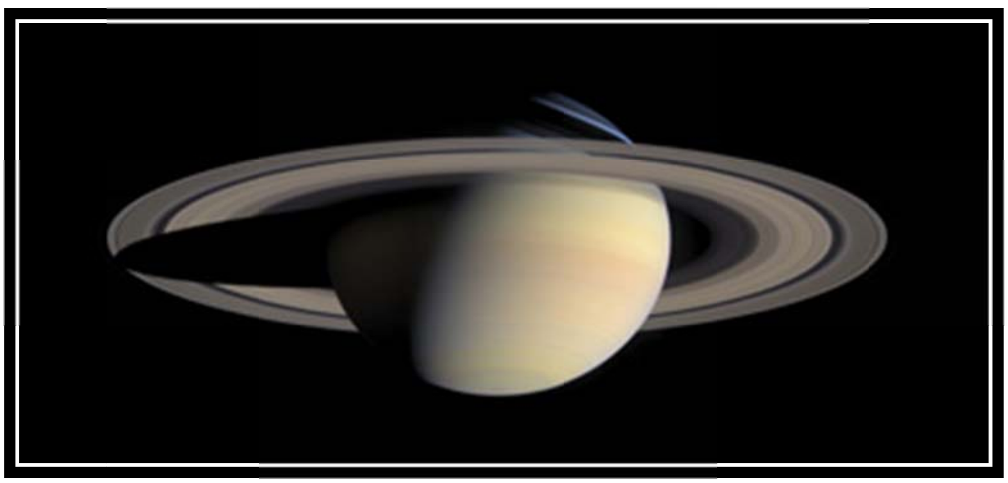
ASTRONOMY 1

PARENT/TEACHER'S GUIDE

A comprehensive course that teaches the big ideas behind Newton's ground-breaking work. Students will learn about magnetic storms, listen to the song of the sun, discover how to chart the stars, build a simple handheld refractor telescope and more.



Created by Aurora Lipper, Supercharged Science

www.SuperchargedScience.com

This curriculum is aligned with the California State Standards and STEM for Science.

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Introduction

Greetings, and welcome to the unit on astronomy. I hope you will find this helpful in preparing to teach your students, exhaustively thorough in content and a whole lot of fun, because that's when students and teachers do their best work.

This curriculum course has been prepared to be completed over several weeks, completing 1-2 lessons per week. You will find that there are 12 lessons outlined to take you from an introduction of astronomy on through several advanced projects which are complex enough to win a prize at the science fair. If you complete this course and send your kids off, you'll find their high school teachers entirely blown away by their mastery of the subject. Each lesson has a Teacher Page and a Student Worksheet.

The following features are on each set of the Teacher Pages:

- Overview: This is the main goal of the lesson.
- Suggested Time: Make sure you have enough for completing this lesson.
- Objectives : These are the core principles covered with this lesson.
- Materials: Gather these before you start
- Lab Preparation: This outlines any preparation you need to do ahead of time.
- Lesson: This outlines how to present the topic to the students, stirs up interest and gets the students motivated to learn the topic.
- Lab Time & Worksheets: This includes activities, experiments, and projects that reinforce the concepts and really brings them to life. You'll also find worksheets that make up their Scientific Journal.
- Background Lesson Reading: This is optional additional reading material you can utilize ahead of time to help you feel confident when the students ask questions during the Lab Time. I don't recommend giving this reading to the kids beforehand. If you must share it with them, then do so *after* the students have gotten a chance to roll around with the activities. Doing this teaches kids to ask their own questions by getting curious about the concepts through the experiments, the way real scientists do in the real world.
- Exercises & Answer Key: How well did you teach? How well did they learn? Time to find out.
- Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Immediately following the Teacher Pages are "Student Worksheets" for each of the activities. Each set of student worksheets has the following sections:

- Overview
- What to Learn
- Materials
- Lab Time & Worksheets
- Exercises

In addition to the lessons, we have also prepared the following items you'll find useful:

- Scientific Method Guide
- Master Materials and Equipment List
- Lab Safety Sheet
- Written Quiz (with Answer Key)
- Lab Practical Test (with Answer Key)

Master Materials List for All Labs

This is a brief list of the materials that you will need to do *all* of the activities, experiments and projects in each section. The set of materials listed below is just for one lab group. If you have a class of 10 lab groups, you'll need to get 10 sets of the materials listed below. For 10 lab groups, an easy way to keep track of your materials is to give each group a number from 1 to 10, and make up 10 separate lab kits using small plastic tubs or baskets. Put one number on each item and fill each tub with the materials listed below. Label the tubs with the section name, like *Astronomy Study Kit,* and you will have an easy way to keep track of the materials and build accountability into the program for the kids. Copy these lists and stick them in the bin for easy tracking. Feel free to reuse items between lessons and unit sections. Most materials are reusable year after year.

Aluminum pan
Baking soda (1/4 cup)
Balloon
Bar magnet
Circular (disk) magnet
Compass
Dirt (3 cups)
Dollar bill
Duct tape (optional)
Fingernail polish (red, yellow, green, blue)
Flashlights (3 or 4)
Flexible tubing (18") - optional
Flour (9 cups)
Glass jar
Hand-held magnifying lenses (2)
Horseshoe magnet
Liquid crystal thermometers (2)
Liquid dish soap
Marker
Masking tape
Milk (couple drops)
Musical instruments (any you already have)
Pencil
Penny
Plastic bottles (2 liter soda bottles)
Protractor
Rocks
Ruler
Salt (4 cups)
Steel washer with a 3/8 inch hole
Stopwatch
String
Tape (clear, not frosted)
Vegetable oil (1/2 cup)
Water bottle (empty)

TABLE OF CONTENTS

Unit Prep

This is a short list of things that you may want to consider as you prepare for this unit.

Student Lab Books: If you're the kind of teacher who likes to prepare lab books for your kids, now is a good time to do this. You can copy the *Introduction for Kids* and the *Student Worksheets* for each of the experiments, 3-hole punch them, and stick them in a binder. You'll want one binder per student.

Science Journals: One of the best things you can do with your students is to teach them how to take notes in a journal as you go along. This is the same way scientists document their own findings, and it's a lot of fun to look back at the splattered pages later on and see how far you've come. I always jot down my questions that didn't get answered with the experiment across the top of the page so I can research these topics more.

Master Set of Materials: If you plan on doing all the labs in this unit, you'll want to start gathering your materials together. There's a master materials list so you'll have everything you need when you need it.

Test Copies: Students will take two tests at the end of each section. There are quizzes and lab practical tests you can copy and stash away for when you need them.

Classroom Design: As you progress through the units, you'll be making demos of the experiments and kids will be making posters. You can hang these up on your bulletin boards, string them from the ceiling, or display them in a unique way. I always like to snap photos of the kids doing their experiments and hang those up along with their best labs so they can see their progress as we go along.

Lab Safety

Goggles: These should be worn when working with chemicals, heat, fire, or projectiles. These protect your eyes from chemical splatter, explosions, and tiny fast-moving objects aimed at the eyes. If you wear glasses, you can find goggles that fit over them. Don't substitute eyeglasses for goggles, because of the lack of side protection. Eyeglasses don't provide this important protection.

Clean up Messes: Your lab area should be neat, organized, and spotless before you start, during your experiment, and when you leave. Scientists waste more time hunting for lost papers, pieces of an experiment, and trying to reposition sensitive equipment … all of which could have easily been avoided had they been taught organizational skills from the start.

Dispose of Poisons: If a poisonous substance was used, created, or produced during your experiment, you must follow the proper handling procedures for disposal. You'll find details for this in the experiments as needed.

Special Notes on Batteries: Do not use alkaline batteries with your experiments. Find the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty") because these types of batteries have a carbon-zinc core, which does not contain the acid that alkaline batteries have. This means when you wire up circuits incorrectly (which you should expect to do because you are learning), the circuits will not overheat or leak. If you use alkaline batteries (like Energizer and Duracell) and your students short a circuit, their wires and components will get super-hot and leak acid, which is very dangerous.

No Eating or Drinking in the Lab: All foods and drinks are banned from your classroom during science experimentation. When you eat or drink, you run the very real risk of ingesting part of your experiment. For electricity and magnetism labs, always wash your hands after the lab is over to rinse off the lead from the electrical components.

No Horse Play: When you goof around, accidents happen, which means chemicals spill, circuits short, and all kinds of hazards can occur that you weren't expecting. Never throw anything to another person and be careful where you put your hands – it could be in the middle of a sensitive experiment, especially with magnetism and electricity. You don't want to run the risk of getting shocked or electrified when it's not part of your experiment.

Fire: If you think there's a fire in the room (even if you're not sure), let your teacher know right away. If they are not around (they always should be), smother the fire with a fire blanket or use a fire extinguisher and send someone to find an adult. Stop, drop, and roll!

Questions: If you're not sure about something, stop and ask, no matter what it's about. If you don't know how to properly handle a chemical, do part of an experiment, ask! If you're not comfortable doing part of the experiment, then don't do it.

Teaching Science Right

These activities and experiments will give you a taste of how science can be totally cool AND educational. But teaching science isn't always easy. There's a lot more to it than most traditional science books and programs accomplish. If your students don't remember the science they learned last year, you have a problem.

What do kids really need to know when it comes to science? Kids who have a solid science and technology background are better equipped to go to college, and will have many more choices once they get out into the real world.

Learning science isn't just a matter of memorizing facts and theories. On the contrary, it's developing a deep curiosity about the world around us, AND having a set of tools that lets kids explore that curiosity to answer their questions. Teaching science this way isn't just a matter of putting together a textbook with a few science experiments and kits.

Science education is a three-step process (and I mean teaching science in a way that your students will really understand and remember).

Here are the steps:

1. Get kids genuinely interested and excited about a topic.

2. Give them hands-on activities and experiments to make the topic meaningful.

3. Teach the supporting academics and theory.

Most science books and curriculum just focus on the third step and may throw in an experiment or two as an afterthought. This just isn't how students learn. When you provide your students with these three keys (in order), you can give your students the kind of science education that not only excites them, but that they remember for many years to come.

So what do you do? First, don't worry. It's not something that takes years and years to do. It just takes commitment.

What if you don't have time? What I'm about to describe can take a bit of time as a teacher, but it doesn't have to. There is a way to shortcut the process and get the same results! But I'll tell you more about that in a minute. First, let me tell you how to do it the right way:

Putting It into Action

Step one: Get students genuinely interested and excited about a topic. Start by deciding what topic you want your students to learn. Then, you're going to get them really interested in it. For example, suppose I want my fifth-grade students to learn about aerodynamics. I'll arrange for them to watch a video of what it's like to go up in a small plane, or even find someone who is a pilot and can come talk with the kids. This is the kind of experience that will really excite them.

Step two: Give your students hands-on activities and experiments to make the topic meaningful. This is where I take that excitement and let them explore it. I have flying lesson videos, airplane books, and real pilots interact with my students. I'll also show videos on how pilots plan for a flight. My students will learn about navigation, figuring out how much fuel is needed for the flight, how the weight the plane carries affects its aerodynamics, and so much more. (And did I just see a spot for a future math lesson also?) I'll use pilot training videos to help us figure this out (short of a live demo, a video is incredibly powerful for learning when used correctly).

My students are incredibly excited at this point about anything that has to do with airplanes and flying. They are all positive they want to be pilots someday and are already wanting flying lessons (remember - they are only fifth-graders!).

Step three: Teach the supporting academics and theory. Now, it's time to introduce academics. Honestly, I have my pick of so many topics, because flying includes so many different fields. I mean my students use angles and math in flight planning, mechanics and energy in how the engine works, electricity in all the equipment on board the plane, and of course, aerodynamics in keeping the plane in the air (to name just a few).

I'm going to use this as the foundation to teach the academic side of all the topics that are appropriate. We start with aerodynamics. They learn about lift and drag, make paper and balsa-wood gliders and experiment by changing different parts. They calculate how big the wings need to be to carry more weight (jelly beans) and then try their models with bigger wings. Then we move on to the geometry used in navigation. Instead of drawing angles on a blank sheet of paper, our workspace is made of airplane maps (free from the airport). We're actually planning part of the next flight my students will "take" during their geography lesson. Suddenly, angles are a lot more interesting. In fact, it turns out that we need a bit of trigonometry to figure out some things.

Of course, a 10-year old can't do trigonometry, right? Wrong! They have no idea that it's usually for high school and learn about cosines and tangents. Throughout this, I'm giving them chances to talk with the pilot in class, share what they've learned with each other, and even plan a real flight. How cool is that to a kid?

The key is to focus on building interest and excitement first, and then the academics are easy to get students to learn. Try starting with the academics and ... well, we've all had the experience of trying to get kids do something they don't really want to do.

The Shortcut: Okay, so this might sound like it's time-intensive. If you're thinking, "I just don't have the time to do this!" Or maybe, "I just don't understand science well enough myself to teach it to my students at that level." If this is you, you're not alone.

The good news is, you don't have to. The shortcut is to find someone who already specializes in the area you want your students to learn about and expose them to the excitement that the person gets from the field. Then, instead of you being the one to invent an entirely new curriculum of hands-on activities and academics, use a solid science program or curriculum (live videos, not cartoons). This will provide them with both the hands-on experiments and the academic background they need.

If you use a program that is self-guided (that is, it guides you and your students through it step-by-step), you don't need to be hassled with the preparation. That's what this unit is intended to do for you and your students. This program uses these components and matches your educational goals set by state standards.

This unit implements the three key steps we just talked about and does this all for you. My hope is that you now have some new tools in your teaching toolbox to give your students the best start you can. I know it's like a wild roller coaster ride some days, but I also know it's worth it. Have no doubt that that the caring and attention you give to your students' education today will pay off manifold in the future.

Educational Goals

Astrophysics combines the knowledge of light (electromagnetic radiation), chemical reactions, atoms, energy, and physical motion all into one. The things we're going to study in this unit border on sci-fi weird, but I assure you it's all the same stuff real scientists are studying.

Here are the scientific concepts:

- Objects in the sky move in regular and predictable patterns. The patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
- The tilt of the Earth and its location in orbit are the reasons for the seasons.
- The Earth is one of several planets that orbit the Sun, and the Moon orbits the Earth.
- The solar system consists of planets and other bodies that orbit the Sun in predictable paths.
- Our solar system includes rocky terrestrial planets (Mercury, Venus, Earth, and Mars), gas giants (Jupiter and Saturn), ice giants (Uranus and Neptune), and assorted chunks of ice and dust that make up various comets and asteroids.
- Two planets (Ceres and Pluto) have been reclassified after astronomers found out more information about their neighbors.
- Telescopes magnify the appearance of the Moon and the planets.
- Telescopes magnify the appearance of the Sun using special lenses and make it possible to locate sunspots and solar flares.
- Stars are the source of light for all bright objects in outer space. The Moon and planets shine by reflected sunlight, not by their own light.
- The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

By the end of the labs in this unit, students will be able to:

- Design and build a telescope using optical equipment like lenses.
- Know how to demonstrate how the position of objects in the sky changes over time.
- Know the celestial objects in the solar system and how they relate and interact with each other.
- Formulate and justify predictions based on cause-and-effect relationships.
- Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- Construct and interpret graphs from measurements.
- Follow a set of written instructions for a scientific investigation.

Lesson #1: Planetarium and Star Show

Teacher Section

Overview This is an introduction to astronomy and why it's important to study. Today students (and you) will take an intergalactic star tour without leaving their seats. You'll be watching the video right along with the kids. This video you're about to watch is best with a big bowl of popcorn.

Suggested Time: 60-75 minutes

Objectives: We're going to cover a lot in this presentation, including: The Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium. The solar system includes the Earth, Moon, Sun, eight other planets and their satellites, and smaller objects such as asteroids and comets. The structure and composition of the universe can be learned from the study of stars and galaxies. Galaxies are clusters of billions of stars, and may have different shapes. The Sun is one of many stars in our own Milky Way galaxy. Stars may differ in size, temperature, and color.

Materials (per lab group)

- Popcorn
- Pencil

Lab Preparation

1. Inflate a balloon and tie it off. You'll need one for every lab group.
2. Print out copies of the student worksheets.
3. Read over the Background Lesson Reading before teaching this class.
4. Watch the video at the beginning of this section to prepare yourself for this class.

Background Lesson Reading

Astronomers study celestial objects (stars, planets, moons, asteroids, comets, galaxies, etc.) that exist outside our planet's atmosphere. It's the one field that combines the most science, engineering and technology areas in one fell swoop. Astronomy is also one of the oldest sciences on the planet.

Our solar system includes rocky terrestrial planets (Mercury, Venus, Earth, and Mars), gas giants (Jupiter and Saturn), ice giants (Uranus and Neptune), and assorted chunks of ice and dust that make up various comets and asteroids.

