In turn, Kepler's laws were crucial to Galileo's discoveries, based on telescopic investigation. Following the path of discovery, Sir Isaac Newton was later able to determine the principle of gravity based on the combined works of all three of his predecessors—Copernicus, Kepler, and Galileo.



Galileo Galilei (1564–1642)
Italian Astronomer

Galileo, who lived 100 years after Copernicus, made observations of the moon, and the planet Jupiter and its moons, that convinced him Copernicus was right. His ideas disagreed with the teachings of the powerful Catholic Church, so the Church declared him a heretic and forced him to renounce his views. He had to spend the rest of his life being watched over by officers from the Church. It took another hundred years of careful research and determination on the part of scientists around the world for Copernicus's theory to enjoy universal acceptance.

All observations are potentially influenced by experience, beliefs, or worldview. For example, if you and a friend go for a walk in the park, the two of you might notice different things. Afterward, if asked to describe what you observed, you might have noticed all the people there—what they are doing, what they are wearing, where they are in relation to you. Your friend might have observed all the plants and animals—trees, flowers, squirrels, birds, and bees. Your observations were somewhat subjective because you only paid attention to what you were interested in. If you had taken a video camera with you and recorded everything while you walked around, you would be able to replay the video and each of you would be able to see the things that you missed. A video camera recording is like an objective observer because it records everything in its field of vision.

Objective scientific observation attempts to be like a video camera, recording everything. Scientists record everything they notice, even when they don't think it is important and even when the observations that they are making are different from what they expected or when they disagree with the results. Scientists strive for objective observation.

The easiest way to tell if an observation is subjective or objective is whether someone else could disagree with you. If they could disagree because they have a different opinion or view, then the observation is ***subjective***. For instance, if you and a friend sat on a park bench and saw a group of three squirrels nearby, you both would agree on the number of squirrels. That's an objective observation. If asked, "Were the squirrels friendly or shy?" you might say they acted friendly but your friend might say they acted shy. These are subjective observations, based on your opinions or feelings. However, if asked, "Did the squirrels approach when you sat on the bench?" it's likely your answers would agree because the question asks for an objective observation.

An objective observation is an example of good science if it contains the three features of scientific observation: it is measurable, repeatable, and objective.

Measurements and Quantitative Data

Physical science focuses on the physical properties of energy and matter, and how they interact with each other. Why does the skateboard roll downhill? What makes your computer run? Why does salt dissolve in water? What happens to light as it comes through the window? All these questions have to do with the physical objects and how they move or change.

Measuring is an integral part of all scientific exploration. ***Quantitative data*** is anything that can be measured or counted. Quantitative measurements involve numbers. In physical science, commonly measured things include temperature, time, area, volume, sound, weight, speed, and distance. These are all measured with numbers.

Qualitative data involves characteristics that relate to appearance or behavior. It describes the qualities of whatever is being observed. Qualitative measurements include color, texture, smell, taste, sound, movement, and other characteristics that can't be measured with numbers. Accuracy of detail is extremely important in both qualitative and quantitative observations.

All quantitative measurements are expressed in units. For example, when you weigh yourself, you may express your weight in pounds. A pound is the unit of measure. Other units include grams, ounces, millimeters, inches, seconds, miles, and kilometers.

Measurements can record different types of data:

> **Linear distance** measures the distance from one point to another.
>
> **Area** is the amount of flat (or two-dimensional) space, and includes length and width. Area is measured in square units, such as square meters.
>
> **Volume** is the amount of three-dimensional space taken up by a solid, and includes length, width, and height. Volume is measured in cubic units, such as cubic meters.
>
> **Liquid volume** differs from solid volume since liquids change shape depending on the container. Liquid volume is measured in liters (or related measurements).

The volume of a liquid is generally measured using a ***graduated*** container, which means that there are units marked on the container at regular intervals. A measuring cup is an example of a graduated container.

There is a certain technique involved in measuring liquids. If you put water in a glass measuring cup, you'll see that the water clings to the sides of the container, so that the edge of the liquid is curved. This curve is called the ***meniscus***. Because of this curved surface, you need to have your eyes level with the top of the liquid to get an accurate volume measurement.

Originally every culture had its own system of measurement. Today, the standard system of weights and measures used by the scientific community and most of the world is the metric system, also known as Système International (SI). The metric system is based on units of ten. The name of each unit tells you how many tens (or hundreds or thousands) there are. For example, if you add the prefix *centi-* to the word *meter,* you get centimeter. The prefix *centi-* means one hundredth, so a centimeter is one hundredth of a meter. If you add the prefix *kilo-*, you get kilometer. The prefix *kilo-* means one thousand, so a kilometer is one thousand meters.

Metric system prefix	**Meaning**	**Example**	**Equivalency**
Mega-	one million	1 megaliter is 1,000,000 liters	1,000,000 liters = 1 megaliter
Kilo-	one thousand	1 kilogram is 1,000 grams	1,000 grams = 1 kilogram
Hecto-	one hundred	1 hectogram is 100 grams	100 grams = 1 hectogram
Deca-	ten	1 decameter is 10 meters	10 meters = 1 decameter
Deci-	one tenth	1 deciliter is one tenth $\left(\frac{1}{10}\right)$ of a liter	10 deciliters = 1 liter
Centi-	one hundredth	1 centimeter is one hundredth $\left(\frac{1}{100}\right)$ of a meter	100 centimeters = 1 meter
Milli-	one thousandth	1 milliliter is one thousandth $\left(\frac{1}{1{,}000}\right)$ of a liter	1,000 milliliters = 1 liter
Micro-	one millionth	1 microgram is one millionth $\left(\frac{1}{1{,}000{,}000}\right)$ of a gram	1,000,000 micrograms = 1 gram

Common Abbreviations of Metric Measurements

Meter	Meter	m
	Kilometer	km
	Centimeter	cm
	Millimeter	mm
Gram	Gram	g
	Kilogram	kg
	Milligram	mg
Liter	Liter	L (or l)
	Milliliter	mL (or ml)

Sometimes volume is given in cubic centimeters (cc). This is often used in medicine to measure dosage. A cubic centimeter is exactly the same volume as a milliliter. They are used interchangeably. If you were measuring a volume of water, 1 mL (1 cc) weighs exactly 1 gram (at a water temperature of 4°C). This works out because a liter is the same volume as a cubic decimeter (a decimeter is one tenth of a meter, or 10 centimeters). If you had a cube that was 10 cm on each side, the volume of it is exactly 1 liter.

Scientific Argument

In addition to making careful measurements and objective observations, scientists also strive to draw conclusions based on the data collected. Any claims made based on results should be supported by data. Presenting a scientific argument lets scientists “argue” or prove their claims or conclusions using measurable, replicable, and objective data.

Here are the steps to making a scientific argument:

- **Make a claim based on research.**

A claim is a statement that suggests or infers a relationship (correlation) between factors, or draws a conclusion about what the data indicates. It’s important to be careful with how a claim is stated because one experiment or data set doesn’t prove something conclusively. Scientific claims often use phrases like “this suggests,” “it appears,” or “it seems likely” to indicate whatever the observations or results might show.

- **Provide evidence (data) to support the claim.**

Observations (both quantitative and qualitative) form the data that become evidence to support a claim. Usually this data is assembled into an easy-to-read form, such as a chart, graph, or table. The data should directly relate to the claim or conclusion in a logical way. If the claim is sound, others who see the data are likely to agree with the statement.

- **Use reasoning to explain how the data supports the claim.**

The bulk of a scientific argument is explaining how the data relates to and supports the initial claim. It clearly presents the logical flow of reasoning that led to the claim or conclusion. The argument explains what the data shows so that others can judge the accuracy of the claim for themselves.

Scientists, like everyone else, have personal opinions, feelings, beliefs, and biases. However, they try very hard to remain objective when making observations, interpreting data, making claims, and providing scientific argumentation. Throughout this course, you’ll be practicing these essential scientific habits.

Lesson 2

Controlled Experiments and the Scientific Method

Learning Objectives

At the end of this lesson you will be able to:

- Identify the variable factors in an experiment.
- Design an experiment that controls all variables but one.
- Write a conclusion based on experiment results.
- Differentiate between causation and correlation.

Reading

Read the following sections (found in Reading Selections at the end of this lesson).

- Scientific Method
- Variable and Constant Factors
- Controlled versus Uncontrolled Environments
- Using the Scientific Method
- Causation and Correlation

Look over the amount of reading before you begin, and make a plan to divide it up so you aren't trying to absorb too much information at once. If you have any questions about the reading, ask for help or do some extra research on your own.

Assignments

Before you begin your assignments, read through them to get a sense of what you'll be doing and how long it will take. This will help you manage your time better.

Take some time to make an observation around your home. Perhaps you notice that your cat naps in different places at different times of day. Or maybe you see that the temperature on one side of your

ASSIGNMENT SUMMARY

- ☐ Complete the reading selections.
- ☐ Make a list of variables and how they can be controlled.
- ☐ Lab Investigation: Sink or Float?
- ☐ Complete lesson 2 test.

MATERIALS

Lab Investigation: Sink or Float?

clay (about the size of a baseball)

bucket of water

house generally feels colder than on the other. Then make a list of variable factors that you might consider if you were to design an experiment. After each variable you list, explain how you might control that variable to make it a constant in your experiment.

Lab Investigation

Complete the following lab investigation.

- **Lab Investigation: Sink or Float?**

All lab investigations are found in the physical science lab manual. Read the instructions carefully and assemble all your materials before you begin. Use good scientific habits by taking careful observations and measurements, recording your data in an organized way, and using precise, detailed language.

Test

Answer the following questions using scientific terminology. Refer to scientific concepts to support your answer whenever possible.

1. In your own words, explain the steps of the scientific method.
2. What is the difference between a variable and a constant? How many variables are normally in a scientific experiment? How many constants? Why are both part of every experiment? Give an example of each.
3. Define *controlled environment* and give an example.
4. What does the phrase "correlation does not imply causation" mean? Make sure to define *correlation* and *causation* in your answer.

Learning Checklist

Use this learning checklist to keep track of how your skills are progressing. Include notes about what you need to work on. Please remember that these skills continue to develop over time.

