ASTRONOMY 2

A comprehensive course that teaches the big ideas about stars, planets, moon, comets, asteroids, galaxies and more. Students will discover Martian sunsets, eclipses and transits, what drives Neptune's internal furnace, discover how to identify meteorites, learn how binary planetary systems work, diffract light into its rainbow signatures while learning about the electromagnetic spectrum, and so much more.

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

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Introduction

Greetings and welcome to the study of Astronomy. This unit was created by a mechanical engineer, university instructor, airplane pilot, astronomer, robot-builder and real rocket scientist… me! I have the happy opportunity to teach you everything I know about astronomy over the next set of lessons. I promise to give you my best stuff so you can take it and run with it … or fly!

Astrophysics combines the knowledge of light (electromagnetic radiation), chemical reactions, atoms, energy, and physical motion all into one. To get the most out of these labs, there are really only a couple of things to keep in mind. Since we are all here to have fun and learn something new, this shouldn't be too hard.

One of the best things you can do as the student is to cultivate your curiosity about things. *Why did that move? How did that spin? What's really going on here?*

This unit on Astronomy is chock-full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in science is to hone your observational skills. Science experiments really speak for themselves much better than I can ever put into words or show you on a video. And I'm going to hit you with a lot of these science demonstrations and experiments to help you develop your observing techniques.

Scientists not only learn to observe what's going on in the experiment, but they also learn how to observe what their experiment is telling them, which is found by looking at your data. It's not enough to invent some new kind of experiment if you don't know how it will perform when the conditions change a bit, like on Mars. We're going to learn how to predict what we think will happen, design experiments that will test this idea, and look over the results we got to figure out where to go from there. Science is a process, it's a way of thinking, and we're going to get plenty of practice at it.

Good luck with this astronomy unit!

For the Parent/Teacher:
Educational Goals for Astronomy 2

Astrophysics combines the knowledge of light (electromagnetic radiation), chemical reactions, atoms, energy, and physical motion all into one. You'll soon be discovering how to make a real scale model of the solar system (and where most models go wrong), you'll learn about the different atmospheres on planets, how to capture meteorites, design a solar system, learn about different space missions and so much more.

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 position of the Moon changes during the course of the day and from season to season.
- The phases of the Moon and the lunar cycle.
- 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.
- The Oort Cloud holds an estimated 1 trillion comets. The Kuiper Belt holds chunks of ice and dust, like comets and asteroids as well as larger objects like dwarf planets Eris and Pluto.
- The appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.
- How to use astronomical units and light years as measures of distance between the Sun, stars, and Earth.
- The path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.
- The Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium. The Sun uses nuclear reactions to generate its energy.
- The position of the Sun in the sky changes during the course of the day and from season to season.
- 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.
- Visible light is a small band within a very broad electromagnetic spectrum.
- White light is a mixture of many wavelengths (colors), including infrared, ultra-violet, visible, and more. Different instruments detect and measure different wavelengths of light.
- 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.
- Gravitational lensing occurs when black holes and other massive objects bend light.

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

- Design and build an experiment that shows how the shape of the Moon changes over time.
- 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.
- Measure and estimate the length and volume of objects.
- 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.

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 this unit. 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. Most materials are reusable.

Baking soda
Ball bearing or magnetic marble
Balloons (4)
Black paper
Bouncy ball
Calcium chloride
Calculator
Camera (video or still camera)
Cardboard or small piece of clay
CD or DVD
Chalk
Clock
Diffraction grating
Empty CD Case
Feather
Flashlight
Gallon milk jug container
Handheld magnifying glass
Index cards (3)
Magnet (strong!)
Markers
Measuring tape
Pencil
Phenol red or red food dye
Piece of fabric
Plastic wrap
Popsicle sticks
Protractor
Remote control for TV or stereo
Ruler
Salt
Sand
Scale to weigh yourself
Scissors
Skewer
Small balls (5)
Soup cans or plastic containers
Steel wool
Stopwatch
String
Sun block
Sunglasses
Tack or needle
Tape (regular and double-sided)
Tennis ball
Thermometers (4)
Thin plastic cutting board
UV beads (these change colors when exposed to the Sun, 5)
Vinegar
Water bottles (7)
Wax paper
Yardsticks/metersticks (2)

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.