Two planets (Ceres and Pluto) have been reclassified after astronomers found out more information about their neighbors. Ceres is now an asteroid in the Asteroid Belt between Mars and Jupiter. Beyond Neptune, the Kuiper Belt holds the chunks of ice and dust, like comets and asteroids as well as larger objects like dwarf planets Eris and Pluto.

Beyond the Kuiper belt is an area called the Oort Cloud, which holds an estimated 1 trillion comets. The Oort Cloud is so far away that it's only loosely held in orbit by our Sun, and constantly being pulled gravitationally by passing stars and the Milky Way itself. The Voyager Spacecraft are beyond the heliosphere (the region influenced gravitationally by our Sun) but have not reached the Oort Cloud.

The Sun holds 99% of the mass of our solar system. The Sun's equator takes about 25 days to rotate around once, but the poles take 34 days. You may have heard that the Sun is a huge ball of burning gas. But the Sun is not on fire, like a candle. You can't blow it out or reignite it. So, where does the energy come from?

The nuclear reactions deep in the core transform 600 million tons per second of hydrogen into helium. This gives off huge amounts of energy which gradually works its way from the 15 million-degree Celsius temperature core to the 15,000-degree Celsius surface.

Stars like to live together in families. Galaxies are groups of stars that are pulled and held together by gravity. Some galaxies are sparse while others are packed so densely you can't see through them. Galaxies also like to hang out with other galaxies (called galaxy clusters), but not all galaxies belong to clusters, and not all stars belong to a galaxy.

Active galaxies have very unusual behavior. There are several different types of active galaxies, including radio galaxies (edge-on view of galaxies emitting jets), quasars (3/4 view of the galaxy emitting jets), blazars (aligned so we're looking straight down into the black hole jet), and others. Our own galaxy, the Milky Way, has a super-massive black hole at its center, which is currently quiet and dormant.

Dying stars blow off shells of heated gas that glow in beautiful patterns. William Hershel (1795) coined the term "planetary nebula" because the ones he looked at through 18th century telescopes looked like planets. They actually have nothing to do with planets – they are shells of dust feathering away.

Lesson

1. This lab is mostly done for you – you don't even have to teach if you don't want to! Just fire up the video for the students, sit back and enjoy the show. You can have the kids fill out their questions and table either during or after the class, in groups or individually. Personally, I encourage teamwork and group discussions, as the students seem to catch on more when they have others to help them out on the parts they might have missed.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups. Hand each group their materials and give them time to look over the sheet and get familiar with the questions that will be asked about the presentation.
2. When the video is up, ask the kids to fill out their worksheet.
3. Students can share their results with you while you record them on the board for everyone to see.
4. Lead them into a discussion of what they think astronomy is and what it isn't.
5. Ask them to share one thing about astronomy that they now know but didn't before they walked into your class.

6. Finally, ask them to write down three things they want to know about astronomy. Give them a few minutes to write their ideas down and then ask for shares. You can record their requests and post them in your classroom.

Exercises

1. What happened to Pluto? (Pluto was reclassified as a dwarf planet. Beyond Neptune, the Kuiper Belt holds the chunks of ice and dust, like comets and asteroids as well as larger objects like dwarf planets Eris and Pluto.)
2. How does the Sun make energy? (The nuclear reactions deep in the core transform 600 million tons per second of hydrogen into helium by smacking protons together, called nuclear fusion.)
3. Which planet is your favorite and why? (Refer to student responses.)
4. How many moons around Jupiter and Saturn can you see with binoculars? (Four each.)
5. What's the difference between a galaxy and a black hole? (Galaxies are groups of stars that are pulled and held together by gravity. Black holes are the leftover remnants of a supernova explosion that require an escape velocity greater than the speed of light.)
6. How many Earths can fit inside the Sun? (1.3 million)

Closure Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #1: Planetarium Star Show

Student Worksheet

Name____

Overview Greetings and welcome to the study of astronomy! This first lesson is simply to get you excited and interested in astronomy so you can decide what it is that you want to learn about astronomy later on.

What to Learn We're going to cover a lot in this presentation, including: the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.

The solar system includes the Earth, Moon, Sun, eight other planets and their satellites, and smaller objects such as asteroids and comets. The structure and composition of the universe can be learned from the study of stars and galaxies. Galaxies are clusters of billions of stars, and may have different shapes. The Sun is one of many stars in our own Milky Way galaxy. Stars may differ in size, temperature, and color.

Materials

- Popcorn
- Pencil

Lab Time

1. Before the show starts, look over the worksheet table so you know what to listen for as you go through the star show. Then grab your pencil (and a handful of popcorn) and fill it in as you go along, or simply enjoy the show and fill it out at the end.

2. What happened to Pluto?

3. How does the Sun make energy?

4. Which planet is your favorite and why?

5. How many moons around Jupiter and Saturn can you see with binoculars?

6. What's the difference between a galaxy and a black hole?

7. How many Earths can fit inside the Sun?

Write down three things you really want to know about astronomy.

1.

2.

3.

Planetarium Star Show Table

Planet	Interesting Fact You Didn't Know 'Til Now

Homework: This evening, find an article or story that describes how astronomy (knowledge, equipment, discoveries, etc.) improves our lives. Bring the article to school. If you bring in an article that no one else brings in, you get extra points.

Lesson #2: Solar System Treasure Hunt

Teacher Section

Overview: After you've participated in *Lesson #1: Planetarium Star Show,* find out how much your students picked up by doing a Solar System Treasure Hunt. There are two hunts the kids are going on – one is indoors and the other is outdoors. The indoor hunt is a set of 50 questions they answer before pursuing the real hunt outdoors.

Suggested Time: 30-45 minutes

Objectives: Students will know specific details about all eight planets, the Sun and its composition, selected natural satellites, and smaller objects such as asteroids and comets.

Materials (per lab group)

- Copies of the appropriate clue pages
- Treasure for everyone (small candy, special pencils, etc.)

Lab Preparation

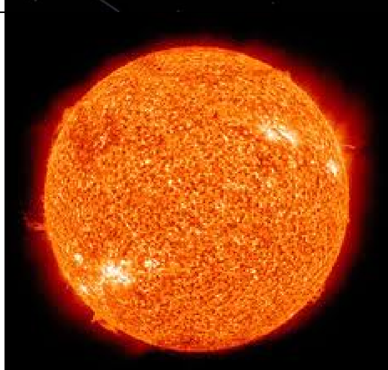
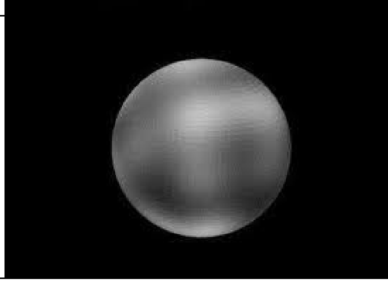
1. There are two sets of clues.
   - The first is a set of 37 that get pasted all over your room in plain view. They are the information cards to help the kids answer questions from the presentation last time in *Lesson 1: Planetarium Star Show.* Tape them to the walls, desks, coat racks, floor, ceiling, windows, and anywhere you can put them. Make sure they can read them quickly and move on.
   - The second set is a real treasure hunt of 10 clues. There are three sets of these, depending on where you plan to do the activity. You can choose to do either: the Household Hunt, the Playground Hunt, or the Classroom Hunt. The treasure goes at the end of these hunts (not at the end of the first set). If the weather's not cooperating, use the Classroom Hunt clues in envelopes that say "Do Not Open" in case the kids run across them when doing the first activity.
2. Cut out the clues and hide them in advance. If you're using the Classroom Hunt, put the second set of 10 clues in envelopes. If not, simply tape the clues into place so they don't walk off with them.
3. Cut out photos of the planets (if you're using them) and hide them with the 10 Hunt clues. You'll find a complete set from NASA here: http://photojournal.jpl.nasa.gov/
4. You'll need some sort of treasure for the final clue for everyone to share (*Mars* candy bars for each lab group?). If you're doing the Household Hunt, stash the treasure in the mailbox. If you're doing the Classroom Hunt, put the treasure under your desk. Stash the treasure in your pocket if you're doing the Playground Hunt.
5. Print out copies of the student worksheets.
6. Watch the video for this experiment to prepare for teaching this class.

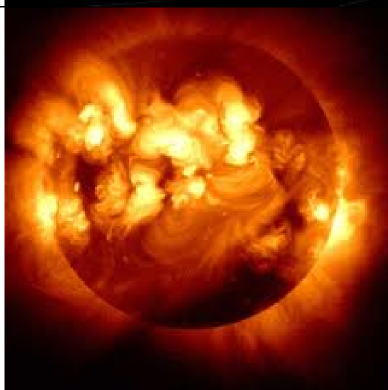
Lab Time

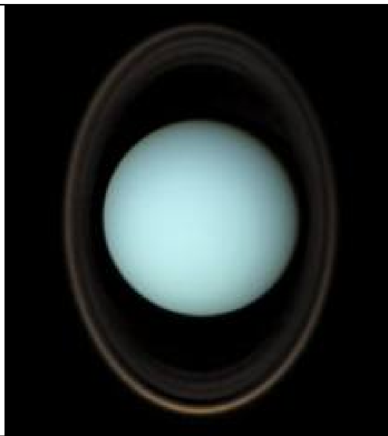
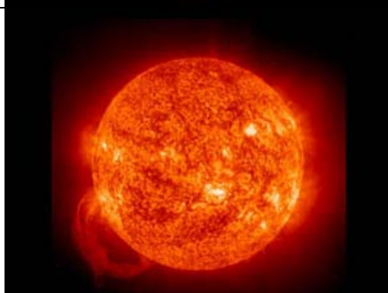
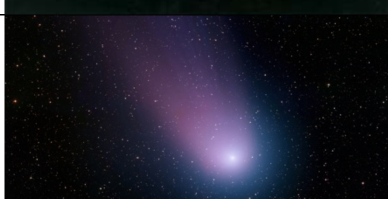
1. Review the instructions on their worksheets, specifically that they are to *look* at the clues, not rip them down and take them. If they find any envelopes, they are to leave those alone until you say so.
2. Break the students into their lab groups.
3. Hand each group their worksheets and let them loose to answer their 50 questions.
4. When they are done, they trade in their papers for a glance at their first clue. Again, remind them that they are not to take the clues (otherwise no one else will get to participate!), but *look* at them and then move on to the next clue.
5. When all the kids are on the second half of the activity, make yourself clearly visible for the Playground Hunt and keep the treasure in your pockets.

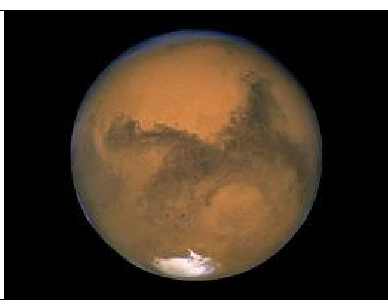
Clue Cards: Cut these out and paste in plain view all over the room for students to find easily. They will be answering 50 questions. Some cards contain information for more than one question, so you'll find there are 37 clue cards for the first part of the activity.

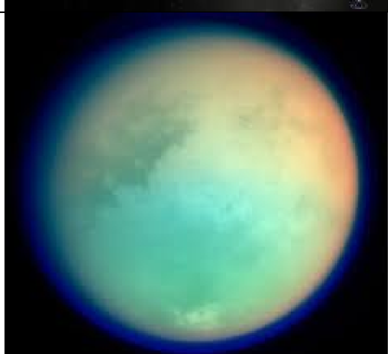
All images provided courtesy of NASA.

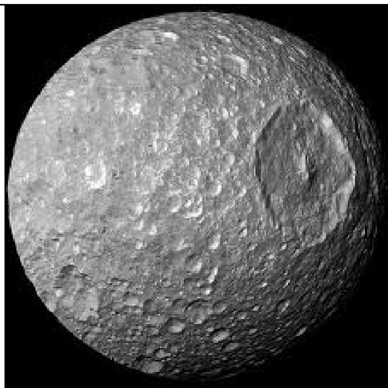
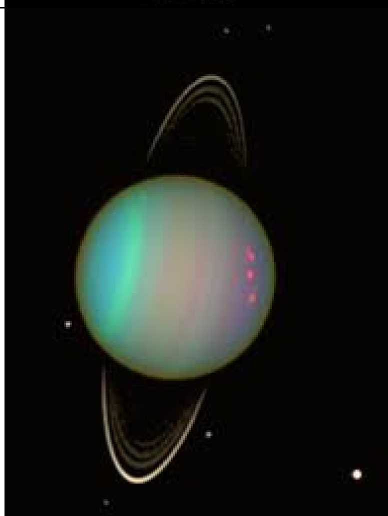
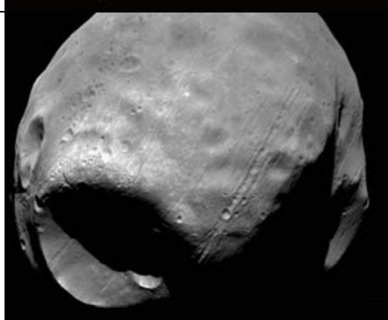
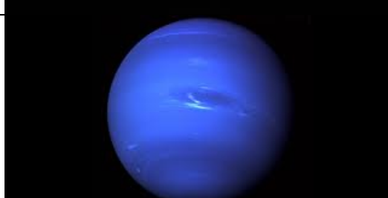
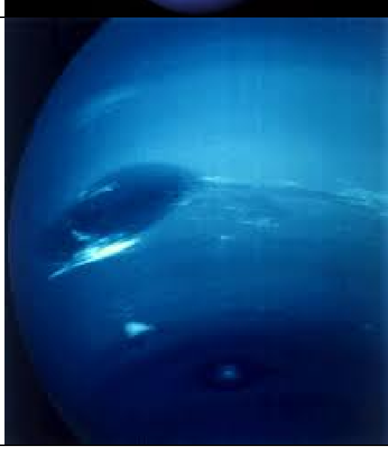
	Shape of our solar system is approximately circular.
	The Sun rotates once every 31 days at the poles and once every 27 days at the equator.
	Pluto is now part of the Kuiper Belt.

	Our solar system has eight planets, their moons, asteroids and comets.
	The core temperature of the Sun is 15 million degrees Celsius.
	A planet is an object that orbits the Sun, is massive enough for its own gravity to make it round, and has cleared its orbit of smaller objects.
	Mercury is the second hottest planet at 800^{o}F (427^{o}C). The side facing away from the Sun is -280^{o}F (-173^{o}C)
	Venus is the hottest planet at 863^{o}F (462^{o}C).

	Although Uranus is made mostly of hydrogen and helium, it's the cold methane gas that gives the blue-green color.
	The Sun is made up of 25% helium and 75% hydrogen.
	Venus takes longer to spin once on its own axis than it does to orbit the Sun. Not only that, it rotates in the opposite direction from the rest of the planets.
	Comets are made of dust and ice, making them just like dirty snowballs. We think that the ice on Mercury was left by impacts from comets.
	The Earth's atmosphere is made up of 21% oxygen and 78% nitrogen, with trace amounts of other molecules.

	Venus was named after the goddess of love and beauty because it is the brightest object in the sky, other than the Sun and Moon.
	The Moon causes both ocean and land tides on the Earth.
	The two moons of Mars are named after Fear/Panic (Phobos) and Fleeing (Deimos).
	Jupiter is made of hydrogen and helium with a metallic hydrogen core. It's as large as it can be without shrinking. If you added more mass (hydrogen gas) to it, Jupiter would condense and get smaller. If you increased its mass by 80X, it would compress and become a star.
	Iron oxide (rust) gives Mars its red color. The white at the poles are dry ice (frozen carbon dioxide) and water ice.
	1400 Earths can fit inside of Jupiter. If Jupiter were the size of a soccer ball, the Earth would be a marble. All the other planets can fit together inside Jupiter.

	Saturn's rings are made mostly out of ice travelling at 75,000 mph.
	There are shepherd moons inside Saturn's rings.
	Mercury, Venus, Earth and Mars are rocky terrestrial planets. Jupiter and Saturn are gas giants. Uranus and Neptune are ice giants. Pluto, Ceres, Haumea, Makemake, and Eris are dwarf planets.
	Titan has an atmosphere made mostly of nitrogen.
	We think Saturn's moon, Iapetus, used to have a ring around it.

	Saturn's moon Mimas is where Star Wars got the idea for the Death Star.
	Uranus is the only planet that rolls around the Sun, tipped over on its side.
	Phobos is slowly moving inward toward Mars, and when the tidal forces inside this moon become stronger, they will either shatter the moon into a meteor shower or cause the bits to form a ring around Mars.
	The average daily wind speed on Neptune is 1200 mph. Neptune radiates 2.6 times as much energy out as it receives from the Sun.
	Neptune's blue color is from the methane gas, but it's also made up of hydrogen and helium. Since it's the furthest planet from the Sun (30 au, or 4.5 billion km, or 2 billion miles), it's also the coldest. Note that the five dwarf planets are colder objects than Neptune, since they are further still.