SKILLS	Developing	Consistent	Competent	Notes
Describe the steps of the scientific method				
Write a concise, testable hypothesis				
Identify variable and constant factors				
Write a step-by-step procedure for an experiment				

SKILLS (*continued*)	Developing	Consistent	Competent	Notes
Record data with accuracy				
Write a conclusion based on results				
Describe a controlled environment				
Differentiate between causation and correlation				

FOR ENROLLED STUDENTS

When you have completed this lesson, please send lessons 1 and 2 to your Oak Meadow teacher. Include any additional notes about the lesson work or anything you'd like your teacher to know. Feel free to include any questions you have—your teacher is eager to help.

If you have any questions about what to send or how to send it, please refer to your parent handbook and your teacher's welcome letter. Your teacher will respond to your submission of student work with detailed feedback. In the meantime, proceed to the next lesson.

Reading Selections

Scientific Method

The ***scientific method*** is an organized way of testing observed phenomena. However, it is not the only way that scientific progress is made! Scientists observe the world like children do—exploring every new thing, being curious, and asking questions. This observation and questioning is scientific inquiry. Sometimes you cannot create experiments around the observed phenomena. If a shower of meteors falls to Earth, how can you devise an experiment to test what happened and why? You can't recreate the event, but you can observe carefully and relate it to what is already known. This is the way science works.

We are all scientists. We ask questions, we guess what the answer will be, and we watch to see what happens. Our minds record the results and then we decide what the results mean. We take this knowledge and use it to guide our future actions or explorations. In the scientific method, observations are made about the world, and then experiments are conducted to explain the observation. How carefully the experiment is designed and conducted determines how accurate the results will be. If the factors influencing the experiment are not controlled, then the experiment will not give us reliable results and an accurate explanation of what was observed. Often a scientist will repeat an experiment, changing different elements each time, in order to gain a clearer understanding of a phenomenon.

When drawing conclusions about what happened and why, it's important to consider the many different factors that may influence the results. Scientists try to keep these influences under control by following very specific procedures of the scientific method.

Ask a question: Questions often arise from observations. The question should be brief, concise, and testable. For example, "Why does my dog eat so fast?" is a question that would be hard to test—it is too open-ended. There could be many factors influencing how fast the dog eats. However, "Does the type of food influence how fast my dog eats?" is a question that is easy to test. There is one factor that is being looked at: the type of food.

Form a hypothesis: A hypothesis is an educated guess about what the answer to the question might be, based on what you already know. The hypothesis forms the focus of your experiment, which will attempt to prove or disprove the statement. For instance, you might hypothesize, "My dog will eat cooked meat faster than dry dog food, fresh fruit, or fresh vegetables."

Conduct an experiment (procedure): An experiment is designed and conducted to test the hypothesis. The experiment will try to isolate a single factor to test, controlling all other influences. Often a procedure is performed multiple times to see if the results can be repeated.

Record the results: Observations are carefully recorded, and these become the results of the experiment. Results, which can be qualitative or quantitative or both, are recorded as objectively as possible.

Draw a conclusion: The data (results or observations) is compiled and interpreted as you look for patterns and cause-and-effect relationships, and make inferences about what happened and why. The conclusion states whether the hypothesis was proved or disproved.

The conclusion is where you compare your hypothesis with what actually happened.

- Did what you think would happen actually happen?
- Did something unexpected happen?
- Describe the variables and which ones may have impacted your results.
- Consider possible explanations for what happened in your experiment.

The conclusion is a chance to reflect on the experiment and how it might be altered or expanded to produce more accurate or helpful information. Is there an influencing factor that was not properly controlled? Would more trials or a longer time period reveal more patterns of behavior? Is there another factor that needs to be taken into account or tested? When writing a conclusion, scientists will often discuss questions such as these, and propose a relevant follow-up experiment.

Variable and Constant Factors

When we make observations about the world, it is important to understand the factors that may be influencing what we are observing. In an experiment, a ***variable factor*** (or variable) is an aspect of the experiment that can be varied or changed. For instance, temperature might be a variable factor in a plant growth experiment, or the amount of water might be a variable factor. Usually an experiment will have only one variable factor. The variable in the dog food experiment is the type of food.

Factors that are controlled and do not change are called ***constant factors*** (or constants). In a plant growth experiment, you might control the amount and type of soil, the type and number of seeds, how deep the seeds are planted, and the amount of sunshine each plant gets. These constant factors are the same for each plant in the study. The constants in the dog food experiment might be the amount of food, the time of day, the number of people present when the dog is eating, the noise level, the location of the food, and the shape and size of dish the dog eats from. These constant factors are the same throughout the experiment. The only thing that changes is the type of food.

Let's suppose you notice that sometimes the ice cream in your freezer is really hard and sometimes it is a little soft. What are some of the variable factors that could explain this?

- The temperature of the freezer
- The placement or location of the ice cream in the freezer
- The type of ice cream
- How long the ice cream has been in the freezer
- How many times the freezer door has been opened
- How much ice cream is left in the container

If you wanted to conduct an experiment to try to figure out why the ice cream changes its form, you might start by identifying the variables, such as temperature, placement, type of ice cream, and length of time in freezer. To determine which variable is causing the ice cream to be hard or soft at different times, you would have to conduct a series of experiments to look at the influence of each variable, one at a time.

You might put some ice cream in a certain spot in the freezer and then two hours later you test it for hardness. After another two hours, you go to test the ice cream again, but you realize that someone ate it all, and there is another kind of ice cream right in the same spot. Since it is in the same place in the freezer, you do another hardness test and find it much softer than the previous ice cream. When you think about why the ice cream was soft the second time, you come up with several possible reasons.

- The ice cream was a different kind, and it is normally softer than the first kind of ice cream.
- The ice cream had not been in the freezer for very long, and might have been placed there after sitting in the car on the way home from the grocery store.
- The temperature in the freezer rose because someone left the door open while eating the remainder of the first ice cream.

Your hardness tests of the ice cream didn't really prove anything because there were too many variable factors in your experiment.

This is an example of an ***uncontrolled experiment***—there was not enough control over the variables to find an explanation for the observation. If you really want to find out what causes the ice cream to be harder or softer at different times, you will need to limit the variables. Remember:

- There should be only one variable factor in each experiment.
- All other factors should be controlled or constant.

How might you design your ice cream experiment to test only one variable? Let's say you want to test the placement of the ice cream in the freezer. That is your one variable. That means you need to control all the other influencing factors.

Here are some things you might do:

- Make sure no one opens the freezer door while your experiment is being conducted. This also means nothing is added or taken out of the freezer. This controls the temperature element and how many items are in the freezer.
- Buy three containers of the same ice cream, all in the same size container. This controls the amount and type of ice cream.
- Place each of the three ice cream containers in the freezer at the same time and make a note of the time you put them into the freezer. You will test the hardness of each at the same time, and the same number of times (say, one time per hour for three hours). This controls the element of time.

Since you are varying the location of the ice cream in the freezer, you will place each container in a different spot. You then conduct the experiment by checking the hardness in each of the three containers on a set schedule and writing your results down each time. As you do the experiment, you are careful not to change the location of any of the three containers.

If the results showed that the ice cream in one of the containers was soft and the ice cream in the other two containers was hard, then the placement of the ice cream in the freezer affects the hardness of the ice cream. If the results were that the ice cream in all the containers was equally hard or soft in all locations, then the placement of the ice cream in the freezer is not the variable that affects the hardness and softness of the ice cream. You will have to design another experiment that has a different factor as a variable, and where the placement of the ice cream in the freezer is a constant. You would continue to test different variables, one at a time, until your question was answered.

Controlled versus Uncontrolled Environments

The environment or circumstances in which an experiment is conducted has an effect on the outcome of a scientific experiment. It is important to control the environmental factors (the variables), or you will not get reliable results or an accurate explanation for your observation or question.

A ***controlled environment*** is an environment where there is only one variable factor (or at most, a few). Most scientists, when they are working to explain an observation they have made, strive to design and conduct experiments in a controlled environment and to limit the variable factors as much as possible. An example of a controlled environment is a science laboratory where the scientist can control the temperature, humidity, and materials that are used.

An ***uncontrolled environment*** is an environment where there are many variable factors or factors that are hard to control. For example, when dealing with experiments in a natural setting, such as a forest, it is impossible to isolate a single variable—there are simply too many environmental factors that can influence the experiment. Good, careful scientific experiments can still be conducted, however, by having scientists do their best to notice and take into account the many varying influences.

Sometimes variables work together, and isolating them doesn't give you an accurate assessment. This has been the case when studying the human body. Scientists have isolated different organs and studied them individually and made conclusions, only to find later that each organ is quite connected to the whole body/mind system. They interact with the system in many complex ways, and controlled systematic study of each organ separately can give an incomplete picture.

It is always important to remember that your observations and/or experiment may have variable factors that are affecting your results. Try to limit the number of variables so you can figure out what you are actually measuring.

Remember that scientific observations must be measurable, repeatable, and objective. Whenever you use the scientific method for a controlled experiment, it should be written clearly so that others can repeat exactly what you did. You need to document your method or procedure precisely! This allows other scientists to verify your results, and it is how scientific theories are proven.

A repeatable experiment doesn't mean that the same results will be observed each time. We do experiments to see what the results will be rather than expecting them to be one way or another. If someone else repeats the experiment exactly and gets different results, you have a new question: Why did the results differ? You'd probably want to repeat the experiment many more times, and have others repeat it, to see if the data begins to show a pattern. If not, perhaps there is another variable influencing the results that hasn't yet been taken into account or controlled. Science is all about asking questions and looking for answers!

Using the Scientific Method

Let's look at an example of the scientific method in action. Pretend that you are washing the dishes in the sink one day, and you notice something about them. This is how the scientific method would be used to make a conclusion about your observation:

1. **Observation:** You have noticed that some objects sink when put in water, and that others float. You decide to test several items to see if you can figure why certain things sink and others don't.
2. **Hypothesis:** There are several variables that you need to identify, so you can test one of them at a time. Some variables that might affect whether an object sinks or floats are shape, size, weight, and density. You decide to test density (which is mass per unit volume). You need to state

your hypothesis quite specifically: "Objects that are the same shape and size, but different densities, will act differently in water. Objects that are less dense will float, and the more dense objects will sink. Wood will float and clay will sink."