Lesson #1: Stars, Planets, and Black Holes

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 stars like our sun as well as distant stars, ice and gas giants, comets, asteroids, moons, ringed planets, black holes quasars, supernova and more. This is an overview of many different concepts we're going to study in further depth, 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, seven 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

- Metal ball (like a ball bearing) OR a magnetic marble
- Strong magnet (the strongest one you own). I have a neodymium magnet that I am using.
- Thin plastic, cardboard, or wood sheet (like a table or cutting board). Make sure the magnet can influence the metal ball through it (don't use metal.)
- Small bouncy ball and tennis ball OR a tennis ball and a basketball (you need two balls of different sizes)

Experiment

Before watching the video, print out your worksheet so you can jot things down as you listen. 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.

Planetarium Star Show Table

Planet	Interesting Fact You Didn't Know 'Til Now

Reading

Early astronomers tracked the movement of the stars so accurately that in most cases, we've only made minor adjustments to their data. Although Galileo wasn't the first person to look through a telescope, he was the first to point it at the stars. Originally, astronomy was used for celestial navigation and was involved with the making of calendars, but nowadays it's mostly classified in the field called astrophysics.

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.

Questions to Answer:

1. Is Mercury the hottest planet? Why or why not?
2. What is solar wind? What protects planets from it?
3. Can asteroids have moons?
4. Why is Io different colors?
5. Can moons have atmospheres? Do all planets have atmospheres?
6. How many objects in the Pluto system?
7. Name two ways you can detect black holes.
8. If a star collapses when it runs out of fuel, then why do supernovas explode?
9. Name two scientists who contributed to the work on black holes.
10. What is a galaxy, and how is it different from a quasar?

Lesson #2: Solar System Scale Model

Overview: Today you get to make a scale model of the solar system. By scale model, I mean both the sizes of the planets will be to scale as well as the distances between the planets. Your job is to make it as accurate as you can.

What to Learn: You will learn how our solar system is mostly made up of empty space and that the distances between the objects are *huge.* You'll also find out where that pesky dwarf planet Ceres (which was discovered in 1801 and thought to be a planet, but quickly was demoted to an asteroid and later a dwarf planet) lives.

Materials

- Measuring tape
- Ruler (metric or inches)
- Popsicle sticks
- Markers
- Index cards
- Tape
- Tennis ball
- Grassy field or outdoor area to spread out

Experiment

1. First, draw the solar system on a sheet of paper. Once you've completed this step, proceed to the next step. (No peeking!)
2. Most students will tend to draw the planets evenly spaced apart. You'll learn how to correct this mistake the next time after you've worked through this experiment.
3. When building this model, start by marking off the location of the Sun (you can use chalk, a paper circle cut to 2.63" (66.8 mm) or place a tennis ball as a placeholder for the Sun). The rest is for them to figure out.
4. On one end of each stick, write the name of each planet/object from the data table.

1. On the other end, draw the scale size of the planet. If the planet is larger than the Popsicle stick, draw it on an index card and tape it to the stick. Use the fraction-to-decimal converter if needed (depending on your ruler).
2. Place your tennis ball at one end of the area marked off for your experiments. This is the Sun.
3. Using the table and the measuring tape, measure the distance from the Sun to Mercury. Have a lab partner hold one end of the measuring tape at the center of the tennis ball (or an X you've marked on the ground that's under the tennis ball). At 10.4 inches, place your Popsicle stick into the ground so it stands up. If you're on concrete, lay it down with the dot representing Mercury 10.4 inches away from the Sun.
4. Continue with the rest of the planets, as far as you have room to go. Which planet did you have to stop at because your area wasn't big enough? Or didn't you?