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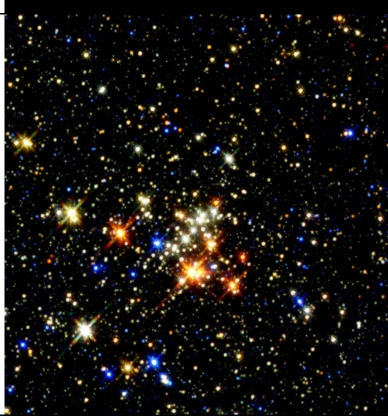
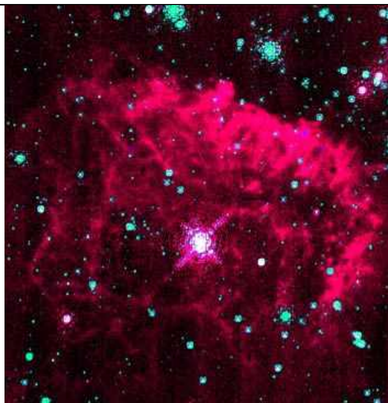
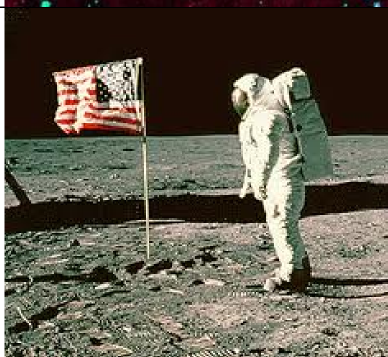
	Pluto and Charon orbit each other, and are also orbited by Hydra and Nix.
	70% of the Earth is covered by water. 2% of this is locked in ice.
	The Sun is 1 au (astronomical unit) from the Earth. 1 au is 93 million miles. It takes light about 8 minutes to travel this distance.
	Venus is the hottest planet because it traps the heat inside once it enters the thick atmosphere. The volcanoes on Venus are so active that the planet is constantly resurfacing itself.
	Blue stars measure above 10,000K (17,540^{o}F or 9,727^{o}C) at the surface. Red stars are about 2500K (4,040^{o}F or 2,227^{o}C). Our Sun, a white star, is 6,000K (10,340^{o}F or 5,727^{o}C). Note: K (Kelvin) is the absolute temperature scale for Celsius.

	The Pistol star releases as much energy in one second as our Sun does in one year.
	12 people have walked on the Moon. Approximately 7 billion people walk on the Earth today.
	Jupiter's giant storm, the Great Red Spot, is actually getting smaller. The current size is about two Earth diameters.

Answer Key to First Activity's 50 Questions:

1. The shape of our Solar System is circular.
2. How many planets do we have in our solar system? 8
3. Pluto is now part of the Kuiper Belt.
4. The Sun rotates once every 27 days at its equator and 31 days at the poles.
5. The core temperature of the Sun is 15 million degrees Celsius.
6. A planet has three criteria: It orbits the Sun, has cleared its orbit of smaller objects, and is large enough so its own gravity makes it round.
7. There are three types of planets: rocky terrestrial, gas giants and ice giants.
8. Mercury is the closest, but not the hottest planet. The side facing the Sun gets to 800°F, and the side facing away from the Sun gets to -280°F.
9. The solar system includes eight planets, their moons, the Sun at the center, and smaller objects such as comets and asteroids.
10. The Sun is made out of 75% hydrogen and 25% helium.
11. Venus is called the goddess of love because it looks so bright to us from Earth, but it really has a surface temperature of 863°F.
12. Comets are really dirty snowballs.
13. Venus is the brightest thing in the sky, other than the Sun and Moon.
14. Cold methane is what gives Uranus its blue-green color. It's classified as an ice giant.
15. One day is longer than a year on Venus. Not only that, it rotates in the opposite direction .
16. Earth's atmosphere is made up of 21% oxygen and 78% nitrogen
17. The Moon pulls on the surface on the Earth and causes tides on both the land and ocean.
18. Mars's moons are named after Fear/Panic and Fleeing/Flight.
19. Iron oxide (rust) gives Mars its red color.
20. If the Earth was the size of a marble, Jupiter would be the size of a soccer ball.
21. Jupiter can fit 1400 Earths inside.
22. If you added more mass to Jupiter it would get smaller because it's a big ball of gas.
23. Jupiter is made out of hydrogen and helium with a metallic hydrogen core.
24. The volcanoes on Jupiter's moon Io spew its ice ash 300 miles high.
25. Saturn is surrounded by rings made mostly of ice moving at 75,000 mph.
26. Inside Saturn's rings are shepherd moons.
27. Titan has an atmosphere made mostly of nitrogen so thick that if you strapped wings onto your arms and flapped, you'd fly!
28. Scientists think that Iapetus used to have a ring around it, and it crashed down onto the surface.
29. Jupiter is so large that all of the planets in the solar system could fit inside of it.
30. Mimas looks just like the Death Star.
31. The planet Uranus rolls around the Sun while tipped on its side.
32. Phobos is slowly moving inward toward Mars and will either shatter or form a ring around Mars.
33. Our best guess is that the ice on Mercury was caused by comets.
34. Average daily wind speed on Neptune is 1,200 mph.
35. Neptune is a giant ball of gas, which is also known as an ice giant.
36. Charon and Pluto are a pair of objects because they both rotate around a point outside of each. These two are also orbited by Hydra and Nix.
37. Seventy percent of the Earth's surface is covered by water.
38. The Sun is 93 million miles from the Earth, also known as 1 au.
39. The hottest planet is Venus because the heat that comes into the planet gets trapped inside.

40. There are how many stars are in our solar system? One. The Sun.
41. Which color stars are the hottest? Blue. Coolest? Red.
42. The Pistol star is the biggest one we've found and it releases as much energy in one second as our Sun does in one year.
43. The planets and moons that people have walked on are Earth and the Moon.
44. Jupiter's Great Red Spot is getting smaller. It's about the size of two Earths right now.
45. Jupiter and Saturn are gas giants, and Uranus and Neptune are ice giants.
46. Neptune is the coldest planet in our solar system.
47. The five dwarf planets in our solar system are: Eris, Makemake, Haumea, Pluto, and Ceres.
48. It takes light 8 minutes to travel from the Sun to Earth.
49. Venus has so much volcanic activity that it constantly resurfaces itself.
50. What kind of ice is on Mars? Dry ice and water ice.

Clues for the Playground Hunt: Cut these out and tape them around the playground. You can add a picture of each object along with the clue if you wish. Make sure you've warned the kids *not* to take the clues, but just LOOK at them. In addition to a playground, you'll need to toss a soccer ball and football on your field far apart from each other. As you place each clue in its proper spot, rip off the tab on the left with the instructions that were just for you. Make sure you've got the treasure with you when the kids come tearing back to you with the final clue. Have fun!

The Sun *(CLUE #1): Show this clue to get started.*	This object is hot, but not on fire. Explore the swings but don't perspire!
Mercury *(CLUE #2): Tape this clue under one of the swings.*	This planet is closest, but not the hottest. Check the football, and don't be modest!
Venus *(CLUE #3): Tape this clue to a football.*	This planet is so hot it can melt a cannonball, Crush spaceships, rain acid, and is in a tree tall.
Earth *(CLUE #4): Tape this clue in a tree (or plant).*	Most of this planet is covered with water. Find some water that never gets hotter.
Mars *(CLUE #5): Tape this clue near the drinking fountain.*	This planet is basically a rusty burp. Discover the slide and take a ride.
Jupiter *(CLUE #6): Tape this clue at the top of a slide.*	A planet so large it can hold the rest, Explore the bars with infinite zest!
Saturn *(CLUE #7): Tape this clue on the monkey bars.*	This planet had rings, but not made of gold. Explore near a door like an astronaut bold!
Uranus *(CLUE #8): Tape this clue on the exterior of a nearby door.*	Smacked so hard it now rolls on its side, Find the window that is ever so wide.
Neptune *(CLUE #9): Tape this clue on the exterior of a window.*	Check the soccer ball for hurricane, gigantic blue farts, and diamond rain.
Pluto *(CLUE #10): Tape this clue on a soccer ball.*	Instead of one there were two, then four… Visit your teacher for the one that is no more.

Clues for the Classroom Hunt: Cut these out and hide them in envelopes around your classroom. You can add a picture of each object along with the clue if you wish. This is great for rainy school days. Remind the kids that they have to find the right clue and go in order! You can number them if you want to, or have their lab partners hold them accountable. Also remind them *not* to take the clues, but look at them and move on. When you place the clue in its proper spot, rip off the tab on the left with the instructions that were just for you. Place the treasure under your desk for the final clue. Have fun!

The Sun *(CLUE #1): Show this clue to get started.*	This object is hot, but not on fire. Explore the coats but don't perspire!
Mercury *(CLUE #2): Tape this clue with the coats.*	This planet is closest, but not the hottest. Check the floor, and don't be modest!
Venus *(CLUE #3): Tape this clue in a corner on the floor.*	This planet is so hot it can melt a cannonball, Crush spaceships, rain acid, and is on an object tall.
Earth *(CLUE #4): Tape this clue on something very tall.*	Most of this planet is covered with water. Find some water but don't make it hotter.
Mars *(CLUE #5): Tape this clue to your sink or a water bottle left out on the counter.*	This planet is basically a rusty burp. Where would you take a bite and slurp?
Jupiter *(CLUE #6): Tape this clue next to where they store lunches. You can also stick it right on a lunchbox.*	A planet so large it can hold the rest, Explore our library with infinite zest!
Saturn *(CLUE #7): Hide this clue with a stack of books.*	This planet had rings, but not made of gold. Explore the door like an astronaut bold!
Uranus *(CLUE #8): Tape this clue on the classroom door.*	Smacked so hard it now rolls on its side, Find the window that is ever so wide.
Neptune *(CLUE #9): Tape this clue on a window.*	Check the ceiling for hurricane, gigantic blue farts, and diamond rain.
Pluto *(CLUE #10): Tape this clue on the ceiling.*	Instead of one there were two, then four… Look under a desk for the one that is no more.

Clues for the Household Hunt: Cut these out and hide them in envelopes around your house. You can add a picture of each object along with the clue if you wish. This is great for homework assignments, homeschool students, and home study programs. Remind the kids that they have to find the right clue and go in order! When you place the clue in its proper spot, rip of the tab on the left with the instructions that were just for you. Place the treasure in the mailbox for the final clue. Have fun!

The Sun *(CLUE #1): Show this clue to get started.*	This object is hot, but not on fire. Explore the dryer but don't perspire!
Mercury *(CLUE #2): Hide this in the dryer.*	This planet is closest, but not the hottest. Check the sock drawer, and don't be modest!
Venus *(CLUE #3): Hide this in the sock drawer.*	This planet is so hot it can melt a cannonball, Crush spaceships, rain acid, and is in a tree tall.
Earth *(CLUE #4): Hide this clue in a tree (or plant).*	Most of this planet is covered with water. Visit the bathtub without making it hotter.
Mars *(CLUE #5): Hide this clue in the bathtub.*	This planet is basically a rusty burp. Discover the refrigerator and take a slurp.
Jupiter *(CLUE #6): Hide this clue next to the milk.*	A planet so large it can hold the rest, Explore our library with infinite zest!
Saturn *(CLUE #7): Hide this clue with a stack of books.*	This planet had rings, but not made of gold. Explore near the front door like an astronaut bold!
Uranus *(CLUE #8): Hide this clue on the front door.*	Smacked so hard it now rolls on its side, Find the window that is ever so wide.
Neptune *(CLUE #9): Hide this clue by sticking it on a window.*	Check the sink for hurricane, gigantic blue farts, and diamond rain.
Pluto *(CLUE #10): Hide this clue in the sink.*	Instead of one there were two, then four… Visit the mailbox for the one that is no more.

Closure Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #2: Solar System Treasure Hunt

Student Worksheet

Name____

Overview: Fun day! You get to do not one, but *two* treasure hunts during class time today. The first is on paper and asks questions about the presentation from last time. The second activity has 10 clues with real treasure. The more you know about astronomy, the faster you'll move through these.

What to Learn : Today you'll discover how much you already know about the specific details about all eight planets, the Sun and its composition, selected natural satellites, and smaller objects such as asteroids, dwarf planets, and comets.

Materials

- A pencil

Lab Time

There are two rounds for this treasure hunt: indoors and outdoors (if the weather's cooperating). In a moment, your lab team is going to search your indoor classroom for answers to these clues below. Once you've completed this task, let your teacher know and they will hand you the second round and send you on your way.

First Treasure Hunt: Answer the questions below as you search around you for clues to the answer. Good luck!

1. The shape of our Solar System is ______________________.

2. How many planets do we have in our solar system? _________________________

3. Pluto is now part of the ________________________ Belt.

4. The Sun rotates once every ___________________ at its equator and _________________ at the poles.

5. The core temperature of the Sun is ____________________________.

6. A planet has three criteria: it orbits the ______________________________, has ___________________________ its orbit of smaller objects, and is large enough so its own _________________________ makes it round.

7. There are three types of planets: _______________________, ____________________________, and ___________________.

8. ___________________is the closest, but not the hottest planet. The side facing the Sun gets to ___________________ºF, and the side facing away from the Sun gets to _______________________ ºF.

9. The solar system includes ___________________ planets, their ________________, the ______________ at the center, and smaller objects such as ____________________and _______________________.

10. The Sun is made out of 75% _______________ and 25% _________________.

11. Venus is called the goddess of ___________________, because it looks so bright to us from Earth, but it really has a surface temperature of ___________________ºF.

12. Comets are really dirty ____________________________________.

13. ________________is the brightest thing in the sky, other than the Sun and Moon.

14. Cold _________________ is what gives Uranus its blue-green color. It's classified as ______________ giant.

15. One day is longer than a year on ________________________. Not only that, it rotates _________________.

16. Earth's atmosphere is made up of 21% _____________ and 78% _______________.

17. The Moon pulls on the surface on the Earth and causes tides on both the __________ and ____________.

18. Mars's moons are named after _____________________ and _______________________.

19. _____________________ gives Mars its red color.

20. If the Earth was the size of a marble, Jupiter would be the size of a __________________________.

21. Jupiter can fit ________________________ Earths inside.

22. If you added more mass to ___________________________ it would get smaller because it's a big ball of _______________________.

23. Jupiter is made out of ______________________ and ______________________ with a metallic _______________ core.

24. The volcanoes on Jupiter's moon __________ spew ice ash __________________miles high.

25. Saturn is surrounded by rings made mostly of _______________ moving at _______________ mph.

26. Inside Saturn's rings are _______________.

27. Titan has an _______________________________ made mostly of _________________________, so thick that if you strapped wings onto your arms and flapped, you'd fly!

28. Scientists think that _______________________ used to have a ring around it, and it crashed down onto the surface.

29. Jupiter is so large that all of the _______________ in the solar system could fit inside of it.

30. ______________________ looks just like the Death Star.

31. The planet ____________________ rolls around the Sun while tipped on its side.

32. Phobos is slowly moving inward toward _______________ and will either shatter or form a ________________ around _________________________.

33. Our best guess is that the ice on Mercury was caused by ____________________________________

34. Average daily wind speed on Neptune is ____________ mph.

35. Neptune is a giant ball of ___________________, which is also known as ________________.

36. _________________ and Pluto are a pair of objects because they both rotate around a point outside of each. These two are also orbited by _____________ and ______________.

37. Seventy percent of the Earth's surface is covered by ______________________.

38. The Sun is ______________________________ miles from the Earth, also known as ___________________________.

39. The hottest planet is ____ because the heat that comes into the planet gets ____.

40. There are how many stars are in our solar system? ______________________________________

41. Which color stars are the hottest?________________________________ Coolest?____________________________

42. The _________________________ star is the biggest one we've found and it releases as much energy in one ______________________ as our Sun does in one year.

43. The planets and moons that people have walked on are____

44. Jupiter's _________________________ is getting ______________________. It's about the size of two ________________ right now.

45. _______________________ and _____________________ are gas giants, and ____________________ and ______________________ are ice giants.

46. _________________________ is the coldest planet in our solar system.

47. The five dwarf planets in our solar system are:

____

48. It takes light ______________________ to travel from the Sun to Earth.

49. ______________________ has so much volcanic activity that it constantly resurfaces itself.

50. What kind of ice is on Mars? ______________________ and ____________________________.

STOP!!!

You're done with the first activity!

Great job answering the questions! Staple your papers together (or put your name at the top of each page at the very least) and turn it in to your teacher for the second activity.

Remember, for this next part, **you MUST find the clues in order**, meaning that you have to find the object the clue is describing or it doesn't count. Your lab partners will help you. Have fun!

Lesson #3: Magnetic Tornadoes

Teacher Section

Overview: Students will do a demonstration that models the magnetic twisters on Mercury.