3. **Experiment:** Now you need to clearly document your method, identifying how you will control each variable: "I will take a small block of wood and a lump of clay. I will form the clay to be the exact shape and size as the block of wood. I will put each of them in a sink with water in it and observe whether they sink or float. Both are exposed to the exact same conditions in the room and the water. The only difference is the material they are made of."

4. **Results:** Write your results in detail: "When dropped into the water, the block of wood went under the water and then immediately bobbed back to the surface. The clay object sank to the bottom in less than one second, and landed on its side."

National Weather Service observation platform being installed at the lighthouse in Saginaw Bay, Michigan (Image credit: NOAA)

5. **Conclusion:** First review your original observation (that some objects sink and others float), and your hypothesis. Your results indicate that what you predicted did actually happen. But what is your conclusion? Basically, all you can conclude from this is that wood floats and clay sinks. You would like to make the theory that objects that are less dense will float and those that are more dense will sink. As you think about it more, though, you wonder whether this is always true. "Less dense" and "more dense" are vague terms. Less dense than what? What about ships that sail on the ocean? They are metal and quite dense, but they don't sink. Will clay always sink, no matter what shape it's in? There are many more questions raised by this experiment than answers obtained—this is the way science works!

Your experiment is an important start. Information was learned, and now further testing can be done. You see that you need to clarify your hypothesis even more, perhaps adding that those objects that are more dense than water will sink, and those less dense than water will float. But what about the ships that float? You might consider that there is more than one variable that determines whether an object will float. There could be variables that you haven't thought of yet. It's important to remain inquisitive and keep questioning.

Causation and Correlation

When scientists draw conclusions or make statements based on data, they are often looking for a connection or cause-and-effect relationship between factors. However, proving that one thing causes another can be harder than it sounds. Just because two things happen together or under the same circumstances doesn't mean that one caused the other. In fact, science studies are often misunderstood by the public because of the confusion between correlation and causation.

Imagine that you trip on the sidewalk every time you wear a certain pair of shoes. You notice a correlation because the two events—wearing that pair of shoes and tripping on the sidewalk—seem to always happen together. This might lead you to believe that the shoes are the cause of your stumbles. But hold on—that's a big assumption to make. Perhaps you only wear those shoes to walk to your grandmother's house, and the sidewalk near her house is cracked and broken. Or perhaps you only wear those shoes in the rain and the sidewalk is always slippery in the rain, or you only wear those shoes at night, and you are more likely to trip in the dark. On the other hand, maybe the shoes are new and stiff or uncomfortable or too large, and they actually are the cause of all that tripping! However, without a comprehensive experiment, it's hard to prove it—there are just too many other factors involved. You can't say for certain that one thing (the shoes) causes another (tripping), so you can't claim causality. There is not enough evidence to prove it.

"Correlation does not imply causation" is a well-known phrase in science, and it is repeated often with good reason. Many people think correlation and causation are the same thing. If two things always seem to happen together, ask yourself, "Does *A* always lead to *B*?" And then try to answer the question through careful, methodical scientific inquiry and repeated trials.

This is how scientists try to determine cause and effect. When experiment results seem to indicate causation (one thing causing another), scientists look carefully at whether uncontrolled variables might have influenced the results.

Lesson 6

Types of Mixtures

ASSIGNMENT SUMMARY

- ☐ Complete the reading selections.
- ☐ Identify homogeneous and heterogeneous substances.
- ☐ Create a graphic showing different types of matter.
- ☐ List soluble and insoluble substances.
- ☐ Answer questions about temperature and solubility of gases.
- ☐ Identify compounds and mixtures.
- ☐ Lab Investigation: Chocolate Solution
- ☐ Lab Investigation: Mixtures and Solutions
- ☐ Lab Investigation: Saturation of Sugar Solution
- ☐ Optional Activities:
  - Activity A: Soda Shake
  - Activity B: Oil Marble
  - Activity C: Ocean in a Bottle
- ☐ Complete lesson 6 test.

MATERIALS

Lab Investigation: Chocolate Solution

3 small pieces of chocolate (uniform in size) or other candy

Lab Investigation: Mixtures and Solutions

8 glass jars with lids
hot water
spoon
vinegar
rubbing alcohol
solid (powdered) laundry soap
liquid soap (hand, dish, or laundry soap)
flour
ground-up chalk
dirt
cooking oil

Lab Investigation: Saturation of Sugar Solution

granulated sugar
3 glass jars with lids (all the same size)
measuring spoons
cold, warm, and hot water
thermometer

Activity A: Soda Shake

2 unopened cans of soda or seltzer water

Activity B: Oil Marble

rubbing alcohol
cooking oil
eyedropper
blue or green food coloring
small glass or jar
water

Activity C: Ocean in a Bottle

clear plastic bottle with tight-fitting cap
cooking oil
food coloring
water

Learning Objectives

At the end of this lesson you will be able to:

- Demonstrate mixtures, solutions, and saturated solutions.
- Explain the variables that influence solubility.
- Differentiate between compounds and different types of mixtures.

Reading

Read the following sections (found in Reading Selections at the end of this lesson).

- Different Types of Solutions
- Solubility, Concentration, and Saturation
- Solutions, Colloids, and Suspensions
- Separating Mixtures

Assignments

1. Look for homogeneous and heterogeneous substances in your refrigerator or food cupboard. Make a list of what you find.
2. Create a graphic or visual representation to show how matter is either an element, a compound, or a mixture. Also on your graphic, show that a mixture can be either a solution, colloid, or suspension. You might draw a concept map or Venn diagram to show this information (look up what these are if you aren't familiar with them).
3. List three soluble substances and three insoluble substances.
4. Thermal pollution is caused when warm water is released into rivers from power plants and factories, raising the temperature of the river in that location and far downstream. All aquatic life depends on the oxygen that is in solution in the water (known as *dissolved oxygen*). What happens to the dissolved oxygen level if the water is warmed up, and how would this affect the aquatic life?

5. Indicate if the following items are compounds or mixtures, and for the mixtures, indicate which type.

Item	Compound	Mixtures (solution, colloid, or suspension?)
air		
seltzer water		
mayonnaise		
salt		
salad dressing		
bronze		
baking soda		
sweetened iced tea		
vegetable soup		
whipped cream		
strawberry ice cream (with real strawberries throughout)		
mud		
iron oxide (rust)		
butter		

Lab Investigation

Complete all three of the following lab investigations.

- **Lab Investigation: Chocolate Solution**
- **Lab Investigation: Mixtures and Solutions**
- **Lab Investigation: Saturation of Sugar Solution**

All lab investigations are found in the lab manual.

Activities

Complete one or more of the following optional activities to learn more about the topics in this lesson.

- Activity A: Soda Shake
- Activity B: Oil Marble
- Activity C: Ocean in a Bottle

Activity A: Soda Shake

Explore how temperature affects the solubility of gas in this simple but exciting activity. You can do this activity with a partner or by yourself.

Materials

- 2 unopened cans of soda or seltzer water

Procedure

1. Soda (solvent) contains dissolved carbon dioxide (solute). Place one can in the refrigerator for the night and the other in a warm place for the night.
2. The next day, take the two cans outside and shake each one ten times. If you do this by yourself, do one can at a time; if you have a partner, you can shake and open the cans simultaneously.
3. Pointing the can away from you and any nearby objects, open it.
4. Measure how far the soda shoots out of the can. Compare the warm soda to the cold soda. Which soda went the farthest?
5. Pour what's left in each can into two separate glasses. Compare how they look. Which one is more bubbly?
6. Write a summary of your results and explain what you think happened. What do your results indicate about the relationship between the solubility of a gas and the temperature of the liquid solvent?

Activity B: Oil Marble

In this activity, you'll make a "marble" out of cooking oil.

Materials

- rubbing alcohol
- cooking oil
- eyedropper

- blue or green food coloring
- small glass or jar
- water

Procedure

1. Fill the glass about halfway with water and add food coloring. Stir until the color is evenly distributed.
2. Pour in about 2 tablespoons of oil, enough to make a thin layer on the water.
3. Add rubbing alcohol with the eyedropper (or pour it in very slowly, a little at a time).
4. Watch what happens to the shape of the oil. Keep adding alcohol until the oil layer becomes a perfect sphere.

Activity C: Ocean in a Bottle

In this activity, you'll experiment with immiscible liquids.

Materials

- clear plastic bottle with tight-fitting cap
- cooking oil
- food coloring
- water

Procedure

1. Fill the bottle halfway with water and add food coloring to make a deep, rich color.
2. Pour in about a 1-inch layer of oil. Put the cap on tightly.
3. Tip the bottle over on its side. Tip the bottle back and forth, making waves with the water. Watch what happens.
4. Turn the bottle upside down. What happens?
5. Give the bottle one good shake, and then let it stand still. What happens, and how long does it take?
6. Give the bottle ten strong shakes, and let it stand still again. How long does it take this time?
7. Do you think you could ever make a solution with this mixture? Why or why not?

Test

1. List the three types of mixtures and explain the similarities and differences between them.
2. Define solute and solvent.
3. Give an example of a homogeneous mixture and a heterogeneous mixture, and explain the difference between them.
4. What are immiscible liquids? How do they differ from miscible liquids? Give an example of each.
5. Explain how temperature influences the solubility of gases in liquids.

Learning Checklist

Use this learning checklist to track how your skills are developing over time and identify skills that need more work.

SKILLS	Developing	Consistent	Competent	Notes
Identify similarities and differences between types of mixtures				
Differentiate between homogeneous and heterogeneous substances				
Differentiate between miscible and immiscible liquids				
Use scientific terminology in writing lab results and conclusions				
Record observations with accuracy and clear language				

FOR ENROLLED STUDENTS

Submit lessons 5 and 6 to your Oak Meadow teacher. Make sure to include the conclusions from your lab investigations. If you chose to complete any activities, please include information about them as well. Let your teacher know if you made any adjustments to the assignment or the workload.

Reading Selections

Different Types of Solutions

Have you ever mixed sugar into a cup of tea, or salt into warm water? When a substance ***dissolves*** in a liquid, it seems to disappear. But you know it is still there because if you were to taste the cup of tea or water, you would taste the sugar or salt.