Solar System Data Table

All distances are measured from the center of the Sun. The Sun is 2.63” (66.8 mm) in diameter.

Planet/Object	Object Diameter		Distance from the Sun	
Mercury	0.009 inches	0.2 mm	10.4 inches	0.264 m
Venus	0.023 inches	0.5 mm	1 foot 7.4 inches	0.493 m
Earth	0.024 inches	0.6 mm	2 feet 2.9 inches	0.682 m
Mars	0.013 inches	0.3 mm	3 feet 4.9 inches	1.039 m
Jupiter	0.27 inches	6.8 mm	11 feet 7.76 inches	3.649 m
Saturn	0.22 inches	5.5 mm	21 feet 4.3 inches	6.51 m
Uranus	0.089 inches	2.2 mm	42 feet 11.5 inches	13.094 m
Neptune	0.086 inches	2.1 mm	67 feet 4.2 inches	20.529 m
Pluto (dwarf planet)	0.004 inches	0.1 mm	88 feet 6 inches	36.975 m

Reading

How large of a sheet of paper do you need to make a scale model of the solar system if the Sun was as big as a beach ball? You would need a sheet of paper nearly a mile long!

How would you measure the distance of a football field if you only had a ruler? How would they measure how high a tree is (without climbing it) using the same ruler? How would you measure the distance to the Moon?

One of the first ways we figured out the distances to the planets. Since the planets move in their orbits, scientists had to take that into account when they did their measurements and calculations. In order to get the hang of how big and far away celestial objects really are, we’re going to make a scale model of the solar system.

A Greek mathematician, Eratosthenes, was the first person to measure the Earth's circumference as well as calculate the tilt of the Earth's axis, both with remarkable accuracy. Scientists think he was also the first to correctly calculate the distance from the Earth to the Sun. His system of latitude and longitude is still used today.

The diameter of our solar system is a little harder to figure out, since the exact boundary still hasn't been explored thoroughly yet in order to provide enough information about what should be included and what doesn't belong. For measuring large distances, astronomers use "AU" or "au" meaning *astronomical unit*. One AU is the distance from the Earth to the Sun, or 93 million miles (150 million km).

Gian Domenico Cassini made the first good planet measurements in 1672 by using parallax. Here's how he did it: If you hold your hand out at arm's length and look at it with only one eye at a time, you'll see your hand shift slightly back and forth. This is called parallax. This happens because your eyes are separated by a couple inches. If we know how far apart your eyes are, and carefully measure the how far your hand appears to shift, we can find out how long your arm is.

Now imagine doing this but instead the distance between your eyes, we'll use the distance the Earth moves when it's on one side of the Sun versus the other, like in winter and summer. The spacing between the eyes now isn't a couple inches; it's nearly 2 AU's apart. By carefully measuring how much an object appears to shift, we can find out how far that object is from us.

Today we use a radio signal and time how long it takes the signal to travel from the Earth to a spacecraft parked in orbit around another planet. Since the signal travels at the speed of light (186,000 miles per second), it's easy to find out how far away the object is. Scientists also bounce radar signals off a planet and time how long it takes to echo back to Earth, much the same way the police can find out your speed using a radar gun.

Questions to Answer

1. What do you notice about the position of the rocky terrestrial planets?

2. Are the ice giants further apart from each other than the gas giants are?

3. Mariner 10 took 147 days to reach Mercury from Earth. How long do you think it would take to get to Neptune?

4. If the Earth is 93 million miles (150 million km) from the Sun, and Ceres is 413 million miles (665 million km) from the Sun, where would you place it in your scale model?

Lesson #3: Atmospheres

Overview: Scientists do experiments here on Earth to better understand the physics of distant worlds. We're going to simulate the different atmospheres and take data based on the model we use.