Suggested Time: 20-30 minutes

Objectives: This lab is a physical model of what happens on Mercury when two magnetic fields collide and form magnetic tornadoes.

Materials (per lab group)

- Two clear plastic bottles (2 liter soda bottles work best)
- Steel washer with a 3/8 inch hole
- Ruler and stopwatch
- Glitter or confetti (optional)
- Duct tape (optional)

Lab Preparation

1. Optional: two super-strong magnets. Refer to Lesson section (below) for information on how to use these as a quick demonstration.
2. Determine the different water conditions, such as: changing the temperature, changing the volume (height of water), adding another molecule such as oil, isopropyl alcohol, vinegar, and dish soap, adding solid pieces such as glitter, salt, sugar, or small grains. The different mixtures will give different vortex rotation speeds and different drain times. This is equivalent to changing the atmosphere on Earth and seeing how it affects weather (not magnetic) tornadoes. Write the conditions you wish to test in the data table before making copies.
3. Print out copies of the student worksheets.
4. Read over the Background Lesson Reading before teaching this class.
5. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Mercury looks peaceful at first glance. However, when you measure the surface with scientific instruments, you'll see how the Sun blasts away any hope Mercury has of a thin atmosphere with its radiation and solar wind. Not only that, Mercury is ravaged by invisible magnetic tornadoes that start from the planet's interior magnetic field. If you've ever experienced a tornado, you know how terrifying they can be. Now imagine they are the diameter of your entire planet.

These tornadoes are different from the Earth's, which form when two weather systems smack into each other, creating instability in the atmosphere. The magnetic tornadoes on Mercury form when two magnetic fields collide. These monstrous cyclones form without warning and disappear within minutes.

Magnetic fields, like the Earth's, are invisible shields that constantly protect us from the Sun. Our Earth is constantly being bombarded with high energy particles that are deflected off the magnetosphere of our planet. Mercury's magnetic field is weak and it's constantly being blasted by solar wind, which also carries a magnetic field. When these two fields collide, the magnetic fields spiral and twist to form a magnetic tornado. (Solar wind is a stream of high energy particles from the Sun's outer atmosphere.)

Lesson

1. Review the Background Reading and share tornado information with the kids.
2. I bring in two super-strong neodymium magnets and hand them to a student, asking them to take them apart and bring them back together north-to-north. While the student struggles, I talk to the students about how magnetic fields are invisible, and when they interact, unusual effects can be observed.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Assign each lab group a water condition in the data table.
3. Hand each group their materials and give them time to perform their experiment and write down their observations.
4. Fill one of the soda bottles with water using the data table below. (You can put in bits of paper or confetti for added fun.) Set the bottle upright on the table.
5. Set the washer on top of the bottle opening. Make sure there's no cap on the bottle.
6. Invert the empty bottle over the water-filled bottle and line up the openings so they can be easily taped together. You want to tape them before they get wet with the washer between them.
7. Place the two bottles on a table and watch the water drip from the top to the lower bottle as air bubbles move from bottom to top.
8. Invert so that the water is in the top bottle and circle it a couple of times to start a whirlpool in the bottle. You should see a vortex form inside as the top bottle drains into the lower bottle. The hole in the vortex lets the air from the lower bottle flow easily into the upper bottle, so the upper drains easily.
9. When you've finished your experiment, swap bottles with a lab partner and fill out the data table below.

Exercises

1. Define an atmosphere. (An envelope surrounding an object like a planet or a moon that is held in place by the object's gravitational field.)
2. What is a magnetic field? (A force field around a magnet.)
3. Where do magnetic fields come from in planets? (We think they originate from the molten metallic core of a planet. When the core cools off, the magnetic field disappears.)
4. Which planets do not have a magnetic field? (Venus does not because of its super-slow rotation, and Mars does not have a planet-wide magnetic field, though it does have magnetic hotspots.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #3: Magnetic Tornadoes

Student Worksheet

Name____

Overview: This lab is a physical model of what happens on Mercury when two magnetic fields collide and form magnetic tornadoes.

What to Learn: You'll get to investigate what an invisible magnetic tornado looks like when it sweeps across Mercury.

Materials

- Two clear plastic bottles (2 liter soda bottles work best)
- Steel washer with a 3/8 inch hole
- Ruler and stopwatch
- Glitter or confetti (optional)
- Duct tape (optional)

Lab Time

1. Fill one of the soda bottles with water using the data table below. Your teacher will assign you a water condition. (You can put in bits of paper or confetti for added fun.) Set the bottle upright on the table.
2. Set the washer on top of the bottle opening. Make sure there's no cap on the bottle.
3. Invert the empty bottle over the water-filled bottle and line up the openings so they can be easily taped together. You want to tape them before they get wet with the washer between them.
4. Place the two bottles on a table and watch the water drip from the top to the lower bottle as air bubbles move from bottom to top.
5. Invert so the water is in the top bottle and circle it a couple of times to start a whirlpool in the bottle. You should see a vortex form inside as the top drains into the lower bottle. The hole in the vortex lets the air from the lower bottle flow easily into the upper bottle, so the upper drains easily.
6. When you've finished your experiment, swap bottles with a lab partner and fill out the data table below.

Magnetic Tornadoes Data Table

Note: Water height is measured when all the water is in the lower container.

Water Condition	Height of the Water	How Long Did It Take to Drain to Lower Bottle? *(measure in seconds)*

Exercises Answer the questions below:

1. Define an atmosphere.

2. What is a magnetic field?

3. Where do magnetic fields come from in planets?

4. Which planets do not have a magnetic field?

Lesson #4: Sky in a Jar

Teacher Section

Overview Why is the sky blue? Why is the sunset red? This lab will answer those questions by showing how light is scattered by the atmosphere.

Suggested Time 30-45 minutes

Objectives Particles in the atmosphere determine the color of the planet and the colors we see on its surface.

Materials (per lab group)

- Glass jar
- Flashlight
- Fingernail polish (red, yellow, green, blue)
- Clear tape
- Water
- Dark room
- Few drops of milk

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Why is the sunset red? The colors you see in the sky depend on how light bounces around. The red/orange colors of sunset and sunrise happen because of the low angle the Sun makes with the atmosphere, skipping the light off dust and dirt (not to mention solid aerosols, soot, and smog). Sunsets are usually more spectacular than sunrises, as more "stuff" floats around at the end of the day (there are less particles present in the mornings). Sometimes just after sunset, a green flash can be seen ejecting from the setting Sun.

The Earth appears blue to the astronauts in space because the shorter, faster wavelengths are reflected off the upper atmosphere. The sunsets appear red because the slower, longer wavelengths bounce off the clouds.

Sunsets on other planets are different because they are farther (or closer) to the Sun, and also because they have a different atmosphere than planet Earth. The image shown here is a sunset on Mars.

Lesson

1. The Earth appears blue to the astronauts in space because the shorter, faster wavelengths are reflected off the upper atmosphere. The sunsets appear red because the slower, longer wavelengths bounce off the clouds.
2. Uranus and Neptune appear blue because the methane in the upper atmosphere reflects the Sun's light and the methane absorbs the red light, allowing blue to bounce back out.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Make your room as *dark* as possible for this experiment to work.
4. Make sure your label is removed from the glass jar or you won't be able to see what's going on.
5. Fill the clear glass jar with water.
6. Add a teaspoon or two of milk (or cornstarch) and swirl.
7. Shine the flashlight down from the top and look from the side – the water should have a bluish hue. The small milk droplets scatter the light the same way our atmosphere dust particles scatter sunlight.
8. Try shining the light up from the base – where do you need to look in order to see a faint red/pink tint? If not, it's because you are looking for hues that match our real atmosphere, and the jar just isn't that big, nor is your flashlight strong enough! Instead, look for a very *slight* color shift. If you do this experiment after being in the dark for about 10 minutes (letting your eyes adjust to the lack of light), it is easier to see the subtle color changes. Just be careful that you don't let the brilliant flashlight ruin your newly acquired night vision, or you'll have to start the 10 minutes all over again.
9. If you are still having trouble seeing the color changes, shine your light through the jar and onto an index card on the other side. You should see slight color changes on the white card.
10. Cover the flashlight lens with clear tape.
11. Paint on the tape (not the lens) the fingernail polish you need to complete the table below.
12. Repeat steps 7-9 and record your data.

Exercises

1. What colors does the sunset go through? (The sunset goes through the colors of the rainbow as the Sun sets lower in the sky, starting with yellow, then orange, and then red as it sets.)
2. Does the color of the light source matter? (Yes. White light gives the best results.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #4: Sky in a Jar

Student Worksheet

Name____

Overview: Have you ever wondered why the sky is blue? Or why the sunset is red? Or what color our sunset would be if we had a blue giant instead of a white star? This lab will answer those questions by showing how light is scattered by the atmosphere.

What to Learn: Particles in the atmosphere determine the color of the planet and the colors we see on its surface. The color of the star also affects the color of the sunset and of the planet.

Materials

- Glass jar
- Flashlight
- Fingernail polish (red, yellow, green, blue)
- Clear tape
- Water
- Dark room
- Few drops of milk

Lab Time

1. Make your room as *dark* as possible for this experiment to work.
2. Make sure your label is removed from the glass jar or you won't be able to see what's going on.
3. Fill the clear glass jar with water.
4. Add a teaspoon or two of milk (or cornstarch) and swirl.
5. Shine the flashlight down from the top and look from the side – the water should have a bluish hue. The small milk droplets scatter the light the same way our atmosphere's dust particles scatter sunlight.
6. Try shining the light up from the base – where do you need to look in order to see a faint red/pink tint? If not, it's because you are looking for hues that match our real atmosphere, and the jar just isn't that big, nor is your flashlight strong enough! Instead, look for a very *slight* color shift. If you do this experiment after being in the dark for about 10 minutes (letting your eyes adjust to the lack of light), it is easier to see the subtle color changes. Just be careful that you don't let the brilliant flashlight ruin your newly acquired night vision, or you'll have to start the 10 minutes all over again.
7. If you are still having trouble seeing the color changes, shine your light through the jar and onto an index card on the other side. You should see slight color changes on the white card.
8. Cover the flashlight lens with clear tape.
9. Paint on the tape (not the lens) the fingernail polish you need to complete the table below.
10. Repeat steps 7-9 and record your data.

Sky in a Jar Data Table

Flashlight Color	Location	Color(s)
White	*Side of jar*	
White	*Bottom of Jar*	
Red	*Side of jar*	
Red	*Bottom of Jar*	
Yellow	*Side of jar*	
Yellow	*Bottom of Jar*	
Green	*Side of jar*	
Green	*Bottom of Jar*	
Blue	*Side of jar*	
Blue	*Bottom of Jar*	

Exercises Answer the questions below:

1. What colors does the sunset go through?

2. Does the color of the light source matter?

Lesson #5: Planetary Magnetic Fields

Teacher Section

Overview: I can still remember in second-grade science class wondering about this idea. And I still remember how baffled my teacher was when I asked her this question: *"Doesn't the north tip of a compass needle point to the south pole?"* Think about this – if you hold up a magnet by a string, just like the needle of a compass, does the north end of the magnet line up with the north or south pole of the Earth?

Suggested Time: 30-45 minutes

Objectives: Students are going to learn how compasses turn with the force of the magnetic field. They will measure the field from a magnet by mapping the two different poles and how the lines of force connect the two. A magnetic field must come from a north pole of a magnet and go to a south pole of a magnet (or atoms that have turned to the magnetic field.)

Materials (per lab group)

- Magnets: bar magnet, horseshoe magnet, and a circular (disk) magnet
- Compass
- String
- Ruler

Lab Preparation

1. Print out copies of the student worksheets.
2. Watch the video for this experiment to prepare for teaching this class.
3. Precut the string into 12" pieces, one per lab group.
4. Read over the Background Lesson Reading before teaching this class.

Background Lesson Reading

Right under your feet, there's a magnet. Go ahead take a look. Lift up your feet and see what's under there. Do you see it? It's huge! In fact, it's the largest magnet on the Earth. As a matter of fact, it is the Earth! That's right; the Earth is one huge, gigantic, monolithic magnet! We're going to use a magnet to substitute for the Earth and plot out the magnetic field lines.

Lesson

1. The magnetic pole which was attracted to the Earth's North Pole was labeled as the *Boreal* or "north-seeking pole" in the 1200s, which was later shortened to "north pole." To add to the confusion, geologists call this pole the North Magnetic Pole.
2. Kids are going to make their own compasses in one of the next lessons; however you might want to demo how a compass is magnetized by skipping ahead and making a model right in front of them so they can see how and why it works.
3. After the kids play with their magnets and compasses, lead them through the steps for charting magnetic lines.

4. Kids will use their compasses to introduce them to the idea of the Earth's magnetic field. If you remember about magnets, you know that opposites attract; so the north tip of the compass will line up with the Earth's SOUTH Pole. So compasses are upside-down!

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups. Hand each group their materials.
2. Tie a string around your magnet.
3. Bring it close to the compass.
4. Which end is the north end of your magnet? Label it with a pencil right on the magnet.
5. Flip the magnet around by twisting the string so that the compass flips to the opposite pole. Label the opposite site of the magnet with the appropriate letter (N or S).
6. Bring a second magnet close to the first one. What happens when you bring two opposite poles together? What if the poles are the same?

Now untie or cut the string for the next part of your lab.

7. Lay a piece of paper on your desk.
8. Place one of the magnets in the middle of the paper and trace the outline.
9. Draw 12 dots (just like on a clock) all the way around the magnet. These are the locations where you will place your compass, so make sure that they are close enough to the magnet so the magnet influences the compass.
10. Place your compass on one of the dots and look at the direction the arrow is pointing. Remove the compass and draw that exact arrow direction right over your dot. Do this for all twelve dots.
11. Draw another ring of dots an inch or two out from the first ring and repeat step 9.
12. Repeat steps 7-11 for the horseshoe magnet.
13. Repeat steps 7-11 for the circular disk magnet.

Exercises

1. How are the lines of force different for the two magnets? (Since this is going to depend on the kind of magnets you use, refer to the data collected.)
2. How far out (in inches measured from the magnet) does the magnet affect the compass? (Since this is going to depend on the kind of magnets you use, refer to the data collected.)
3. What makes the compass move around? (The magnetic lines of force that are invisible to your eye.)
4. Do you think the compass's *north-south* indicator is flipped, or the Earth's North Pole where the South Pole is? How do you know? (It's an arbitrary denotation, but the Earth's North Pole is deemed to be north.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #5: Planetary Magnetic Fields

Student Worksheet

Name____

Overview: You're going to use a compass to figure out the magnetic lines of force from a magnet by mapping the two different poles and how the lines of force connect the two. A magnetic field must come from a north pole of a magnet and go to a south pole of a magnet (or atoms that have turned to the magnetic field.)

What to Learn: Compasses are influenced by magnetic lines of force. These lines are not necessarily straight. When they bend, the compass needle moves. The Earth has a huge magnetic field. The Earth has a weak magnetic force. The magnetic field comes from the moving electrons in the currents of the Earth's molten core. The Earth has a north and a south magnetic pole which is different from the geographic North and South Pole.

Materials

- Bar magnet
- Horseshoe magnet
- Circular (disk) magnet
- Compass
- String
- Ruler

Lab Time

1. Tie a string around your magnet.
2. Bring it close to the compass.
3. Which end is the north end of your magnet? Label it with a pencil right on the magnet.
4. Flip the magnet around by twisting the string so that the compass flips to the opposite pole. Label the opposite site of the magnet with the appropriate letter (N or S).
5. Bring a second magnet close to the first one. What happens when you bring two opposite poles together? What if the poles are the same? Write down your observations here:

____

____

____

Now untie or cut the string for the next part of your lab.

6. Lay a piece of paper on your desk.
7. Place the magnet in the middle of the paper and trace the outline.
8. Draw 12 dots (just like on a clock) all the way around the magnet. These are the locations where you will place your compass, so make sure that they are close enough to the magnet so the magnet influences the compass.
9. Place your compass on one of the dots and look at the direction the arrow is pointing. Remove the compass and draw that exact arrow direction right over your dot. Do this for all 12 dots.
10. Draw another ring of dots an inch or two out from the first ring and repeat step 9.
11. Repeat steps 6-10 with a circular magnet on a new sheet of paper.
12. Repeat steps 6-10 for the horseshoe magnet on another sheet of paper.

Exercises

1. How are the lines of force different for the two magnets?

2. How far out (in inches measured from the magnet) does the magnet affect the compass?

3. What makes the compass move around?

4. Do you think the compass's *north-south* indicator is flipped, or the Earth's North Pole where the South Pole is? How do you know?

Lesson #6: Seasons

Teacher Section

Overview: One common misconception is that the seasons are caused by how close the Earth is to the Sun. Students will perform an experiment that shows how the seasons are affected by axis tilt, not by distance from the Sun.