The mixture of salt and water is an example of a ***solution***. Solutions are a type of mixture in which one substance dissolves in another substance. They do not make a compound because there are different types of molecules—the components have not chemically bonded.

Solutions can be mixtures of solids, liquids, or gases. The substance that dissolves is called the ***solute***. The substance in which the solute dissolves is called the ***solvent***. In the example above, the salt or sugar is the solute and the water is the solvent. Solvents can be water or any other substance that dissolves a solute. The solvent is the part of the solution that is in the greater quantity, and the solute is the smaller portion of the solution.

Liquid solutions are formed when solids, liquids, or gases dissolve in a liquid. When a solid dissolves in a liquid (such as sugar dissolving in tea), it is called a ***solid-liquid solution***. When a liquid is dissolved in a solvent, the result is a ***liquid-liquid solution***. For instance, alcohol (solute) dissolves in water (solvent). However, if the amount of alcohol is greater than the amount of water, the water becomes the solute, and the alcohol is the solvent. A gas can also dissolve in a liquid to form a ***gas-liquid solution***, such as seltzer or soda water. Carbon dioxide (solute) is dissolved in water (solvent) to make soda water. This is the carbonation that makes soda fizz. In nature, oxygen and carbon dioxide from the air dissolve in fresh water and seawater. Fish and other aquatic animals depend on that dissolved oxygen. Aquatic plants depend on dissolved carbon dioxide, and help to add oxygen to the water through photosynthesis.

Liquid solutions are always clear. They can be colored (as tea or coffee are), but there are no floating particles in them. This is how you can determine the difference between a mixture that is a solution and a mixture that is not a solution.

Liquids that can be mixed together to form a solution are called ***miscible liquids***. Liquids that do not dissolve when mixed together are called ***immiscible liquids***. Oil and water are immiscible because they do not form a solution when mixed—one does not dissolve into the other.

Balsamic vinegar and oil are immiscible liquids because they do not dissolve into a solution when mixed together. (Image credit: Ewan Munro)

Gas solutions are formed when solids, liquids, or gases dissolve in a gas. An example of a solid dissolving in a gas solution is when iodine (solute) dissolves in air (solvent) to make iodine vapor. When water (solute) dissolves in air (solvent) through the process of evaporation to make water vapor, this is an instance where liquid dissolves into a gas solution. Gas dissolves in a gas to make a solution when nitrogen, oxygen, and other gases mix together to form the air that we breathe. Air is a solution (a mixture, not a compound) because each type of gas in air keeps its own properties.

Solid solutions are formed when solids, liquids, or gases dissolve in a solid. Many metal alloys (such as steel, sterling silver, brass, and bronze) are mixtures of solids forming solid solutions. The metals are dissolved into each other at high temperatures, when the metals are in a liquid state, and then they revert to their solid state once they have cooled. Although it may look like a new substance, the elements retain their original chemical properties and they can be separated again by physical means (melting).

Solubility, Concentration, and Saturation

Some substances dissolve completely in another substance, such as salt or sugar dissolving in water to make a solution. This means sugar and salt are ***soluble*** in water. Some substances are not soluble in water. For example, if you put some sand in water, it would not dissolve. Sand is ***insoluble*** in water, so you can make a mixture of sand and water but you cannot make a solution.

What is happening to the molecules in a mixture that is a solution? The solute is broken down by the solvent into pieces the size of molecules. That is why liquid solutions are transparent. The particles of the solute are so small that you can't see them, and all you can see is the solvent. When you make a solution by dissolving salt in water, the water breaks the salt down into pieces the size of molecules.

Solutions are always ***homogeneous***, meaning that the solution is consistent or uniform throughout. The solution is mixed very well so each part of the liquid is the same as every other part. Mixtures can be homogeneous or ***heterogeneous*** (not the same throughout), but to be a solution, the mixture must be homogeneous.

To understand the term *homogeneous*, think of mixing paints. When you first start to mix blue and yellow paints you can see bits of yellow paint, bits of blue paint, and bits of green paint. As you keep mixing though, eventually the paint becomes thoroughly mixed and the same throughout. Now all you see is green, and the mixture is now homogeneous. The blue and yellow have been mixed up completely to make the same green throughout.

If you dissolve one teaspoon of sugar or honey in a cup of tea, your drink becomes somewhat sweet. If it isn't sweet enough for your taste, you add more sugar or honey to make it sweeter. As you add more sweetener, your solution becomes more ***concentrated***. A concentrated solution has a large amount of solute dissolved in it. A ***dilute*** solution has a small amount of solute dissolved in it.

If you were to keep adding more and more sugar to the tea, would there ever be a point when you had added so much sugar that it could no longer dissolve? Yes! When a solution is so concentrated that it cannot dissolve any more of the solute it is ***saturated***. A solution that can still dissolve solute is called ***unsaturated***.

Temperature can affect the saturation point of a solution. Usually liquid solutions that are warm or hot can dissolve more of the solute than solvents that are cool or cold. The amount of a solute that can be dissolved in a solvent is called its ***solubility***. The solubility of a solid generally goes up with the temperature of the solvent. However, the opposite is true when you try to dissolve a gas in water. The solubility of a gas in liquid increases as the temperature of the liquid goes down.

Solutions, Colloids, and Suspensions

There are three main types of mixtures. The size of the particles determines what type of mixture it is. In a solution, the particles are broken down or dissolved by the solvent into the size of molecules. The molecules are evenly mixed together so that the substance is homogeneous and clear.

In mixtures that are not solutions, the substances break down into smaller pieces but not to the size of molecules. Think of mixing clay with water. You can stir the clay around and around until you get a liquid. The clay has been broken down into smaller pieces than you started with, but the liquid is not clear. You can see little pieces of clay floating around. The clay has not been broken down into pieces the size of molecules and the mixture is not a solution.

In a ***suspension***, you can easily see particles of the components floating around. When you mix dirt with water, or shake up salad dressing, or see dust particles floating in the air, you are looking at a suspension. A pot of vegetable soup is another example of a suspension. There are particles of one thing (vegetables) suspended in another (broth), so the substance is heterogeneous, not homogeneous. If the suspension is allowed to rest, the particles will either float to the top or sink to the bottom.

In a ***colloid***, a substance is broken down into microscopic particles so it can mix well with another substance, but the particles are insoluble. This means they won't dissolve but they remain suspended. Whipped cream and Jell-O are examples of colloids.

How can you tell the difference between a colloid and a solution or suspension? One difference between a colloid and a solution is that a colloid involves insoluble materials and a solution involves soluble materials; another difference is that it is hard to see through a colloidal mixture but a solution is clear. A colloid involves microscopic particles and a suspension involves particles that can be seen without a microscope. A suspension is heterogeneous and will "settle" into its component parts and a colloid is often homogeneous and will not separate into its parts.

Separating Mixtures

Compounds are the result of chemical reactions causing different elements or molecules to bond. Compounds form new substances that have different properties than the original components, and they cannot be separated except by chemical means—you have to actually break the chemical bond. Once different elements or molecules are chemically joined into a compound, every molecule of that compound is identical. The different elements and molecules that went into the compound have been transformed into something new.

Mixtures are different than compounds because when different substances are mixed together, the molecules in the mixture are not all alike. This means they can be physically separated again. Mixtures do not have chemical formulas, nor do they have definite chemical compositions, because they consist of so many different molecules. Since the component molecules still retain their original properties, the substances in a mixture can be separated by physical means.

Here's an example: Imagine you were to prepare a mixture of salt and pepper. The properties of the salt and pepper are not changed by being next to each other in the mixture. You could actually separate them again—if you had a lot of time and patience! If you picked out a grain of salt and a grain of pepper and ate them, they would still taste just like they did before you mixed them. To make a mixture of salt and pepper, you don't need to use a specific amount of salt and a specific amount of pepper. You can use however much of each as you like. Some of the molecules in your mixture will be salt molecules and some will be pepper molecules. The molecules are not all alike so mixing them together did not create a compound.

Compounds can only be separated by chemical means, but mixtures can be separated by physical means. How a mixture can be separated depends on its properties. The size of the particles in the mixture, its density, or its boiling point are properties that affect how something can be separated into its component parts. Separation techniques include filtering, flotation and sedimentation (particles float to the top or sink to the bottom), evaporation, using a magnet, and using a strong rotational force, like a centrifuge. There are many reasons for wanting to separate a mixture into its components. For instance, taking the salt out of seawater transforms it into drinkable water. Separating a blood sample into its parts can help doctors determine a person's health.

Lesson 17/18

Scientific Inquiry: Energy in Food Systems

Lesson Objectives

- Design an original project related to energy use in food systems.
- Create a scientifically accurate informational graphic.
- Reflect on project design and learning experience.

For your final assignment in the first semester of this course, you will design a project based on an area of interest related to food. The goal of this lesson is to give you an opportunity to explore how energy is used in the production of food. You will look at how energy changes forms during the food production process, where energy escapes in an unusable form, and how this energy loss can be minimized or recaptured for practical use.

Refer to the lab manual for full instructions.

- **Scientific Inquiry: Energy in Food Systems**

You will have two weeks to complete this project. The instructions in the lab manual will give you a framework to help you organize your time.

If you haven't yet worked with someone else on a project, consider collaborating with one or more partners. This will allow you to experiment with new ways of working, and to generate a design that is based on multiple perspectives. (If you are enrolled in Oak Meadow School, your Oak Meadow teacher can help you find a partner.)

After you have completed your project, complete the self-assessment found in the lab manual.

ASSIGNMENT SUMMARY

- ☐ Research an element of energy use in food production.
- ☐ Design a project to convey your findings.
- ☐ Discuss the project with others to refine the design.
- ☐ Create a scientifically accurate graphic related to energy use in food production.
- ☐ Share the project with others.
- ☐ Reflect on project design and learning experience.
- ☐ Complete semester 1 review.

Semester 1 Review

The following review gives an overview of the topics you have studied in the first semester. Read each question and then ask yourself if you fully understand the concept and could answer the question orally without looking at the book. Alternately, you might like to have someone ask you each question and answer it aloud, or you may prefer to write down your answers. Make a note of any questions you can't answer, and take some time to go back and review the material to refresh your memory.

Semester 1 Review

1. What did both Galileo and Copernicus propose about the universe?
2. How many centimeters are there in a kilometer?
3. What is the difference between a milliliter and a cubic centimeter?
4. Describe the steps of the scientific method.
5. What is the difference between weight and mass?
6. If you take a cup of water vapor, and put it into a 2-cup container, what happens to the pressure?
7. What is the difference between a mixture, a compound, and a solution?
8. Describe the three ways that heat is transferred.
9. Give an example each of the following types of forces: applied force, normal force, action-at-a-distance force.
10. What is your weight in kilograms (kg)?
11. Explain Newton's First Law of Motion.
12. What is the difference between velocity and acceleration?
13. What is Newton's Third Law? Describe an example.
14. List four types of energy.
15. What are the two laws of thermodynamics?
16. What is work? What is power?
17. What is a turbine?
18. After learning about all these different forms of energy, if you could build your dream home, what type(s) of energy would you use in it?

FOR ENROLLED STUDENTS

Feel free to contact your teacher if you have any questions about your project ideas or design, or how to share your project.

When you have completed your project and reflection, share them with your Oak Meadow teacher. Also, let your teacher know how you did on the semester 1 review; you don't have to send your answers to your teacher, just write a note about the review process.

Lesson 23 Sight and Lenses

ASSIGNMENT SUMMARY

- ☐ Complete the reading selections.
- ☐ Explain the difference between convex and concave shapes.
- ☐ Identify and draw one type of lens.
- ☐ Complete demonstrations regarding perspective and focus.
- ☐ Demonstrate and explain depth perception.
- ☐ Describe observations of double image.
- ☐ Lab Investigation: Image Projection
- ☐ Optional Activities:

  Activity A: Anatomy of the Eye

  Activity B: Focusing a Light Beam
- ☐ Complete lesson 23 test.

MATERIALS

metal spoon
eyeglasses or magnifying glass
clear glass jar
clay or beeswax
pencil

Lab Investigation: Image Projection

magnifying glass (convex lens)
stiff white paper or cardboard
candle
matches or lighter
clay or beeswax
metric tape measure

Activity B: Focusing a Light Beam

magnifying glass (convex lens)
white paper
metric measuring tape
container of water
sunglasses
block of wood (optional)

Learning Objectives

At the end of this lesson you will be able to:

- Illustrate light refraction through convex and concave lenses.
- Demonstrate the correlation between focal length and distance from object to lens.
- Explain the difference between a converging and a diverging lens.

Reading

Read the following sections (found in Reading Selections at the end of this lesson).

- Lenses
- Converging and Diverging Light Rays
- Creating Images with the Eye
- How Do Eyeglasses Work?
- How a Camera "Sees"

You might find the videos included on the curriculum resource page very useful in understanding these concepts.

Assignments

1. Take a shiny soup spoon and look at your reflection in the side that holds soup. What does it look like? Now turn the spoon over and look at your reflection in the back of it. What does it look like now? Describe what you observed, using the terms *concave* and *convex*.
2. Find in your house (or among your friends) either a pair of glasses or a magnifying glass. Examine it closely. What kind of lens is it? Draw a sketch of it and name the type of lens.
3. Complete the following exercises.
    a. Stand and look at a small object (for example, a candle, a small bowl, or a knot on a tree). Keep looking at the object and place your hand over one eye. Observe whether the object stayed in the same place or moved. Look at the object again with both eyes. Now put your hand on the other eye. What happened? Which eye kept the image in the same place? Which eye made the object move? (The eye that kept it in the same place is your dominant eye.)
    b. Hold the first two fingers of each hand horizontally, touching tip to tip four to six inches away from your eyes. Focus your eyes on something in the distance beyond your fingertips. Keeping your focus in the distance, slowly separate the fingertips about a half inch. What do you see "floating" between your fingertips?
4. Put a piece of paper on a table in front of you and make a dot on it with a pencil. Touch the dot with the tip of the pencil with both eyes open. Then cover one eye with your hand and try touch the dot with the tip of the pencil again. Explain what happens, using the term *depth perception*.
5. Fill a clear, smooth, round jar with water. Stand a pencil vertically about a foot behind it on a table (use some modeling clay or beeswax to hold it up). Now look at the pencil through the jar. How many pencils do you see? What happens to its size? Now close one eye. Which pencil disappears? Close the other eye. Which pencil disappears? Taking into account the convex shape

of the glass, why do you think this is happening? (It's okay if you aren't sure—just try to explain it based on what you know.)

Lab Investigation

Complete the following lab investigation (found in the lab manual).

- **Lab Investigation: Image Projection**

Activities

These activities are optional.

- Activity A: Anatomy of the Eye
- Activity B: Focusing a Light Beam

Activity A: Anatomy of the Eye

Go into a darkened room and look in a mirror at your pupils (the black center of your eye). Look at the size of the pupil. Now turn a light on or go into a bright room and look in a mirror at your pupils. Describe the difference in the size of your pupils in the darkened room and in the lightened room.

Now go into a darkened room with a flashlight, and cover one eye with your hand. Hold the flashlight to the side of your forehead so the light rays are shining across your other eye from the side. Now look straight ahead, and move the flashlight slowly back from your forehead. Do this several times. After a while, you will see a treelike branched image in front of you. These are very tiny blood vessels on your retina that are throwing shadows on the optic nerve behind it. Your brain sees them as an image floating in front of you.

Activity B: Focusing a Light Beam

You will need a sunny day to conduct this activity. **Adult supervision is required.**

Materials

- magnifying glass (convex lens)
- white paper
- metric measuring tape
- container of water
- sunglasses
- block of wood (optional)

Procedure

1. Use the magnifying glass to look at the words in a book. Move the lens until you have the text in focus. Measure the length between the lens and the book. This is the focal length for magnifying the text. Write down the measurement: ________________

2. Go outside on a sunny day and put the piece of paper on a patch of asphalt, concrete, or a large flat rock.
3. Make sure there is no other combustible material or debris in the vicinity. Place your container of water nearby.
4. Put on your sunglasses to protect your eyes and make it easier to focus on the bright light.
5. Hold the magnifying glass close to the paper with rays of sunlight shining through it and projecting onto the paper. Safety note: Do not focus the beam of light onto your skin or clothing as it can cause serious burns.
6. Tilt the magnifying glass side to side and move it closer to or away from the paper until the most concentrated ray of light is shining on the paper. This is the focal point for the magnifying glass to concentrate a beam of light.
7. Measure the distance between the focal point and magnifying glass. This is the focal length for concentrating a beam of light. Write down the measurement: ____________________
8. With adult supervision, focus the beam of light onto the paper again (make sure there is no other flammable material nearby). Hold the magnifying glass in place long enough for the paper to blacken and begin to burn.
9. Douse the paper with water to put out the smoldering flames.
10. Optional further study: Use the lens to focus a beam of light and burn your name or an image into a piece of wood. Notice if it takes longer for the wood to begin smoldering. If so, why do you think that is?

Test

1. Draw a picture of a convex and a concave lens, and use arrows to show what happens to light waves when they hit each type of lens. Be sure to label your drawing to clarify what it shows.
2. What is the difference between the focal point and the focal length?
3. What is the difference between a converging lens and a diverging lens?
4. What type of lens is in the eyeball?

Learning Checklist

Use this learning checklist to track how your skills are developing over time and identify skills that need more work.

SKILLS	Developing	Consistent	Competent	Notes
Differentiate between concave and convex lenses				
Illustrate refraction of light through a convex lens				
Illustrate refraction of light through a concave lens				
Explain the difference between a converging lens and a diverging lens				
Identify correlation between focal length and distance from object to lens				

Reading Selections

Lenses

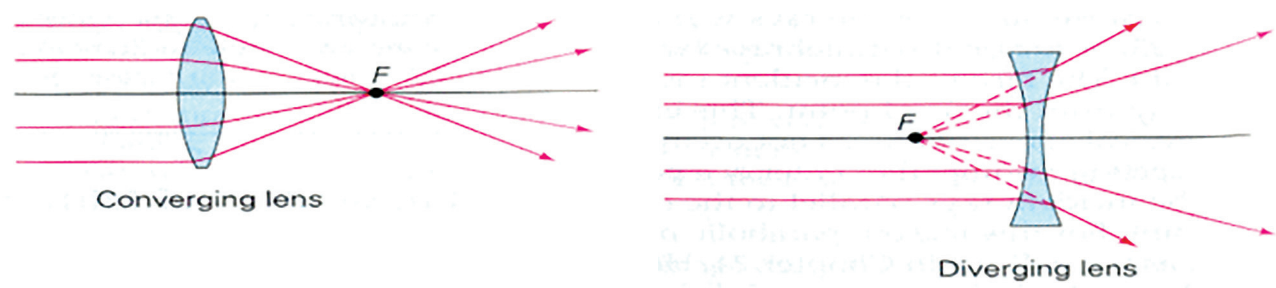
Have you ever tried to light a piece of paper on fire by using a magnifying glass? Do you or any of your family members have glasses? Have you ever wondered how a camera works? All of these things use ***lenses***, curved pieces of transparent glass that bend light rays in a specific way. We use lenses all the time. Telescopes, binoculars, and microscopes all use lenses. Your eyes are a type of lens too.

Light rays refract when they pass from one medium to another. When light rays pass from air into glass, they bend. Lenses are used to take advantage of this tendency to bend light rays in very specific ways.

Any regular piece of glass has two sides, a front and a back. When the two sides are parallel to each other (both are flat), the refraction is minimized and the light will pass through the glass without changing direction very much. However, if one or both sides of the glass are curved, light will bend as it passes through one side of the curved glass and then bend again as it passes through the other side of the curved glass.

There are two main types of lenses. A ***converging lens*** bends light rays toward one another, so they converge on a point. A converging lens uses a ***convex*** curve, which means it bulges outward. (One way to remember this is by looking at the first four letters: *converge* and *convex* both begin with the letters *conv*.) The lens is thicker in the middle than on the edges.