Suggested Time: 30-45 minutes

Objectives: The seasons are caused by the Earth's axis tilt of 23.4^{o} from the ecliptic plane. Students will also understand the position of the Sun in the sky changes during the course of the day and from season to season.

Materials (per lab group)

- Bright light source (not fluorescent)
- Balloon
- Protractor
- Masking tape
- 2 liquid crystal thermometers
- Ruler, yardstick or meter stick
- Marker

Lab Preparation

1. Blow up the balloons. You'll need one per lab group.
2. Print out copies of the student worksheets.
3. Read over the Background Lesson Reading before teaching this class.
4. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

The North and South Poles only experience two seasons: winter and summer. During a South Pole winter, the Sun will not rise for several months, and also the Sun does not set for several months in the summer. We go into more detail about how this works in a later lesson entitled: *Star Trails and Planet Patterns*.

At the equator, there's a wet season and a dry season due to the tropical rain belt. Since the equator is always oriented at the same position to the Sun, it receives the same amount of sunlight and always feels like summer.

The changing of the seasons is caused by the angle of the Sun. For example, in June during summer solstice, the Sun is high in the sky for longer periods of time, which makes warmer temperatures for the Northern Hemisphere. During the December winter solstice, the Sun spends less time in the sky and is positioned much lower. This makes the winters colder. (Don't forget that seasons are also affected by oceans and winds, though this is out of the scope of this particular activity.)

Lesson

1. Activity notes: This activity can be done solely as a demonstration if you prefer (or are short of materials). This may not be an option, but one time we didn't have enough lamps, so I drove up with my car and used

the car headlights. I've also brought in lamps with 100W bulbs (without lamp shades) and had a couple of lab teams work with each one.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Place the lamp in the middle of the desk. Make sure there's room to walk all the way around it. You'll want to circle the lamp at a distance of about 2 feet away.
4. Mark on the floor with tape and label the four positions: winter, spring, summer, and fall. They should be at the 12, 3, 6, and 9 o'clock positions. Winter is directly across from summer. The Earth rotates counterclockwise around the Sun when viewed from above.
5. Blow up your balloon so it's roughly round-shaped (don't blow it up all the way). Mark and label the north and south poles with your marker. Draw an equator around the middle circumference.
6. The Earth doesn't point its north pole straight up as it goes around the Sun. It's tilted over 23.4^o. Here's how you find this point on your balloon:
    a. Put the South Pole mark on the table, with north pointing straight up. Find the midway point between the equator and the North Pole and make a tiny mark. This is the 45^o latitude point. You'll need this to find the 23^o mark.
    b. Find the midway point between the 45^o mark and the North Pole and make another mark, larger this time and label it with 23^o. When this mark is pointing up, the Earth is tilted over the right amount.
    c. You'll need to do this three more times so you can draw a line connecting the dots. You want to draw the latitude line at 23^o so you can rotate the balloon as you move around to the different seasons. The line will always be pointed up.
7. Place the thermometers on the balloon at these locations:
    a. Find the halfway point between the South Pole and the equator. Put one thermometer on this mark.
    b. Put the other thermometer on the northern hemisphere's 45^o mark from above.
8. Make sure your lamp is facing the balloon as you stand on summer. Let the balloon be heated by the lamp for a couple of minutes and then record the temperature in the data table.
9. Rotate the lamp to point to fall. Move your balloon to fall, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading.
10. Rotate the lamp to point to winter. Move your balloon to winter, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading.
11. Rotate the lamp to point to spring. Move your balloon to spring, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading. You've completed a data set for planets with an axis tilt of about 23^o, which includes the Earth, Mars, Saturn and Neptune.
12. Repeat steps 3-11 for Mercury. Note that Mercury does not have an axis tilt, so the North Pole really points straight up. Jupiter (3.1^o axis tilt) and Venus (2.7^o) are very similar. The Moon's axis tilt is 6.7^o, so you can approximate these four objects with this data set.
13. Repeat steps 3-11 for Uranus. Since the axis tilt is 97.8^o, you can approximate this by pointing the North Pole straight at the Sun during summer. The orbit for Uranus is 84 years, which means 21 years passes between each season. The North Pole will experience continues sunlight for 42 years from spring through fall, then darkness for 42 years.

Exercises

1. What is the main reason we have seasons on Earth? (Because the axis is tilted 23.4^{o}, exposing one hemisphere to more sunlight each day and warming the planet.)
2. Why are there no sunsets on Uranus for decades? (The orbit for Uranus is 84 years, which means 21 years pass between each season. The north pole will experience continued sunlight for 42 years from spring through fall, then darkness for 42 years.)
3. Are there seasons on Venus? (No. It's the same temperature (460^{o}C) everywhere you go on the planet for two reasons: first the axis tilt makes almost difference between summer and winter. Second, the thick atmosphere traps the heat, which flows around the planet.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #6: Seasons

Student Worksheet

Name____

Overview: One common misconception is that the seasons are caused by how close the Earth is to the Sun. Today you get to do an experiment that shows how seasons are affected by axis tilt, not by distance from the Sun. And you also find out which planet doesn't have sunlight for 42 years.

What to Learn The seasons are caused by the Earth's axis tilt of 23.4^o from the ecliptic plane.

Materials

- Bright light source (not fluorescent)
- Balloon
- Protractor
- Masking tape
- 2 liquid crystal thermometers
- Ruler, yardstick or meter stick
- Marker

Lab Time

1. Place the lamp in the middle of the desk. Make sure there's room to walk all the way around it. You'll want to circle the lamp at a distance of about 2 feet away.
2. Mark on the floor with tape and label the four positions: winter, spring, summer, and fall. They should be at the 12, 3, 6, and 9 o'clock positions. Winter is directly across from summer. The Earth rotates counterclockwise around the Sun when viewed from above.
3. Blow up your balloon so it's roughly round-shaped (don't blow it up all the way). Mark and label the north and south poles with your marker. Draw an equator around the middle circumference.
4. The Earth doesn't point its north pole straight up as it goes around the Sun. It's tilted over 23.4^o. here's how you find this point on your balloon:
    a. Put the South Pole mark on the table, with north pointing straight up. Find the midway point between the equator and the North Pole and make a tiny mark. This is the 45^o latitude point. You'll need this to find the 23^o mark.
    b. Find the midway point between the 45^o mark and the North Pole and make another mark, larger this time and label it with 23^o. When this mark is pointing up, the Earth is tilted over the right amount.
    c. You'll need to do this three more times so you can draw a line connecting the dots. You want to draw the latitude line at 23^o so you can rotate the balloon as you move around to the different seasons. The line will always be pointed up.
5. Place the thermometers on the balloon at these locations:
    a. Find the halfway point between the South Pole and the equator. Put one thermometer on this mark.
    b. Put the other thermometer on the northern hemisphere's 45^o mark from above.
6. Make sure your lamp is facing the balloon as you stand on summer. Let the balloon be heated by the lamp for a couple of minutes and then record the temperature in the data table.

7. Rotate the lamp to point to fall. Move your balloon to fall, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading.
8. Rotate the lamp to point to winter. Move your balloon to winter, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading.
9. Rotate the lamp to point to spring. Move your balloon to spring, rotating the balloon so that the thermometers are facing the lamp. Wait a few more minutes and take another reading. You've completed a data set for planets with an axis tilt of about 23°, which includes the Earth, Mars, Saturn and Neptune.
10. Repeat steps 1-9 for Mercury. Note that Mercury does not have an axis tilt, so the North Pole really points straight up. Jupiter (3.1° axis tilt) and Venus (2.7°) are very similar. The Moon's axis tilt is 6.7°, so you can approximate these four objects with a 0° axis tilt.
11. Repeat steps 1-9 for Uranus. Since the axis tilt is 97.8°, you can approximate this by pointing the north pole straight at the Sun during summer (90° axis tilt). The orbit for Uranus is 84 years, which means 21 years passes between each season. The north pole will experience continued sunlight for 42 years from spring through fall, then darkness for 42 years.

Seasons Data Table

Don't forget to circle or label your units!
Note that Uranus's axis tilt is approximated by 90° and Venus, Jupiter, and Mercury's axis tilt are approximated by 0°

Axis Tilt	Season	Northern Hemisphere Temperature (°C / °F)	Southern Hemisphere Temperature (°C / °F)
23°	*Summer*		
23°	*Fall*		
23°	*Winter*		
23°	*Spring*		
0°	*Summer*		
0°	*Fall*		
0°	*Winter*		
0°	*Spring*		
90°	*Summer*		
90°	*Fall*		
90°	*Winter*		
90°	*Spring*		

Exercises Answer the questions below:

1. What is the main reason we have seasons on Earth?
2. Why are there no sunsets on Uranus for decades?
3. Are there seasons on Venus?

Lesson #7: Indoor Rain Clouds

Teacher Section

Overview: Students get to vaporize liquid oceans of molecules and make it rain when the rising cloud decks hit the coldness of space. All right at their desks.

Suggested Time: 30-45 minutes

Objectives: This lab demonstrates the movement of planetary atmospheres as temperature changes.

Materials (per lab group)

- Glass of ice water
- Glass of hot water
- Towel
- Ruler

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

This experiment demonstrates state changes of matter. When hot vapor rises (like from the hot core of a gaseous planet) and hits a cold front (like the coldness of outer space in the upper atmosphere), the vapor condenses into liquid drops and rains, or can even freeze solid into ice chunks. Neptune and Uranus both have methane ice in their upper atmospheres. Both Jupiter and Saturn have upper cloud decks of water vapor and clouds of ammonia. The water vapor clouds are right at the freezing temperature of water.

Lesson

1. Please be careful with this lab! The hot water can burn the kids. If you prefer, you can give this as a homework assignment and give the responsibility of the kid's safety to the parents.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Take two clear glasses that fit snugly together when stacked. (Cylindrical glasses with straight sides work well.)

4. Fill one glass half-full with ice water and the other half-full with very hot water (definitely an adult job – and take care not to shatter the glass with the hot water!). Be sure to leave enough air space for the clouds to form in the hot glass.
5. Place the cold glass directly on top of the hot glass and wait several minutes. If the seal holds between the glasses, a rain cloud will form just below the bottom of the cold glass, and it actually rains inside the glass! (You can use a damp towel around the rim to help make a better seal, if needed.)

Exercises

1. Which combination made it rain the best? Why did this work? (The greater the temperature difference, the better this experiment will work. The more water you have, the less the temperature will fluctuate for each glass, thus making it able to rain for longer periods of time.)
2. Draw your experimental diagram here, labeling the different components:
3. Add in labels for the different phases of matter. Can you identify all three states of matter in your experiment? (Ice = solid; water = liquid, gas between two glasses is water vapor, nitrogen, and oxygen.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #7: Indoor Rain Clouds

Student Worksheet

Name____

Overview: Today you get to vaporize liquid oceans of molecules and make it rain when the rising cloud decks hit the coldness of space. Sound like fun?

What to Learn: The movement of atmospheres on different planets is affected by the temperature of the planet and the molecules in the atmosphere.

Materials

- Glass of ice water
- Glass of hot water
- Towel
- Ruler

Lab Time

1. Take two clear glasses that fit snugly together when stacked. (Cylindrical glasses with straight sides work well.)
2. Fill one glass half-full with ice water and the other half-full with very hot water (definitely an adult job – and take care not to shatter the glass with the hot water!). Be sure to leave enough air space for the clouds to form in the hot glass.
3. Place the cold glass directly on top of the hot glass and wait several minutes. If the seal holds between the glasses, a rain cloud will form just below the bottom of the cold glass, and it actually rains inside the glass! (You can use a damp towel around the rim to help make a better seal, if needed.)
4. Complete the table below. Measure the water height carefully with your ruler. If you have 2" of water in the hot water glass, then write 2". Please be careful when measuring hot water!

Indoor Rain Clouds Data Table

Hot Water Height	Ice Water Height	How well did it rain?

Exercises Answer the questions below:

1. Which combination made it rain the best? Why did this work?

2. Draw your experimental diagram here, labeling the different components:

3. Add in labels for the different phases of matter. Can you identify all three states of matter in your experiment?

Lesson #8: Volcanoes

Teacher Section

Overview: Mars has some of the biggest canyons and the highest volcanoes in the solar system. Valles Marineris measures 2,800 feet wide and 4 miles deep. That's 40 times the size of the Grand Canyon. And Olympus Mons is 15 ½ miles high, nearly three times the size of Mount Everest. So how does this happen? That's what this lab will help you figure out.

Suggested Time: 30-45 minutes

Objectives: Students will investigate the different gas-generating chemical reactions similar to those found with Martian volcanoes.

Materials (per lab group)

- Look over the Lab Time for a complete list of materials. There are several variations to choose from.

Lab Preparation

1. I do this lab outdoors, because of the mess it makes that seems to flow everywhere. Find a nice-weather day and do this outside.
2. Print out copies of the student worksheets.
3. Read over the Background Lesson Reading before teaching this class.
4. Watch the video for this experiment to prepare for teaching this class.
5. There are a couple of choices with this experiment. You get to pick what the volcano is made out of (there are two different dough recipes), and also which kind of chemical reaction you'd like to demonstrate (there are two different ones here, too). If you're in a hurry, use a slab of clay for the dough and use the first set of chemicals.
6. If you'd like the kids to fill out the data table for their experiment (this is questionable, as it's going to be a messy lab), then you'll need measuring cups for each team. Make simple ones from paper cups with marks on the side.

Background Lesson Reading

Mars is a litter box for volcanoes. Some of these volcanoes are dead, but others are simply dormant. Nearly all volcanoes on Mars are shield volcanoes, created by currents and hotspots beneath the surface (just like the ones in Hawaii). There are so many volcanoes on Mars that scientists have drawn lines to corral them into volcanic provinces. Without tectonic plates, the currents under the volcanoes can flow easily and freely.

Lesson

1. Have you ever noticed how lots of volcanic rocks have bubbles inside? The gas that bubbled up through the rocks as they cooled gives them a porous appearance.
2. What do you think would happen if the lava doesn't make it all the way out of the volcano? It cools and coats the inside, and then gets reheated with the next explosion. This can happen over and over again, making the lava undergo some pretty radical changes, molecularly speaking.

3. The reaction the kids are making today is similar to the action Mars saw with its shield volcanoes. The gas produced is carbon dioxide. The bubbles that get trapped inside make pockets, and the dish soap helps them stay as bubbles long enough for you to catch them in action.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. The first thing you will do is mix up volcano dough. There are two different recipes provided with this lab: Standard Volcano Dough is just like play dough, and Earthy Volcano Dough looks more like the real thing. Pick one and make it first. Then proceed to the chemical reactions.

<u>**Making the Volcano**</u>

Standard Volcano Dough

a. Mix together 6 cups flour, 2 cups salt, ½ cup vegetable oil, and 2 cups warm water.
b. The resulting mixture should be firm but smooth.
c. Stand a water or soda bottle in a roasting pan and mold the dough around it into a volcano shape.

Earthy Volcano Dough

a. Mix 2½ cups flour, 2½ cups dirt, 1 cup sand, and 1½ cups salt.
b. Add water by the cup until the mixture sticks together.
c. Build the volcano around an empty water bottle on a disposable turkey-style roasting pan.
d. It will dry in two days if you have the time, but why wait? You can erupt when wet if the mixture is stiff enough! (And if it's not, add more flour until it is).

<u>**Chemical Reactions:**</u>

Soda Volcanoes

a. Fill the bottle most of the way with warm water and a bit of red food coloring.
b. Add a splash of liquid soap and ¼ cup baking soda. Stir gently.
c. When ready, add vinegar in a steady stream and watch that lava flow.

Air Pressure Sulfur Volcanoes

a. Wrap the volcano dough around an 18" piece of clear, flexible tubing.
b. Shape the dough into a volcano and place in a disposable roasting pan.
c. Push and pull the tube from the bottom until the other end of the tube is just below the volcano tip. If you clog the ends of the tubing with clay, just trim away the clog with scissors.
d. Using your fingers, shape the inside top of the volcano to resemble a small paper cup.
e. Your solution needs a chamber to mix and grow in before overflowing down the mountain. The tube goes at the bottom of the clay-cup space.
f. Be sure the volcano is SEALED to the cookie sheet at the bottom. You won't want the solution running out of the bottom of the volcano instead of popping out the top!

Make your chemical reactants for Air Pressure Sulfur Volcanoes:

g. *Solution 1:* Fill one bucket halfway with warm water and add 1 to 2 cups baking soda. Add 1 cup of liquid dish soap and stir very gently so you don't make too many bubbles.
h. *Solution 2:* Fill a second bucket halfway with water and add 1 cup of aluminum sulfate (also called alum; find this in the gardening section of the hardware store or check the spice section of the grocery store). Add red food coloring and stir.
i. Putting it all together: Count ONE (and pour in Solution 1) … TWO (inhale air only!) …… and THREE (pour in Solution 2 as you put your lips to the tube from the bottom of the volcano and puff as hard as you can!) Lava should not only flow but burp and spit all over the place!