A ***diverging lens*** bends the light rays away from each other, so they diverge from a common starting point. A diverging lens uses a ***concave*** curve, which means it has a hollow or caved-in center. (One way to remember this is that *concave* is hollow like a *cave*.) The lens is thicker on the edges than in the middle. There are other types of lenses but all are variations of convex and concave curves.

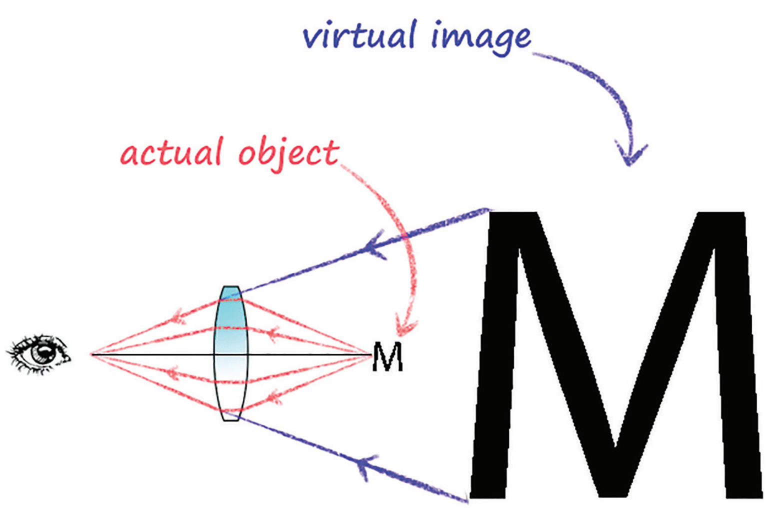


Convex lenses gather or converge light rays and concave lenses spread or diverge light rays. This diagram shows a double convex lens (both sides curve outward) and a double concave lens (both sides curve inward). (Image credit: TAKSreview)

Converging and Diverging Light Rays

Convex or outward-curving lenses are the most common type of lens. When the light enters a convex lens, the bulging shape of the lens bends them inward toward a center ***focal point***. The focal point is where an image will be in focus and will appear clear and sharp. Since the light waves are moving from a faster to a slower medium, they bend toward the normal line (remember, the normal line is the line drawn perpendicular to any point on the curve), causing the light ray to converge. Upon exiting the lens, the light moves from a slower to faster medium, and bends away from the normal line. Both bends cause the light ray to converge.

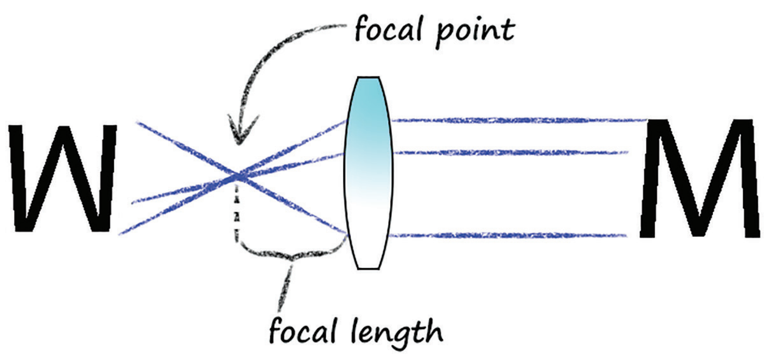
The position of the focal point varies with the shape and size of the lens. The distance between the lens and the focal point is called the ***focal length***. Look at the diagram below.



If your eye is at the focal point of a convex lens, the image you would see would be in focus, and it would appear larger than the real object. Your eye pictures the image as if the lens wasn't there. This is the same thing that happens any time light is refracted—we see an image that is different than the actual object. The larger *M* illustrates the image that your eyes would see.

This type of lens—the double convex lens—is used in magnifying glasses. Note on the diagram that there is one place where the light ray doesn't get refracted—light waves traveling along the normal line.

If you trace the refracted lines beyond the focal point length, you'll see they cross. The lines coming from the top will now be at the bottom and vice versa. This means that if the light is focused beyond the focal length, the object will appear smaller and inverted (upside down and backward). As the object is moved closer to the front of the lens, the image will appear larger, and still inverted. When the object is placed at a distance of twice the focal length, the object and the inverted image will appear the same size. When the object is moved closer to the front of the lens (at a distance of less than twice the focal length), the object will appear magnified and inverted. Microscopes and telescopes use multiple lenses to correct this inversion so that the object being viewed looks right side up.



When light waves refract through a convex lens and focus beyond the focal length, the object appears inverted and smaller.

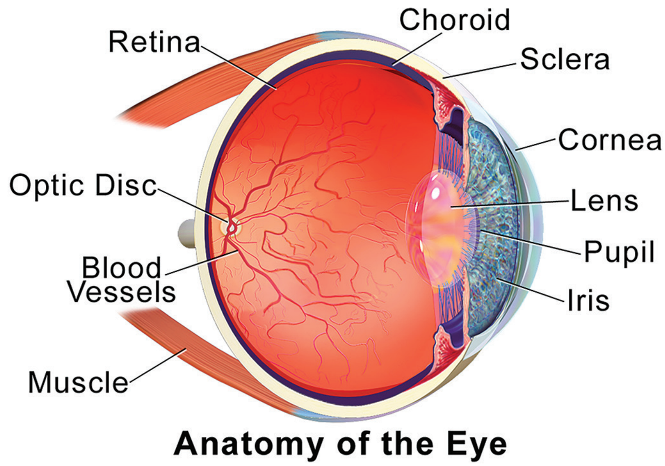
A common way to remember how light bends is with these initials:

FST: when light is going from a **f**ast speed (a less dense medium) to a **s**low speed (a more dense medium), it is bent **t**oward the normal line.

SFA: when light is going from a **s**low speed to a **f**aster speed, it is bent **a**way from the normal line.

Now look again at the diagram of the diverging lens with the concave surface. This lens works differently. Notice the focal point is in front of the lens, and not behind it as it is with the converging lens. When looking at an object through a concave lens, the light reflecting off the object is bent twice as it enters and then exits the lens (first bending toward the normal line when moving from the air through the lens, and then bending away from the normal line when moving from the lens into the air). When your eye detects that light, it traces back those diverged rays to find the focal point, which tends to bring far away objects into focus.

Creating Images with the Eye



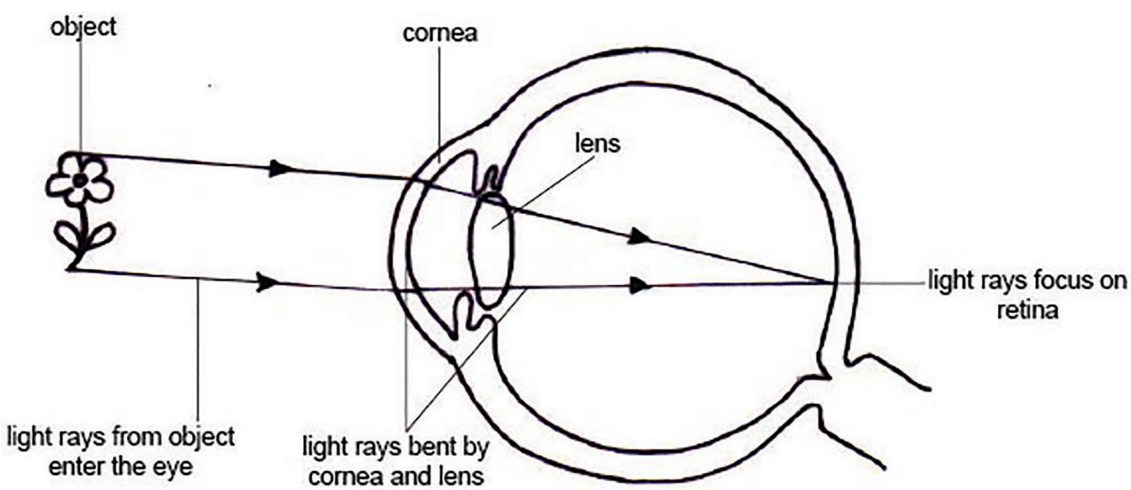
The lens of the eye is convex. (Image credit: BruceBlaus)

Eyes have lenses that help us see. Look at the diagram of the eye. The main parts of an eye are the cornea, pupil, iris, lens, and retina.

The cornea is a clear material at the front of the eye that protects your eye. The pupil is the opening into the eye. It is where light enters the eye and allows you to see things. The iris is the colored part of the eye that surrounds the pupil. It contains muscles that surround the pupil and expand and contract the pupil to regulate the amount of light that is allowed to enter the eye. When there is a lot of light, the pupil contracts into a small hole that lets in just a little of the light. When it is dark and you need more light in order to be able to see, the iris causes the pupil to open up to allow more light in. The lens of the eye focuses the light rays to allow you to see images.

In the eye, the shape of the lens changes in order to focus the light so you can see both near and distant objects clearly. Normally the muscles of the eye can compress the lens enough so that objects as close as about ten inches away can be seen clearly. The lens changes so that the light can be focused onto the retina in the back of the eye. The retina changes the light rays into nerve signals, which are sent to your brain through the optic nerve. These signals are interpreted by your brain and allow you to understand what you are seeing.

The lens is not the only part of the eye that refracts light. Two-thirds of the light that enters our eyes is refracted by the cornea. The shape of our eyeball also has an effect on just where the image converges. These three parts—the lens, cornea, and eyeball—have to be the right shape and in the right proportion for us to be able to see clearly.



Light rays are refracted by the eye's lens so an image converges on the retina. (Image credit: Ruth Lawson)

Having two eyes is the reason we are able to see how far away or how close an object is. Two eyes give us perspective or ***depth perception***. Each eye looks at the object from slightly different angles and casts an image of the object on the retina. The optic nerve makes a composite of the two images, allowing the brain to determine the distance fairly accurately.

Your eyes use a convex lens to make images on your retina, but the image produced is upside down. Of course, we don't see the world as upside down, so what happens to the upside-down image made on the retina? The image is transferred through the optic nerve and is interpreted by the brain. The brain understands how to turn the image over so that it looks like the real world.

How Do Eyeglasses Work?

Our eye has a lens that changes shape to accommodate objects both near and far. It's not only the lens that refracts light, but also the cornea. The shape of our eyeball helps determine where the image converges. The shape and proportion of three structures—the lens, cornea, and eyeball—help us see clearly.