Exercises

1. How is this activity similar to the volcanoes on Mars? (The bubbles that get trapped inside make pockets, and the dish soap helps them stay as bubbles long enough for you to catch them in action).
2. What gas is produced with this reaction? (Carbon dioxide)
3. Which planets have volcanoes, active or extinct? (Mercury, Mars, Venus, Earth, Io (moon of Jupiter), Triton (moon of Neptune), Enceladus (moon of Saturn), and our very own Moon.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #8: Volcanoes

Student Worksheet

Name____

Overview: Mars has some of the biggest canyons and the highest volcanoes in the solar system. Valles Marineris measures 2,800 feet wide and 4 miles deep. That's 40 times the size of the Grand Canyon. And Olympus Mons is 15 ½ miles high, nearly three times the size of Mount Everest. So how does this happen? That's what this lab will help you figure out.

What to Learn: The reaction you are making today is similar to the action Mars saw with its shield volcanoes. The gas produced is carbon dioxide. The bubbles that get trapped inside make pockets, and the dish soap helps them stay as bubbles long enough for you to catch them in action.

Lab Time

1. The first thing you will do is mix up volcano dough. There are two different recipes provided with this lab: Standard Volcano Dough is just like play dough, and Earthy Volcano Dough looks more like the real thing. Your teacher will let you know which one you are to make. Then proceed to the chemical reaction that your teacher has selected for you.

   <u>Making the Volcano</u>

   Standard Volcano Dough
   a. Mix together 6 cups flour, 2 cups salt, ½ cup vegetable oil, and 2 cups warm water.
   b. The resulting mixture should be firm but smooth.
   c. Stand a water or soda bottle in a roasting pan and mold the dough around it into a volcano shape.

   Earthy Volcano Dough
   a. Mix 2½ cups flour, 2½ cups dirt, 1 cup sand, and 1½ cups salt.
   b. Add water by the cup until the mixture sticks together.
   c. Build the volcano around an empty water bottle on a disposable turkey-style roasting pan.
   d. It will dry in two days if you have the time, but why wait? You can erupt when wet if the mixture is stiff enough! (And if it's not, add more flour until it is.)

   <u>Chemical Reactions:</u>

   Soda Volcanoes
   a. Fill the bottle most of the way with warm water and a bit of red food coloring.
   b. Add a splash of liquid soap and ¼ cup baking soda. Stir gently.
   c. When ready, add vinegar in a steady stream and watch that lava flow.

   Air Pressure Sulfur Volcanoes
   a. Wrap the volcano dough around an 18" piece of clear, flexible tubing.
   b. Shape the dough into a volcano and place in a disposable roasting pan.

c. Push and pull the tube from the bottom until the other end of the tube is just below the volcano tip. If you clog the ends of the tubing with clay, just trim away the clog with scissors.
d. Using your fingers, shape the inside top of the volcano to resemble a small paper cup.
e. Your solution needs a chamber to mix and grow in before overflowing down the mountain. The tube goes at the bottom of the clay-cup space.
f. Be sure the volcano is SEALED to the cookie sheet at the bottom. You won't want the solution running out of the bottom of the volcano instead of popping out the top!

Make your chemical reactants for Air Pressure Sulfur Volcanoes:

g. *Solution 1:* Fill one bucket halfway with warm water and add 1 to 2 cups baking soda. Add 1 cup of liquid dish soap and stir very gently so you don't make too many bubbles.
h. *Solution 2:* Fill a second bucket halfway with water and add 1 cup of aluminum sulfate (also called alum.) Add red food coloring and stir.
i. Putting it all together: Count ONE (and pour in Solution 1) … TWO (inhale air only!) …… and THREE (pour in Solution 2 as you put your lips to the tube from the bottom of the volcano and puff as hard as you can!) Lava should not only flow but burp and spit all over the place!

Soda Volcanoes Data Table

How Much Baking Soda?	**How Much Vinegar?**	**How Long Did It React?** *(measure in seconds)*

Air Pressure Sulfur Volcanoes Data Table

Note: Don't blow through the tube when taking your data.

How Much Solution 1?	**How Much Solution 2?**	**How Long Did It React?** *(measure in seconds)*

Exercises Answer the questions below:

1. How is this activity similar to the volcanoes on Mars?

2. What gas is produced with this reaction?

3. Which planets have volcanoes?

Lesson #9: Star Gazing

Teacher Section

Overview: We're going to learn how to go star gazing using planetarium software, and how to customize to your location in the world so you know what you're looking at when you look up into the sky tonight!

Suggested Time: 30-45 minutes

Objectives: Students will investigate how objects in the sky move in regular and predictable patterns, and how the patterns of stars stay the same, although they appear to move across the sky nightly, and how different stars can be seen in different seasons.

Materials (per lab group)

- Planetarium software (Stellarium is free at this link: http://www.stellarium.org/)
- OR use a star wheel (http://www.skyandtelescope.com/letsgo/familyfun/Make_a_Star_Wheel.html)

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. This lab can be taught in a number of ways, including doing the computer simulation as a demonstration in front of the entire class, and assigning computer work for homework tonight, having students work at computer stations while you check over their work, or anything in between.

Background Lesson Reading

Telescopes and binoculars are pretty useless unless you know where to point them. I am going to show you some standard constellations and how to find them in the night sky, so you'll never be lost again in the ocean of stars overhead. You'll need to download and install Stellarium Planetarium Software before watching the instructional video to get the most out of this lesson.

Lab Time

You're about to locate several different celestial objects by first finding them in your planetarium software (or after assembling your star wheel.

1. If you haven't already, customize your planetarium software to your location by entering in your location and elevation.
2. Now adjust the time so that it's set to the time you'd like to star gaze tonight. What time will you star gaze tonight? Write it here… Time:________________________
3. For folks in the Northern Hemisphere, find the Big Dipper (or the Plough). For Southern Hemisphere folks, find the Southern Cross (or the Crux, but it really looks like a big kite). These are one of the most recognizable patterns, and easy for beginners to find.
4. For Northerners, use the Big Dipper to locate Polaris, the North Star. The two stars at the edge of the dipper point straight to the North Star.
5. For Southerners, use the Southern Cross to find the south pole of the sky (sometimes called the "south pole pit" since there's no star there at the exact pole point of the southern sky). The longer bar in the cross points almost exactly toward the South Pole.
6. Using the Search option, find the planets that will be visible tonight by typing in their name into the search window. Which ones will be visible for you tonight?

   Planet Name: Where is it in the sky? (Where should you look?)

   ____

   ____

   ____

7. In Stellarium, click the "Search" icon, then the "Lists" tab, and select "Constellations". Select two different constellations you'd like to find tonight that are visible to you, and record information about them here:

   Constellation Name: Pointer Stars/Location Indicators (How will you find it?):

   ____

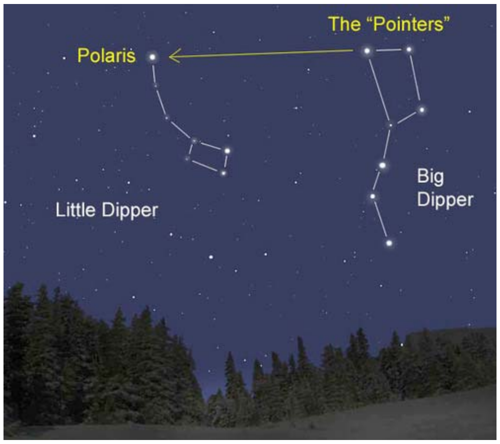
   ____

8. When you're ready, flip over to the observing data table, grab a flashlight, pencil, and then go outside to log your observations, just like a real scientist!

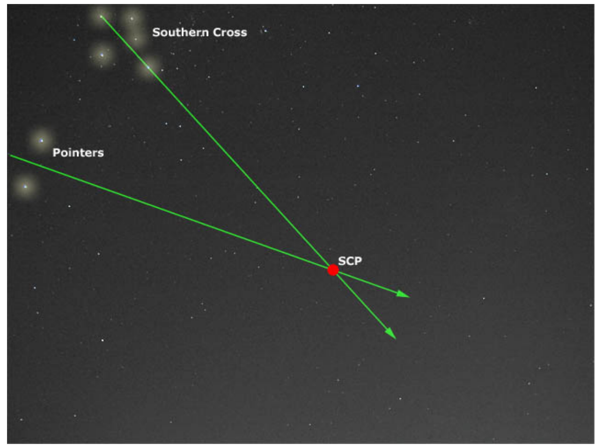
Observing Tip: Try to observe when the moon is less than first quarter phase or more than three quarters (meaning that the moon is less than 50% illuminated). You don't need any fancy viewing equipment, only your log sheet, and if you can do it, bring your planetarium software program with you outside to help you locate the objects. Start small, and find a couple of things on the first night. If you don't figure it out the first time, try again the next night. I learned the northern sky by learning one new constellation every time I went star gazing, and pretty soon I had a lot of them that I could identify easily.

Note: This isn't something that's going to work by osmosis. You will have to go outside, figure out where to look, and find the object. Figure out what you're looking for, and about where you can expect to find it, and practice and test yourself over and over until you can successfully find it every time. If you're getting frustrated, it's time to stop and have a sip of hot cocoa before you try again. This is supposed to be a fun treasure hunt, so make it enjoyable!

How to Find the North Star (Polaris)



How to Find the South Pole



Lesson #9: Star Gazing

Student Worksheet

Overview: We're going to learn how to go star gazing using planetarium software, and how to customize to your location in the world so you know what you're looking at when you look up into the sky tonight!

What to Learn: Telescopes and binoculars are pretty useless unless you know where to point them. I am going to show you some standard constellations and how to find them in the night sky, so you'll never be lost again in the ocean of stars overhead.

Materials:

- Planetarium software (Stellarium is free at this link: http://www.stellarium.org/)
- OR use a star wheel (http://www.skyandtelescope.com/letsgo/familyfun/Make_a_Star_Wheel.html)

Lab Time:

You're about to locate several different celestial objects by first finding them in your planetarium software (or after assembling your star wheel.

9. If you haven't already, customize your planetarium software to your location by entering in your location and elevation.
10. Now adjust the time so that it's set to the time you'd like to star gaze tonight. What time will you star gaze tonight? Write it here… Time:______________________
11. For folks in the Northern Hemisphere, find the Big Dipper (or the Plough). For Southern Hemisphere folks, find the Southern Cross (or the Crux, but it really looks like a big kite). These are one of the most recognizable patterns, and easy for beginners to find.
12. For Northerners, use the Big Dipper to locate Polaris, the North Star. The two stars at the edge of the dipper point straight to the North Star.
13. For Southerners, use the Southern Cross to find the south pole of the sky (sometimes called the "south pole pit" since there's no star there at the exact pole point of the southern sky). The longer bar in the cross points almost exactly toward the South Pole.
14. Using the Search option, find the planets that will be visible tonight by typing in their name into the search window. Which ones will be visible for you tonight?

<u>Planet Name:</u> <u>Where is it in the sky? (Where should you look?)</u>

____

____

____

15. In Stellarium, click the "Search" icon, then the "Lists" tab, and select "Constellations". Select two different constellations you'd like to find tonight that are visible to you, and record information about them here:

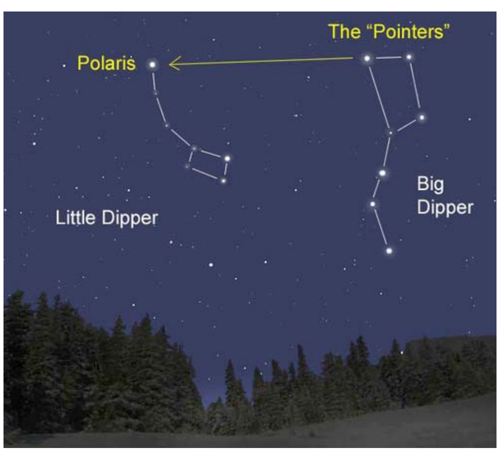
Constellation Name:	Pointer Stars/Location Indicators (How will you find it?):

16. When you're ready, flip over to the observing data table, grab a flashlight, pencil, and then go outside to log your observations, just like a real scientist!

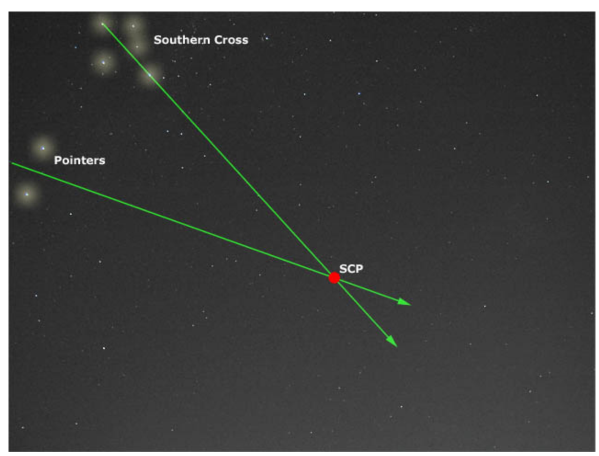
Observing Tip: Try to observe when the moon is less than first quarter phase or more than three quarters (meaning that the moon is less than 50% illuminated). You don't need any fancy viewing equipment, only your log sheet, and if you can do it, bring your planetarium software program with you outside to help you locate the objects. Start small, and find a couple of things on the first night. If you don't figure it out the first time, try again the next night. I learned the northern sky by learning one new constellation every time I went star gazing, and pretty soon I had a lot of them that I could identify easily.

Note: This isn't something that's going to work by osmosis. You will have to go outside, figure out where to look, and find the object. Figure out what you're looking for, and about where you can expect to find it, and practice and test yourself over and over until you can successfully find it every time. If you're getting frustrated, it's time to stop and have a sip of hot cocoa before you try again. This is supposed to be a fun treasure hunt, so make it enjoyable!

How to Find the North Star (Polaris)



How to Find the South Pole



Astronomy Star Gazing Observational Log

Observing Date:____________________ Lat/Long:_____________________ Site Elev:___________________

Observing Location/Site:____Moon Phase:_____________

Weather conditions:________________________________Dimmest Star Visible Overhead:_______________

Notes:____

Time: (UTC or Local Time)	**Sketch of Object Observed:**	**Object Name or Classification:**	**Notes:**

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Lesson #10: Song of the Sun

Teacher Section

Overview: Helioseismology is the study of wave oscillations in the Sun. *Helios* means *Sun*, *seismos* means *tremor*, and *logos* means *reasoning*. The waves are affected by temperature, composition of the Sun, and movement deep inside. By studying the waves, scientists can tell what's going on inside the Sun. It'd be like studying earthquakes to learn what's going on inside the earth. The Sun is filled with sound, and studying these sound waves is currently the *only* way scientists can tell what's going on inside, since the light we see from the Sun is from the upper surface.

Suggested Time: 30-45 minutes

Objectives: Students will discover how to tell certain characteristics about an object using sound, even though it's not visible. This is a model for how scientists determine what's going on inside the Sun.

Materials (per lab group)

- Musical instruments: triangles, glass bottles that can be blown across, metal forks, tuning forks, recorders, jaw harps, harmonicas, etc. Whatever you have will work fine.

Lab Preparation

1. Find yourself a slinky. I bought I giant one that's 12" in diameter and stretches over 30 feet long, but you can use one from your toy store to demonstrate this lab.
2. Gather your materials for the lab. You can ask the kids to bring their own musical instruments to help out with the materials for this class.
3. Print out copies of the student worksheets.
4. Read over the Background Lesson Reading before teaching this class.
5. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Molecules are vibrating back and forth at fairly high rates of speed, creating waves. Energy moves from place to place by waves. Sound energy moves by longitudinal waves (the waves that are like a slinky). The molecules vibrate back and forth, crashing into the molecules next to them, causing them to vibrate, and so on and so forth. All sounds come from vibrations.

Waves are the way energy moves from place to place. Sound moves from a mouth to an ear by waves. Light moves from a light bulb to a book page to your eyes by waves. Waves are everywhere. As you sit there reading this, you are surrounded by radio waves, television waves, cellphone waves, light waves, sound waves and more. (If you happen to be reading this in a boat or a bathtub, you're surrounded by water waves as well.) There are waves everywhere!

Do you remember where all waves come from? Vibrating particles. Waves come from vibrating particles and are made up of vibrating particles.

Here's rule one when it comes to waves … the waves move, the particles don't. The wave moves from place to place. The wave carries the energy from place to place. The particles however, stay put. Here are a couple of examples to keep in mind.

If you've ever seen a crowd of people do the "wave" in the stands of a sporting event you may have noticed that the people only "vibrated" up and down. They did not move along the wave. The wave, however, moved through the stands.