People who need glasses have lenses in their eyes that need some help. Since the lens is the only part that can change shape, it must accommodate for any differences in the cornea or eyeball. Especially as we age, our eye lenses are often no longer able to change shape to focus a sharp and clear image on the retina. Some people are born with eyes that don't focus quite clearly enough.

People who are ***nearsighted*** are able to clearly see objects that are close to them, but objects that are at a distance appear fuzzy and out of focus to them. As the light rays pass through the lens of a nearsighted person, the focal point is in front of the retina instead of on it. Using a diverging lens with the proper curve or focal length, eyeglasses can correct the light images so that the focal point is correct and the image will be clear. The light rays are diverged before entering the eye. Thus, when they enter the eye, they are farther apart, so when the lens converges that image in the eye, it is farther back, right on the retina.

People who are ***farsighted*** are able to clearly see objects that are far away from them, but objects that are close to them appear fuzzy and out of focus. As the light rays pass through the lens of a farsighted person, the focal point is behind the retina instead of on it. This means the light rays strike the retina before they have had a chance to cross at the focal point. This can be corrected by a converging lens of the correct curvature. The convex converging lens brings the light rays closer together before they reach the eye, which causes the eye to converge the image farther forward, on the retina.

How a Camera "Sees"

A camera works in much the same way as your eyes work. Light passing through the lens is converged so that the image is focused on the film, just as the eye receives an image on the retina. Cameras are either automatic-focus cameras (where you don't have to focus anything—the camera does it for you) or manual-focus cameras (where you move the lens in and out until you get a clear and sharp image for the film to capture).

When light passes through the lens of a camera, the amount of light that is allowed to get to the film is controlled by the aperture. The aperture is just like the pupil of your eye; it is the opening through which the light passes. Opening the aperture lets in more light and closing the aperture lets in less light. Just as your eyes contract the pupil in bright light and open it wide in dim light, photographers close the aperture on very bright days to keep the picture from being too bright and open the aperture on dark days in order to let in more light.

After you have focused the lens and figured out what aperture setting you want (how much light you want to let in), you push a button and take a picture. When you push the button, a piece of metal opens quickly and lets the light rays into the inside of the camera where the film is located, exposing the film to light. Photographic film is light-sensitive and when the light strikes the film, it captures the real image on the film. The image on the film is inverted; it is upside down and turned around. This is similar to how your eye works.

When film is further processed, the inverted image is projected through another lens onto light-sensitive paper. When it is projected through this last lens, the image is again inverted, finally becoming "right-side up" and giving an accurate representation of the object. Digital cameras don't use film, but they still have a lens and an aperture. The light is detected and stored electronically on a silicon chip instead of film. The information is then changed from analog to digital information by a computer in the camera.

Johannes Kepler (1571–1630)
German Astronomer

Thirty years after Copernicus's death, Johannes Kepler was born in Weil, Germany. He was the first astronomer to openly support Copernicus's heliocentric theory (that the sun is the center of the solar system and the planets revolve around it) and discovered the three laws of planetary motion. Without Kepler's work, Newton would not have been able to formulate his theory of gravitation. Kepler suggested an improvement over Galileo's telescopes, and founded modern optics by suggesting the ray theory of light to explain vision.

Appendix

Finding Reputable Sources

Whether you use print or online resources when you conduct research, it is important that you use *reputable* (trustworthy or reliable) sources. Reputable sources undergo extensive review to ensure that the information they provide is accurate. Nonfiction books, encyclopedias, news magazines, professional journals, and newspapers are generally considered reputable. Reputable websites include sites that are connected to reputable print and media sources, such as *newyorktimes.com*, *nationalgeographic.com*, or *cnn.com*. In general, websites that end in *.org*, *.edu*, or *.gov* are considered reputable.

Wikipedia.com is not considered a reputable source by academic standards because anyone can go into Wikipedia and change the entries without having to prove the information is correct. Wikipedia is a good website for getting a general overview of your topic, and Wikipedia writers often provide a list of the sources they use to write their articles. However, you should never quote directly from Wikipedia, and you should always double check anything you learn on Wikipedia with a reputable source.

You will find a resource page for this course on the Oak Meadow website (www.oakmeadow.com/curriculum-links/). This page will include a variety of online sources that you might find useful as you are studying physical science. These links are meant to help you in your research, not take the place of it—consider them a starting point.

Citing Your Sources

When writing a research report, you should use at least three sources. Of course, you are welcome to use more! You can use books, magazines, encyclopedias, newspapers, or the internet to find information. Even though doing research on the internet gives you quick access to a wide variety of sources, it's important to use print sources as well. Information in print is likely to be very carefully checked before publication while information on the internet can appear and be altered by anyone with computer know-how.

Even if you don't quote directly from a source, it's important to keep a list of your sources so that you (or your readers) can go back to them later to check your facts or gain more information. These sources are listed on a Works Cited page that goes at the end of your paper.

Oak Meadow uses MLA (Modern Language Association) guidelines for citing sources. You'll find them below. Please notice the punctuation in your citations. These rules may seem really complicated at first, but it's a good idea to get in the habit of using the MLA format now since you'll probably have to use it in high school and all through college as well.

List everything in alphabetical order on your works cited page (alphabetized by the first word listed in each entry, with the exception of entries beginning with *The*, *A*, and *An*,which are alphabetized according to the second word).

To cite print sources in MLA format:

Author last name, first name. *Title*. Publishing company, year.

Here is an example:

Stevenson, Robert Louis. *Treasure Island*. Dover, 1993.

When citing online sources, use this format:

Author last name, first name (if known). "Title of article." *Website*, publication date (if known), URL (without http://).

Here is an example:

Bradbury, Lorna. "25 Classic Novels for Teenagers." *The Telegraph*, 5 April 2012, www.telegraph.co.uk/culture/books/bookreviews/9189047/25-classic-novels-for-teenagers.html.

To cite an online video clip (such as YouTube):

"Title of video." *Website*, uploaded by (if known), date of upload (if known), URL.

Here is an example:

"The Most Astounding Fact—Neil deGrasse Tyson." *YouTube*, uploaded by Max Schlickenmeyer, 2 March 2012, www.youtube.com/watch?v=9D05ej8u-gU.

Note: If the author's name is different from the uploader, put the author's name before the title.

To cite a film:

Film Title. Directed by First name Last name, performance(s) by First name Last name, Distributor, year of release.

Here's an example:

Harry Potter and the Sorcerer's Stone. Directed by Chris Columbus, performances by Daniel Radcliffe, Emma Watson, Rupert Grint, Alan Rickman, Robbie Coltrane, and Tom Felton, Warner Brothers, 2001.

Remember, all your sources are included on one works cited page, and are put in alphabetical order. If you are writing by hand, wherever you see italics, underline the words instead.

Plagiarism

Plagiarism happens when you use the words of others without giving them credit. This is something that can happen accidentally, but it is something writers have to be careful about constantly.

The best way to avoid accidental plagiarism is to take good notes. One of the ways that plagiarism often happens is that students write notes *verbatim* (word for word) from a source, and then forget those words are not their own. When they sit down to write, they use their notes, and suddenly they are caught plagiarizing. When you take notes verbatim, you always need to use quotation marks and cite your source. Whenever possible, all notes should be in your own words. In addition, if you use someone else's ideas, credit must be given.

The widespread use of the internet has caused plagiarism to become a much more serious problem because it is so easy to copy text and paste it into your own paper. Many schools have found that students are not even clear on what constitutes plagiarism and what does not. For instance, what if you are writing a research paper, using facts and details from an array of sources? Can you safely repeat what was printed in an encyclopedia?

Facts cannot be "owned," therefore they can be stated by anyone. There may not be too many ways to state a fact, for example "Astronaut Neil Armstrong landed on the moon in 1969." Stating this fact in your own words does not constitute plagiarism. But if you have found a book that discusses the moon landing, and you use one or more sentences from that book word for word, without citing your source, that is plagiarism.

It's simple: If you use someone else's words, let your reader know. Put the words in quotation marks, and include a citation both in the text and on the works cited page. This makes it clear you are not claiming to have written those words yourself.

Materials List

Lesson	Lab or Activity	Materials
1	**General assignments**	metric ruler or tape measure
2	**Lab Investigation: Sink or Float?**	clay (about the size of a baseball) bucket of water
3	**Lab Investigation: States of Matter**	long-neck glass bottle with a small opening ice cube hot water
5	**Lab Investigation: Oxidation and Combustion**	glass jar candle (small enough to fit inside the jar) matches or lighter toothpick butter knife metric ruler or tape measure clock, watch, or stopwatch
6	**Lab Investigation: Chocolate Solution**	3 small pieces of chocolate (uniform in size) or other candy

Lesson	Lab or Activity	Materials
6	**Lab Investigation: Mixtures and Solutions**	8 glass jars with lids hot water spoon Small amounts of the following: vinegar rubbing alcohol solid (powdered) laundry soap liquid soap (hand, dish, or laundry soap) flour ground-up chalk dirt cooking oil
	Lab Investigation: Saturation of Sugar Solution	granulated sugar 3 glass jars with lids (all the same size) measuring spoons cold, warm, and hot water thermometer
	Activity A: Soda Shake	2 unopened cans of soda or seltzer water
	Activity B: Oil Marble	rubbing alcohol cooking oil eyedropper blue or green food coloring small glass or jar water
	Activity C: Ocean in a Bottle	clear plastic bottle with tight-fitting cap cooking oil food coloring water
7	**Lab Investigation: Insulators and Conductors**	ice cubes 2 metal baking pans 2 ceramic plates 2 paper towels
	Lab Investigation: Thermal Expansion and Contraction of a Gas	glass bottle (such as a soda or juice bottle) cooking pot small balloon (the kind you inflate)

Lesson	Lab or Activity	Materials
7	**Lab Investigation: Water Depth and Pressure**	small can (such as a soup can) large can (such as a large juice can) can opener hammer nail ruler
8	**General assignments**	ruler protractor graph paper
9	**General assignments**	broom pencil with an eraser ruler
	Lab Investigation: Mass and Gravitational Force	2 candles of the same size and weight cork metal knitting needle large darning needle 2 drinking glasses of the same size matches baking sheet aluminum foil
	Lab Investigation: Gravity, Buoyancy, and Weight	sturdy rubber band paper clip ruler bucket or pot of water clay (a ball the size of a large walnut)
	Lab Investigation: Center of Gravity of Irregular Shapes	cardboard scissors string paper clip pushpin bulletin board
	Activity: Gravity on an Incline	aluminum can 2 quarters tape board several books

Lesson	Lab or Activity	Materials
10	**General assignments**	2 eggs, 1 hard-boiled and 1 raw (both in their shells) 21 coins of the same type wooden block paper ruler
	Lab Investigation: Inertia	drinking glass aluminum pie plate empty toilet paper tube (or other short cardboard tube) hard-boiled egg
11	**Lab Investigation: Equal and Opposite**	3 tennis balls 3 pushpins string, cut into 3 lengths of 30 inches (.75 meters) each
	Activity: Action and Reaction	cardboard, about 18 × 9 inches set of pencils (all the same width, such as a set of colored pencils) windup or motorized toy car
13	**General assignments**	rubber band
14	**Lab Investigation: Converting Mechanical Energy to Thermal Energy**	insulated cup with lid (the kind you find in a coffee shop) thermometer timer or clock 1 cup of dry sand $\frac{1}{2}$ cup measuring cup
15	**Lab Investigation: Generating Power**	2 one-gallon jugs full of liquid (such as water, juice, or milk) stopwatch or clock with second hand bathroom scale metric ruler
16	**Lab Investigation: Solar Heating**	4 clear plastic cups black construction paper tape 2 large glass bowls, dishes, or jars thermometer marking pen

Lesson	Lab or Activity	Materials
19	**Lab Investigation: Transverse Waves and Wave Interference**	rope (10 to 20 meters long) measuring tape stopwatch or watch with a second hand
20	**Lab Investigation: Reflection and Absorption of Sound**	2 cardboard tubes, each approximately 2 feet long (you can make them out of cardboard) clock that ticks loudly (or other source of noise of consistent sound intensity and pitch) thick piece of cardboard, approximately 1 foot square piece of wood, approximately 1 foot square and 1 inch thick metal baking sheet metal muffin baking pan pillow table
	Lab Investigation: Transmission of Sound Waves	2 paper cups paper clip string, approximately 10 meters
	Activity: Wind Instrument	several empty glass bottles
21	**Lab Investigation: Rainbow Disc**	white paper 3 small round bowls or cups, each a different diameter cardboard ruler pencil or pen 6 colored markers: red, orange, yellow, green, blue, and purple string, 1 meter scissors Phillips-head screwdriver
22	**General assignments**	2 small mirrors penny small bowl
	Lab Investigation: Refraction and Dispersion	short, clear drinking glass spoon white paper small, flat mirror that will fit into the glass

Lesson	Lab or Activity	Materials
23	**General assignments**	metal spoon eyeglasses or magnifying glass clear glass jar clay or beeswax pencil
	Lab Investigation: Image Projection	magnifying glass (convex lens) stiff white paper or cardboard candle matches or lighter clay or beeswax metric tape measure
	Activity B: Focusing a Light Beam	magnifying glass (convex lens) white paper metric measuring tape container of water sunglasses block of wood (optional)
25	**Lab Investigation: Charged Balloons**	2 balloons sweater, sock, or scarf made of wool or nylon curtain or cotton cloth string, approximately 1 meter
	Lab Investigation: Attraction and Repulsion	plastic comb sweater, sock, or scarf made of wool or nylon newspaper shredded into strips salt* pepper* flour* sugar* paper towel *You only need a pinch of each of these substances.

Lesson	Lab or Activity	Materials
25	**Lab Investigation: Electroscope**	glass jar paper clip, large scissors cardboard or index card aluminum foil comb wool sweater or scarf tape
26	**Lab Investigation: Electrical Conductors**	6-volt battery (rectangular, with two terminals on the top) insulated copper wire, approximately 10 cm or metal scissors (with no insulating plastic or rubber on them) flashlight bulb (such as a #502 bulb) pocket knife or wire-strippers pencil with eraser and metal end sawn off tape assorted objects, such as a key, button, spoon, quarter, glass marble, and wooden block
27	**Lab Investigation: Voltaic Pile**	volt-ohm meter 10 pennies 10 nickels 10 dimes thin carboard or index card vinegar scissors
29	**General assignments**	2 magnets paper clip ruler
	Lab Investigation: Magnetic Force	2 magnets of different strengths glass jar wooden ruler paper clip
	Lab Investigation: Magnetic Strength along a Magnet	bar magnet ruler 24 metal paper clips pencil

Lesson	Lab or Activity	Materials
29	**Lab Investigation: Magnetic Induction**	large steel nail magnet 12 metal paper clips hammer safety goggles
30	**General assignments**	magnetic compass
	Lab Investigation: Electromagnetic Fields	45–60 cm of wire 1.5-volt D cell battery magnetic compass knife or wire-strippers nail
	Activity: Alternating and Direct Current	metal pie plate or pan cloth, approximately 15 × 10 cm 1 teaspoon cornstarch 1 teaspoon potassium iodide (available at a pharmacy) 1.5-volt D cell battery 60 cm of wire low voltage bell transformer (available at hardware stores) knife or wire-strippers alligator clip or paper clip
31	**Lab Investigation: Archimedes Screw**	1-liter plastic bottle (without the cap) glue duct tape cardboard, thin (such as a cereal box) knife or box cutter scissors wooden dowel popcorn or dry cereal
	Lab Investigation: Lever and Fulcrum	wooden ruler 5 nickels wood, cut into a triangular shape (to use as a fulcrum) tape

Lesson	Lab or Activity	Materials
32	**Lab Investigation: Torque and Mechanical Advantage**	manual pencil sharpener (or other hand-crank device) books twine, 1.5–2 meters duct tape screwdriver
	Lab Investigation: Mechanical Advantage of a Block and Tackle	2 broomsticks rope, approximately 6 meters (20 feet) long
33	**Lab Investigation: Aerodynamic Design**	clock or stopwatch measuring tape
	Activity A: Bernoulli Ball	hair dryer with a cylindrical nozzle 1 or more Styrofoam balls or Ping-Pong balls (3–5 cm in diameter) 2 cardboard boxes of different sizes
34	**Lab Investigation: Digital Communication**	graph paper (4 pieces) ruler
	Activity: Flicker Book	small pad of unlined paper (approximately 3 inches square) pen and/or colored pencils

Comprehensive List

aluminum can
aluminum foil
aluminum pie plate
baking pan for muffins, metal
baking pans, metal, 2
baking sheet, metal
balloons, 3
balls, Styrofoam or Ping-Pong balls (1 or more)
bathroom scale
battery, 1.5-volt D cell
battery, 6-volt
bottle, 1-liter plastic (without the cap)
bowls or cups, 3 small round, each a different diameter
broomsticks, 2
bulletin board
butter knife
can opener
can, large
can, small
candle, small
candles, 2 of the same size and weight
carboard or index card
cardboard boxes of different sizes, 2
cardboard tubes, 3
cardboard, various shapes and sizes
chalk
chocolate or other candy, 3 small pieces
clay (about the size of a baseball)
clay or beeswax
clock or stopwatch
clock that ticks loudly
cloth, approximately 15 × 10 cm
coins, 21 of the same type
coins, dimes, 10
coins, nickels, 10
coins, pennies, 10
coins, quarters, 2
colored markers: red, orange, yellow, green, blue, and purple
comb, plastic
cooking oil
cork
cornstarch, 1 teaspoon
cup, insulated with lid (the kind you find in a coffee shop)
cups, clear plastic, 4
cups, paper, 2
curtain or cotton cloth
dirt
duct tape
eggs, 1 hard-boiled and 1 raw (both in their shells)
egg, hard-boiled
eyedropper
eyeglasses or magnifying glass
flashlight bulb
flour
food coloring
glass bottle, long-neck with a small opening
glass bottles, empty (several)
glass bowls, dishes, or jars, large, 2
glass jars with lids, 8
glass, drinking glasses of the same size, 2
glue
graph paper
hair dryer with a cylindrical nozzle (optional)
hammer
insulated copper wire, approximately 10 cm or metal scissors
knife or box cutter
knife or wire-strippers
knitting needle, metal
low voltage bell transformer (available at hardware stores)
magnet, bar type

magnetic compass
magnets of different strengths, 2
magnifying glass (convex lens)
marking pen
matches or lighter
measuring cup, $\frac{1}{2}$ cup
measuring spoons
measuring tape, metric
mirrors, 2 small
nail, large steel
nails
needle, large darning
newspaper shredded into strips
one-gallon jugs full of liquid (such as water, juice, or milk), 2
paper clip
paper clip, large
paper clips, metal 24
paper towels, 3
paper, black construction
paper, small pad of unlined paper (approximately 3 inches square)
paper, white
pen and/or colored pencils
pencil sharpener, manual (or other hand-crank device)
pencil with an eraser
pencil with eraser and metal end sawn off
pencils, approximately 1 dozen (all the same width, such as a set of colored pencils)
pepper
Phillips-head screwdriver
pie plate or pan, metal
pillow
plastic bottle, clear with tight-fitting cap
plates, ceramic, 2
pocket knife or wire-strippers
popcorn or dry cereal
potassium iodide, 1 teaspoon (available at a pharmacy)
protractor
pushpins, 3
rope (10 to 20 meters long)
rubber band
rubber band, sturdy
rubbing alcohol
ruler (metric) or tape measure
ruler, wooden
safety goggles
salt
sand
scissors
soap, laundry, solid (powdered)
soap, liquid (hand, dish, or laundry soap)
soda or seltzer water, 2 unopened cans
spoon
stopwatch or clock with second hand
string, approximately 15 meters
sugar, granulated
sunglasses
sweater, sock, or scarf made of wool or nylon
tape
tennis balls, 3
thermometer
timer or clock
toothpick
toy car, windup or motorized
twine, 1.5–2 meters
vinegar
volt-ohm meter
wood, approximately 1 foot square and 1 inch thick
wood, cut into a triangular shape
wooden block
wooden dowel