Another example would be a duck floating on a wavy lake. The duck is moving up and down (vibrating) just like the water particles but he is not moving with the waves. The waves move, but the particles don't. When I talk to you, the vibrating air molecules that made the sound in my mouth do not travel across the room into your ears. (Which is especially handy if I've just eaten an onion sandwich!) The energy from my mouth is moved, by waves, across the room.

Lesson

1. The Sun is like the biggest musical instrument you've ever seen. A piano has 88 keys, which means you can play 88 different musical notes. The Sun has 10 million.
2. To play a guitar, you pluck one of the six strings. To play the piano, you hit a key and sound comes out. To play the flute, you blow across a hole. Drums require smacking things together. So how do you play the Sun?
3. Convection starts the waves moving. You've seen convection when a hot pot of water bubbles up. You can even hear it when it starts to boil if you listen carefully. Just below the surface of the Sun, the energy that started deep in the core has bubbled up to the surface to make gigantic bubbles emerge that are bigger than the state of Alaska. It's also a noisy process, and the sound waves stay trapped beneath the surface, making waves appear on the surface of the Sun. This makes the Sun's surface look like it's moving up and down.
4. Scientists use special cameras to watch the surface of the Sun wiggle and move, and they look for patterns so they can determine what's going on down inside the Sun. Since the sound is inside the Sun under the part we can see, we use sound to discover what's inside the Sun.
5. Have you ever heard the Sun? The video here is an actual recording of the song of the Sun.
6. Ask the students if they have ever heard echoes, and when and where they have. If you've ever been inside an unfurnished room, you've heard echoes indoors. Sound bounces all around the room, just like it does inside the surface of the Sun.
7. Can sound waves travel through space? No. Sound requires a medium to travel through, since it travels by vibrating molecules, and there aren't enough molecules in space to do this with (there are a couple random ones floating around here and there, but way too far apart to be useful for sound waves).
8. Take out your slinky and stretch it out to its full length on the table or the ground, asking a student to help you hold one end. Now move the slinky quickly to the left and back again, and watch the wave travel down the length and return. Now move your end quickly up and then back down the table, making a longitudinal wave. When this wave finishes, take your end and shove it quickly toward your helper, then pull back again to make a compression wave. Point out to the student how when the wave returns, it's an echo. That's what happens inside the Sun when the sound waves hit the surface of the Sun. They don't go through the surface, but get trapped beneath it as they echo off the inside surface of the Sun.

Lab Time

You can do this part as an entire class, where you get to play the instrument and the students fill out the data sheet, or you can hand out different combinations of instruments and have the kids play them and do their own observations on their own.

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Pull out your bin of as many musical instruments as you have, including triangles (I use three different sizes for this lab), tuning forks, bottles that can be blown across, shoebox guitars, harmonicas, recorders, and so forth.
4. Assign one student to be the noisemaker. The rest will listen with their eyes closed and record their observations.
5. Everyone shuts their eyes except for the noise maker.
6. The noisemaker selects an instrument and plays it once. Everyone else listens.
7. The noisemaker selects another instrument and plays it once. Everyone listens.
8. The noisemaker selects a third instrument and plays it once. Everyone listens.
9. The noisemaker selects one of the three instruments and plays it as it moves. For example, if you're playing the triangle, you can hit it and spin it. Or hit it as you are walking past the closed-eye listeners. Sound changes when the object is moving, so make the sound they hear appear to be different somehow.
10. The noisemaker puts the instruments back and everyone opens their eyes and records their data in the table below. You can cover the instruments with a jacket if you're worried students will look at which ones have moved.
11. Switch roles and find a new noisemaker for the next trial. Repeat steps 1-10.

Exercises

1. What did you notice that is different about the sounds you heard?
2. How can you tell that two sounds are different that came from the same instrument? (Movement causes sound waves to sound different.)
3. What did you notice about your guesses? What kind of instruments were you more correct about?

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #10: Song of the Sun

Student Worksheet

Name____

Overview: Helioseismology is the study of wave oscillations in the Sun. By studying the waves, scientists can tell what's going on inside the Sun. It's be like studying earthquakes to learn what's going on inside the earth. The Sun is filled with sound, and studying these sound waves is currently the *only* way scientists can tell what's going on inside, since the light we see from the Sun is just from the upper surface.

What to Learn: Molecules are vibrating back and forth at fairly high rates of speed, creating waves. Energy moves from place to place by waves. Sound energy moves by longitudinal waves (the waves that are like a slinky). The molecules vibrate back and forth, crashing into the molecules next to them, causing them to vibrate, and so on and so forth. All sounds come from vibrations.

Materials

- Musical instruments: triangles, glass bottles that can be blown across, metal forks, tuning forks, recorders, jaw harps, harmonicas, etc. Whatever you have will work fine.

Lab Time

1. Your teacher will pull out a bin of musical instruments of various types.
2. Assign one student to be the noisemaker. The rest will listen with their eyes closed and record their observations.
3. Everyone shuts their eyes except for the noise maker.
4. The noisemaker selects an instrument and plays it once. Everyone else listens.
5. The noisemaker selects another instrument and plays it once. Everyone listens.
6. The noisemaker selects a third instrument and plays it once. Everyone listens.
7. The noisemaker selects one of the three instruments and plays it as it moves. For example, if you're playing the triangle, you can hit it and spin it. Or hit it as you are walking past the closed-eye listeners. Sound changes when the object is moving, so make the sound they hear appear to be different somehow.
8. The noisemaker puts the instruments back and everyone opens their eyes and records their data in the table below.
9. Switch roles and find a new noisemaker for the next trial. Repeat steps 2-8.

Song of the Sun Data Table

Make sure your eyes are closed when the instruments are played! For the instrument columns two through four, write down a 1, 2, or 3 for the instrument you think answers the question best.

NOTE: You don't have to know what the instrument was, just where it was played in sequence.

The noisemaker will let you know after everyone has placed their guesses on their data table for the trial.

Trial #	Which made the highest note?	Which made the lowest note?	Which one moved?
1			
2			
3			
4			
5			
6			
7			
8			

Exercises Answer the questions below:

1. What did you notice that is different about the sounds you heard?
2. How can you tell that two sounds are different that came from the same instrument? (Movement causes sound waves to sound different.)
3. What did you notice about your guesses? What kind of instruments were you more correct about?

Lesson #11: Simple Microscope & Telescope

Teacher Section

Overview: Did you know you can create a compound microscope *and* a refractor telescope using the same materials? It's all in how you use them to bend the light. These two experiments cover the fundamental basics of how two double-convex lenses can be used to make objects appear larger when right up close or farther away.

Suggested Time: 20-25 minutes

Objectives: Things like lenses and mirrors can bend and bounce light to make interesting things, like compound microscopes and reflector telescopes. Telescopes magnify the appearance of some distant objects in the sky, including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

Materials (per lab group)

- A window
- Dollar bill
- Penny
- Two hand-held magnifying lenses
- Ruler

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Get a pencil and a glass of water ready for your demonstration.

Background Lesson Reading

What I like best about this activity is how easily we can break down the basic ideas of something that seems much more complex and intimidating, like a telescope or microscope, in a way that kids really understand.

Imagine tossing a rock into a still pond and watching the circles of ripples form and spread out into rings. Now look at the ripples in the water -- notice how they spread out. What makes the ripples move outward is energy.

The ripples are like light. Notice the waves are not really moving the water from one side of the pond to the other, but rather moving energy across the surface of the water.

To put it another way, energy travels across the pond in a wave. Light works the same way – light travels as energy waves. Only light doesn't need water to travel through the way the water waves do -- it can travel through a vacuum (like outer space).

Light can change speed the same way sound vibrations change speed. (Think of how your voice changes when you inhale helium and then try to talk.)

The fastest light can go is 186,000 miles per second – that's fast enough to circle the Earth seven times every second, but that's also inside a vacuum. You can get light going slower by aiming it through different gases. In our own atmosphere, light travels slower than it does in outer space.

Lesson

1. When a beam of light hits a different substance (like a window pane or a lens), the speed at which the light travels changes. (Sound waves do this, too!) In some cases, this change turns into a change in the direction of the beam.
2. For example, if you stick a pencil is a glass of water and look through the side of the glass, you'll notice that the pencil appears shifted. The speed of light is slower in the water (140,000 miles per second) than in the air (186,000 miles per second). This is called optical density, and the result is bent light beams and broken pencils.
3. You'll notice that the pencil doesn't always appear broken. Depending on where your eyeballs are, you can see an intact or broken pencil. When light enters a new substance (like going from air to water) perpendicular to the surface (looking straight on), refractions do not occur.
4. However, if you look at the glass at an angle, then depending on your sight angle, you'll see a different amount of shift in the pencil. Where do you need to look to see the greatest shift in the two halves of the pencil?
5. Why does the pencil appear bent? Is it always bent? Does the temperature of the water affect how bent the pencil looks? What if you put two pencils in there?
6. Depending on if the light is going from a lighter to an optically denser material (or vice versa), it will bend different amounts. Glass is optically denser than water, which is denser than air.
7. Not only can you change the shape of objects by bending light (broken pencil or whole?), but you can also change the size. Magnifying lenses, telescopes, and microscopes use this idea to make objects appear different sizes.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Place a penny on the table.
4. Hold one magnifier above the penny and look through it.
5. Bring the second magnifying lens above the first so now you're looking through both. Move the second lens closer and/or further from the penny until the penny comes into sharp focus. You've just made a compound microscope.
6. Who's inside the building on an older penny?
7. Try finding the spider/owl on the dollar bill. (Hint: It's in a corner next to the "1".)
8. Keeping the distance between the magnifiers about the same, slowly lift up the magnifiers until you're now looking through both to a window.
9. Adjust the distance until your image comes into sharp (and upside-down) focus. You've just made a refractor telescope, just like Galileo used 400 years ago.
10. Find eight different items to look at through your magnifiers. Make four of them up-close so you use the magnifiers as a microscope, and four of them far-away objects so you use the magnifiers like a telescope. Complete the table below.

Exercises

1. Can light change speeds? (Yes, when it travels through different mediums.)
2. Can you see ALL light with your eyes? (No, only visible light, like a rainbow.)
3. Give three examples of a light source. (Answer will vary, but here are mine: Sun, a candle, and a glow stick.)
4. What's the difference between a microscope and a telescope? (A microscope magnifies an image before the focal point; a telescope magnifies an image after the focal point. Both are used to make images appear closer and larger. A microscope is used when objects are near; a telescope is used for far away objects.)
5. Why is the telescope image upside-down? (Because you've focused the image beyond the focal point.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #11: Simple Microscope & Telescope

Student Worksheet

Name____

Overview: Did you know you can create a compound microscope *and* a refractor telescope using the same materials? It's all in how you use them to bend the light. These two experiments cover the fundamental basics of how two double-convex lenses can be used to make objects appear larger when right up close or farther away.

What to Learn: Things like lenses and mirrors can bend and bounce light to make interesting things, like compound microscopes and reflector telescopes. Telescopes magnify the appearance of some distant objects in the sky, including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

Materials

- A window
- Dollar bill
- Penny
- Two hand-held magnifying lenses
- Ruler

Lab Time

1. Place a penny on the table.
2. Hold one magnifier above the penny and look through it.
3. Bring the second magnifying lens above the first so now you're looking through both. Move the second lens closer and/or further from the penny until the penny comes into sharp focus. You've just made a compound microscope.
4. Who's inside the building on an older penny?
5. Try finding the spider/owl on the dollar bill. (Hint: It's in a corner next to the "1".)
6. Keeping the distance between the magnifiers about the same, slowly lift up the magnifiers until you're now looking through both to a window.
7. Adjust the distance until your image comes into sharp (and upside-down) focus. You've just made a refractor telescope, just like Galileo used 400 years ago.
8. Find eight different items to look at through your magnifiers. Make four of them up-close so you use the magnifiers as a microscope, and four of them far-away objects so you use the magnifiers like a telescope. Complete the table below.

Simple Microscope & Telescope Data Table

For the last two columns, measure with your ruler carefully. Don't forget to label your units!

Magnification Used: ____ (multiply the magnification of both lenses together)

Object Looked At	Did you use the Magnifiers as a Microscope or Telescope?	How Far Apart are the Lenses?	How Far is your Eye from the Eyepiece?

Exercises Answer the questions below:

1. Can light change speeds?

2. Can you see ALL light with your eyes?

3. Give three examples of a light source.

4. What's the difference between a microscope and a telescope?

5. Why is the telescope image upside-down?

Lesson #12: Star Charting

Teacher Section

Overview: If you want to get from New York to Los Angeles by car, you'd pull out a map. If you want to find the nearest gas station, you'd pull out a smaller map. What if you wanted to find our nearest neighbor outside our solar system? A star chart is a map of the night sky, divided into smaller parts (grids) so you don't get too overwhelmed. Astronomers use these star charts to locate stars, planets, moons, comets, asteroids, clusters, groups, binary stars, black holes, pulsars, galaxies, planetary nebulae, supernovae, quasars, and more.

Suggested Time: 30-45 minutes

Objectives: The solar system consists of planets and other bodies that orbit the Sun in predictable paths. The patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons. The position of the Sun in the sky changes during the course of the day and from season to season.

Materials (per lab group)

- Dark, cloud-free night
- Two friends
- String
- Rocks
- Pencil

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. You'll be playing a video for the students during class time, so have access to a video screen to play it from so everyone can see.
5. If you want to do this lab inside your classroom during the day, then make your classroom completely dark and stick a constellation's worth of glow-in-the-dark stars on the ceiling to pretend it's the night sky. That way, the kids know how to chart the stars that night on their own. You can charge the glow-in-the-dark stars quickly with a camera flash.

Background Lesson Reading

People have been charting stars since long before paper was invented. In fact, we've found star charts on rocks, inside buildings, and even on ivory tusks. Celestial cartography is the science of mapping the stars, galaxies, and astronomical objects on a celestial sphere.

Celestial navigation (astronavigation) made it possible for sailors to cross oceans by sighting the Sun, Moon, planets, or one of the 57 pre-selected navigational stars along with the visible horizon.

Lesson

1. Show the video to the students that shows how the stars appear to move differently, depending on which part of the Earth you're viewing from. Discuss the difference between living on the equator or in Antarctica (explained in video).

2. The first thing to star chart is the Big Dipper, or other easy-to-find constellation (alternates: Cassiopeia for northern hemisphere or the Southern Cross for the southern hemisphere). The Big Dipper is always visible in the northern hemisphere all year long, so this makes for a good target.

3. Use glow–in-the-dark stars instead of rocks, and charge them with a quick flash from a camera (or a flashlight). Keep your hand as still as you can while the second person lines the rock into position. You can also unroll a large sheet of (butcher or craft) paper and use markers to create a more permanent star chart.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Tape your string to the pencil.
4. Loosely wrap the string around your finger several times so that the tip of the pencil is about an inch above the ground.
5. Find a constellation. Point to a star in the constellation.
6. Have a second person place a rock under the pencil tip.
7. When they've placed the rock in position, point to another star.
8. Have a second person place a rock under the pencil tip again.
9. Repeat this process until all the stars have rocks under their positions.
10. You should see a small version of the constellation on your paper.

Exercises

1. If you have constellations on your class ceiling, chart them on a separate page marking the positions of the rocks with X's.
2. Tonight, find two constellations that you will chart. Bring them with you tomorrow using the technique outlined above in Lab Time.

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #12: Star Charting

Student Worksheet

Name____

Overview: If you want to get from New York to Los Angeles by car, you'd pull out a map. If you want to find the nearest gas station, you'd pull out a smaller map. What if you wanted to find our nearest neighbor outside our solar system? A star chart is a map of the night sky, divided into smaller parts (grids) so you don't get too overwhelmed. Astronomers use these star charts to locate stars, planets, moons, comets, asteroids, clusters, groups, binary stars, black holes, pulsars, galaxies, planetary nebulae, supernovae, quasars, and more wild things in the intergalactic zoo.

What to Learn: How to find two constellations in the sky tonight, and how to get those constellations down on paper with some degree of accuracy.

Materials

- Dark, cloud-free night
- Two friends
- String
- Rocks
- Pencil

Lab Time

1. Tape your string to the pencil.
2. Loosely wrap the string around your finger several times so that the tip of the pencil is about an inch above the ground.
3. Find a constellation. Point to a star in the constellation.
4. Have a second person place a rock under the pencil tip.
5. When they've placed the rock in position, point to another star.
6. Have a second person place a rock under the pencil tip again.
7. Repeat this process until all the stars have rocks under their positions.
8. You should see a small version of the constellation on your paper.

Exercises: Answer the questions below:

1. If you have constellations on your class ceiling, chart them on a separate page marking the positions of the rocks with X's.
2. Tonight, find two constellations that you will chart. Bring them with you tomorrow using the technique outlined above in Lab Time.

Astronomy 1 Evaluation

Teacher Section

Overview Kids will demonstrate how well they understand important key concepts from this section.

Suggested Time 45-60 minutes

Objectives Students will be tested on the key concepts of astronomy:

- Objects in the sky move in regular and predictable patterns. The patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
- The tilt of the Earth and its location in orbit are the reasons for the seasons.
- The Earth is one of several planets that orbit the Sun, and the Moon orbits the Earth.
- The solar system consists of planets and other bodies that orbit the Sun in predictable paths.
- Our solar system includes rocky terrestrial planets (Mercury, Venus, Earth, and Mars), gas giants (Jupiter and Saturn), ice giants (Uranus and Neptune), and assorted chunks of ice and dust that make up various comets and asteroids.
- Telescopes magnify the appearance of the Moon and the planets.
- Telescopes magnify the appearance of the Sun using special lenses and make it possible to locate sunspots and solar flares.
- Stars are the source of light for all bright objects in outer space. The Moon and planets shine by reflected Sunlight, not by their own light.
- The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

Materials

- Two handheld magnifiers
- Sheet of paper
- Ball with a toothpick sticking out of the top and bottom to represent the Earth's north and south poles (or use a globe if you have one)
- Strong flashlight

Lab Preparation

1. Print out copies of the student worksheets, lab practical, and quiz.
2. Have materials in front of you at a desk so kids can demonstrate their knowledge using these materials.

Lesson: The students are taking two tests today: the quiz and the lab practical. The quiz takes about 20 minutes, and you'll find the answer key to make it easy to grade.

Lab Practical: Students will demonstrate individually that they know how the moon's appearance changes during the lunar cycle and explain the size of planets and their distance from the Sun. While other kids are waiting for their turn, they will get started on their homework assignment. You get to decide whether they do their assignment individually or as a group.

Astronomy 1 Evaluation

Student Worksheet

Overview: Today, you're going to take two different tests: the quiz and the lab practical. You're going to take the written quiz first, and the lab practical at the end of this lab. The lab practical isn't a paper test – it's where you get to show your teacher that you know how to do something.

Lab Test & Homework

1. Your teacher will ask you to share how much you understand about astronomy. Since science is so much more than just reading a book or circling the right answer, this is an important part of the test to find out what you really understand.
2. While you are waiting to show how much of this stuff you already know, you get to choose which homework assignment you want to complete. The assignment is due tomorrow, and half the credit is for creativity and the other half is for content, so really let your imagination fly as you work through it. Choose one:
    a. Write a short story or skit about gravity from the perspective of the planet or object (like a sun or moon). You'll read this aloud to your class.
    b. Make a poster that teaches one of the main concepts of astronomy you enjoyed most. When you're finished, you'll use it to teach to a class of younger students and demonstrate the principles that you've learned.
    c. Write and perform a poem or song about astronomy, telescopes, gravity, moons or atmospheres. This will be performed for your class.

Astronomy 1 Quiz

Teacher's Answer Key

1. Why isn't Pluto a planet? *Pluto was reclassified as a dwarf planet. Beyond Neptune, the Kuiper Belt holds the chunks of ice and dust, like comets and asteroids as well as larger objects like dwarf planets Eris and Pluto.*
2. How many Earths can fit inside the Sun? *1.3 million*
3. What are comets made out of? *Comets are really dirty snowballs – made from dust and ice.*
4. What is the Earth's atmosphere made up of? *21% oxygen and 78% nitrogen*
5. How many Earths fit inside Jupiter? *1,321*
6. How far is the Earth from the sun? *93 million miles, also known as 1 AU*
7. What is an atmosphere? *An envelope surrounding an object like a planet or a moon that is held in place by the object's gravitational field*
8. What is a magnetic field? *A force field around a magnet.*
9. Are sunsets the same color on all planets? *No, it depends on what their atmosphere is made up of and also what color light the central star is emitting.*
10. What makes a compass needle move around? *The magnetic lines of force that are invisible to your eye.*
11. Why do we have seasons on Earth? Do all planets have seasons? *Seasons are because the axis is tilted* 23.4^{o}*, exposing one hemisphere to more sunlight each day and warming the planet. Planets without an axis tilt will not have seasons.*
12. Name three planets that have volcanoes (active or extinct)? *Mercury, Mars, Venus, Earth, Io (moon of Jupiter), Triton (moon of Neptune), Enceladus (moon of Saturn), and our very own Moon.*
13. Can you detect all kinds of light with your eyes? *No, only visible light, like a rainbow.*
14. Why is the telescope image upside-down? *Because you've focused the image beyond the focal point.*

Astronomy 1 Quiz

Student Quiz Sheet

Name____

1. Why isn't Pluto a planet anymore?
2. How many Earths can fit inside the Sun?
3. What are comets made out of?
4. What is the Earth's atmosphere made up of?
5. How many Earths fit inside Jupiter?
6. How far is the Earth from the sun?
7. What is an atmosphere?
8. What is a magnetic field?
9. Are sunsets the same color on all planets?
10. What makes a compass needle move around?
11. Why do we have seasons on Earth? Do all planets have seasons?
12. Name three planets that have volcanoes (active or extinct)?
13. Can you detect all kinds of light with your eyes?
14. Why is the telescope image upside-down?

Astronomy 1 Lab Practical

Teacher's Answer Key

This is your chance to see how well your students have picked up on important key concepts, and if there are any holes. Your students also will be working on their homework assignment as you do this test individually with the students.

Materials:

- Two handheld magnifiers
- Sheet of paper
- Ball with a toothpick sticking out of the top and bottom to represent the Earth's north and south poles (or use a globe if you have one)
- Strong flashlight

Lab Practical: Ask the student *Note: Answers given in italics!*

- Design and build an experiment that shows how a refractor telescope works. *Take two magnifiers and hold them a fixed distance apart and look through both. Student may draw something on the paper and hold it up at a distance away from you as you peer through the lenses to magnify as a demonstration, or simply look at an object in the distance. (Do not look at the Sun!)*
- Demonstrate why the Earth has seasons. *The tilt of the Earth and its location in orbit are the reasons for the seasons. When the Earth's North Pole is tilted toward the sun, the northern hemisphere gets more sunlight exposure, which means longer days, and warmer climates. The student can use a flashlight to model the sun and stick a toothpick for the north pole into the ball, pointing the toothpick toward the sun as it rotates around its axis (for daily rotation).*

The Scientific Method

Throughout this course, you'll see embedded videos, like the one below. You'll find the videos in each experiment include step-by-step explanations and quick demonstrations you can do with your students. These videos are a great way to help you introduce the topic in a kid-friendly way.

One of the problems kids have is how to experiment with their great ideas without getting lost in the jumble of result data. So often students will not have any clear ideas about what change caused which effect in their results! Students often have trouble communicating their ideas in ways that not only make sense but are also acceptable by science fairs or other technical competitions designed to get kids thinking like a real scientist. Another problem they face is struggling to apply the scientific method to their science project in school, for scout badges, or any other type of report where it's important that other folks know and understand their work.

The scientific method is widely used by formal science academia as well as scientific researchers. For most people, it's a real jump to figure out not only how to do a decent project, but also how to go about formulating a scientific question and investigating answers methodically like a real scientist. Presenting the results in a meaningful way via "exhibit board"… well, that's just more of a stretch that most kids just aren't ready for. There isn't a whole lot of useful information available on how to do it by the people who really know how. That's why I'm going to show you how useful and easy it is.

The scientific method is a series of 5 steps that scientists use to do their work. But, honestly, you use it every day, too! The five steps are Observation, Hypothesis, Test, Collect Data, and Report Results. That sounds pretty complicated, but don't worry, they are just big words. Let me tell you what these words mean and how to play with them.

Step 1: Observation means what do you see, or hear, or smell, or feel? What is it that you're looking at? Is that what it usually does? Is that what it did last time? What would happen if you tried something different with it? Observation is the beginning of scientific research. You have to see or touch or hear something before you can start to do stuff with it, right?

Step 2: Once you observe something, you can then form a hypothesis. All hypothesis really means is "guess." A hypothesis is an educated guess. Tonight at dinner, when someone asks you, "Do you want peas or carrots?" Say, "I hypothesize that I would like the carrots." Everyone will think you're a genius! Basically you're saying "I guess that I would like the carrots." Hypotheses aren't right or wrong, they are just your best guess.

Step 3: To see if your guess is correct, you need to do the next step in the scientific method: test. The test is just what it sounds like: running experiments to see whether or not your hypothesis is correct.

Step 4: As you do your tests, you need to collect data. That means collecting the numbers, the measurements, the times, the data of the experiment. Once you collect your data, you can take a look at it, or in other words, analyze it.

Step 5: Once you analyze your data you can report your results. That basically means tell someone about it. You can put your data in a chart or a graph or just shout it from the rooftops!

Here's a great way to remember the 5 steps. Remember the sentence "Orange Hippos Take Classes Regularly." The first letter in each word of that goofy sentence is the same as the first letter in each step of the scientific method. That's called a mnemonic device. Make up your own mnemonic devices to remember all sorts of stuff.

“OK, so that’s what the words mean. How do I use that every day?”

Well, I’m glad you asked that question. If you had cereal for breakfast this morning, you did the scientific method. On the table you had a bowl of cereal with no milk in it. As you looked at your dry cereal, you made an observation, “I need milk!” At that point, you made a hypothesis, “There’s milk in the fridge.” You can’t be sure there’s milk in the fridge. Someone might have used it up. It might have gone bad. Aliens may have used it to gas up their milk-powered spaceship. You just don’t know! So you have to do a test.

What would be a good test to see if there is milk in the fridge? Open the fridge! Now once you move the week-old spaghetti and the green Jell-O (at least you hope it’s Jell-O) out of the way, you can see if there is milk or not. So you collect your data. There is milk or there isn’t milk. Now you can finally report your results. If there is milk, you can happily pour it on your cereal. If there isn’t any milk, you report your results by shouting, “Hey, Mom ...We need milk!” Scientific method, not so hard is it?

You’ll get familiar with the scientific method by doing the activities and experiments in your lessons. Most scientists don’t use the *full* version of the scientific method, which actually includes several additional steps to the ones I’ve outlined above. You’ll find the full-blown version of the scientific method in the back of this book. I’ve included a copy of a special project which won first prize at a science fair. You’ll find this complete project explains every detail and how it uses the full version of the scientific method so you can see how to do it for yourself on any project you choose.

Vocabulary for the Unit

Asteroid. Object in orbit around the Sun, intermediate in size between meteoroids and planets.

Asteroid belt. The region of the solar system in which most asteroids have their orbits, between Mars and Jupiter.

Black holes. The leftovers of a BIG supernova. When a star explodes, it collapses down into a white dwarf or a neutron star. However, if the star is large enough, there is nothing to keep it from collapsing, so it continues to collapse forever. It becomes so small and dense that the gravitational pull is so great that light itself can't escape.

Center of mass. Mean position of the masses that comprise a system or larger body: for two bodies, the center of mass is a point on the line joining them. For a binary star system, the motion of each star can be computed about the center of mass.

Comet. Small body in the solar system, in orbit around the Sun. Some of its frozen material vaporizes during the closer parts of its approach to the Sun to produce the characteristic tail, behind the right head.

Conjunction. Closest apparent approach of two celestial objects. Planetary conjunctions were once considered important omens for events on Earth.

Constellation. A group of stars that seemed to suggest the shape of some god, person, animal or object. Now a term used to designate a region of the sky. There are 88 constellations.

Dark matter: Matter in the cosmos that is undetectable because it doesn't glow. Dark matter, some of it in the form of as-yet-undiscovered exotic particles, is thought to comprise most of the universe.

Eclipse. Blocking of light from one body by another that passes in front of it. Eclipse can be total or partial.

Eclipse path. Narrow path on the Earth's surface traced by the Moon's shadow during an eclipse.

Eclipsing binary star. Binary star whose mutual orbit is viewed almost edge-on so that light observed is regularly decreased each time one star eclipses the other.

Ecliptic. Path that the Sun appears to follow, against the stars on the celestial sphere, during the course of a year.

Ecliptic plane. Plane defined by the Earth's orbit around the Sun.

Electromagnetic wave: A structure consisting of electric and magnetic fields in which each kind of field generates the other to keep the structure propagating through empty space at the speed of light. Electromagnetic waves include radio and TV signals, infrared radiation, visible light, ultraviolet light, X-rays, and gamma rays.

Ellipse. Type of closed curve whose shape is specified in terms of its distance from one or two points. A circle is a special form of ellipse. In appearance, an ellipse is oval-shaped.

Escape speed: The speed needed to escape to infinitely great distance from a gravitating object. For Earth, escape speed from the surface is about 7 miles per second; for a black hole, escape speed exceeds the speed of light.

Equinox. Two days each year when the Sun is above and below the horizon for equal lengths of time.

Event horizon: A spherical surface surrounding a black hole and marking the "point of no return" from which nothing can escape.

Field: A way of describing interacting objects that avoids action at a distance. In the field view, one object creates a field that pervades space; a second object responds to the field in its immediate vicinity. Examples include the electric field, the magnetic field, and the gravitational field.

Galaxies are groups of stars that are pulled and held together by gravity.

Globular clusters are massive groups of stars held together by gravity, using housing between tens of thousands to millions of stars (think New York City).

Gravitational lensing is one way we can "see" a black hole. When light leaves a star, it continues in a straight line until yanked on by the gravity of a black hole, which bends the light and changes its course and shows up as streaks or multiple, distorted images on your photograph.

Gravitational time dilation: The slowing of time in regions of intense gravity (large spacetime curvature).

Gravitational waves: Literally, "ripples" in the fabric of spacetime. They propagate at the speed of light and result in transient distortions in space and time.

Gravity: According to Newton, an attractive force that acts between all matter in the universe. According to Einstein, a geometrical property of spacetime (spacetime curvature) that results in the straightest paths not being Euclidean straight lines.

Latitude. Coordinate used to measure (in degrees) the angular distance of a point or celestial objects above or below an equator.

Light year. Distance that light travels in 1 year.

Longitude. Coordinate used to specify the position of a point or direction around (or parallel to) an equator.

The **Kuiper Belt** is an icy region that extends from just beyond Neptune (from 3.7 billion miles to 7.4 billion miles from the Sun). This is where most comets and asteroids from our solar system hang out.

Neutron stars with HUGE magnetic fields are known as **magnetars**.

Magnetic field. Region surrounding a magnet or electric current, in which magnetic force can be detected in such a region, high-speed electrically charged particles will generally move along curved paths and radiate energy.

Magnetic pole. One of the two regions on Earth to which a compass needle will point. Poles also exist on magnets, and the magnetic fields of some electric currents can have an equivalent behavior.

Magnetosphere. Region surrounding star or planet (including Earth) in which a magnetic field exists.

Meridian. Great circle, on the celestial sphere or the Earth, that passes through both north and south poles and an observer's zenith or location.

Meteor. Glowing trail in the upper atmosphere, produced by meteoroid burning up as it moves at high speed.

Meteor shower. Numerous meteors seen in short time span as the Earth moves through a cloud of meteoroids, probably remnants of a comet and still following the comet's orbit.

Meteorite. Remnant of meteoroid that has been partially eroded in passage through the Earth's atmosphere before hitting the surface. Term now also applied to similar bodies that collide with the surfaces of the other planets and their satellites, producing craters.

Meteoroid. Large rock (but much smaller than minor planets) moving in an orbit in the solar system. Meteoroids that enter in the Earth's atmosphere are termed meteors or meteorites, depending on their behavior.

Neutron stars are formed from stars that go supernova, but aren't big and fat enough to turn into a black hole.

The **Oort Cloud** lies just beyond the Kuiper belt, housing an estimated 1 trillion comets.

Orbit. Path traced out by one object around another.

The visible surface of the Sun is called the **photosphere**, and is made mostly of plasma (remember the plasma grape experiment?) that bubbles up hot and cold regions of gas.

Dying stars blow off shells of heated gas that glow in beautiful patterns called **planetary nebula**.

Pulsars are a type of neutron star that spins very fast, spews jets of high-energy X-ray particles out the poles, and has large magnetic fields.

Our **solar system** includes **rocky terrestrial planets** (Mercury, Venus, Earth, and Mars), **gas giants** (Jupiter and Saturn), **ice giants** (Uranus and Neptune), and assorted chunks of ice and dust that make up various **comets** (dusty snowballs) and asteroids (chunks of rock).

Spacetime: The four-dimensional continuum in which the events of the universe take place. According to relativity, spacetime breaks down into space and time in different ways for different observers.

Spacetime curvature: The geometrical property of spacetime that causes its geometry to differ from ordinary Euclidean geometry. The curvature is caused by the presence of massive objects, and other objects naturally follow the straightest possible paths in curved spacetime. This is the essence of general relativity's description of gravity.

Spacetime interval: A four-dimensional "distance" in spacetime. Unlike intervals of time or distance, which are different for observers in relative motion, the spacetime interval between two events has the same value for all observers.

Special theory of relativity: Einstein's statement that the laws of physics are the same for all observers in uniform motion.