What to Learn: Each planet has its own unique atmospheric conditions. Mars and Mercury have very thin atmospheres, while Earth has a decent atmosphere (as least, we like to think so). Venus's atmosphere is so thick and dense (92 times that of the Earth's) that it heats up the planet so it's the hottest rock around. Jupiter and Saturn are so gaseous that it's hard to tell where the atmosphere ends and the planet starts, so scientists define the layers based on the density and temperature changes of the gases. Uranus and Neptune are called ice giants because of the amounts of ice in their atmospheres.

Materials

- 4 thermometers
- 3 jars or water bottles
- Plastic wrap or clear plastic baggie
- Wax paper
- Stopwatch

Experiment

1. Place one thermometer in direct sunlight. This is like the atmosphere of Mercury and Mars.
2. Place a second thermometer in a jar and cap it. Place this in sunlight. This is the Earth's, Jupiter's and Saturn's atmosphere.
3. Line the second jar with wax or tissue paper. Place the third thermometer in the jar and cap it. Place it next to the other two in sunlight. This is the atmosphere on Venus.
4. Insert the fourth thermometer into a plastic baggie, insert it into the bottle and cap it. Make sure the baggie is loose. This is Neptune and Uranus.
5. Record your data observations in the table, taking data every couple of minutes.

Atmospheres Data Table

Don't forget to label your units!

Time	Naked Thermometer	Clear Jar Thermometer	Wax Jar Thermometer	Ice Jar Thermometer

Reading

Venus is hot enough to melt cannonballs and crush any spaceship that tries to land on the surface. Carbon dioxide is a "greenhouse gas," meaning that some wavelengths of light can pass through it, but specifically not infrared light, which is also known as heat. Light from the Sun either bounces off the upper cloud layers and back into space, or penetrates the clouds and strikes the surface of Venus, warming up the land. The ground radiates the heat back out, but the carbon dioxide atmosphere is so dense and thick that it traps and keeps the heat down on the surface of the planet. Think of rolling up your windows in your car on a hot day.

The heat is so intense on Venus that the carbon normally locked into rocks sublimated (turned straight from solid to gas) and added to the carbon in the atmosphere, to make even more carbon dioxide.

Mercury doesn't have much of an atmosphere, which is just like a bare thermometer. There's nothing to hold onto the heat that strikes the surface. Mars is in a similar situation.

Earth's atmosphere is simulated by placing the thermometer in a bottle. The Earth has a cloud layer that keeps some of the heat on the planet, but most of it does get radiated back into space. When the clouds are in at night, the planet stays warmer than when it's clear (and cold).

Venus's heavy, dense carbon dioxide atmosphere is simulated by using the waxed paper. Venus is the hottest planet in our solar system because of the runaway greenhouse effect that traps most of the heat that makes it through the atmosphere, bouncing it back down to the surface. The average temperature of Venus is over 900^{o}F.

Jupiter and Saturn's atmospheres are thinner layers of hydrogen and helium than deeper in the core.

Uranus and Neptune are called ice giants because of the amounts of ice in their atmospheres. Their atmospheres are also made of mostly hydrogen and helium.

Questions to Answer

1. Which atmosphere reached the highest temperature?
2. Each of the jars received the same amount of energy from the Sun. Why is this not quite like the real solar system?

Lesson #4: Lunar Phases

Overview: The Moon appears to change in the sky. One moment it's a big white circle, and next week it's shaped like a sideways bike helmet. There's even a day where it disappears altogether. So what gives?

What to Learn The Sun illuminates half of the Moon all the time. Imagine shining a flashlight on a beach ball. The half that faces the light is lit up. There's no light on the far side, right? For the Moon, *which* half is lit up depends on the rotation of the Moon. And which part of the illuminated side we can see depends on where we are when looking at the Moon. Sound complicated? This lab will straighten everything out so it makes sense.

Materials

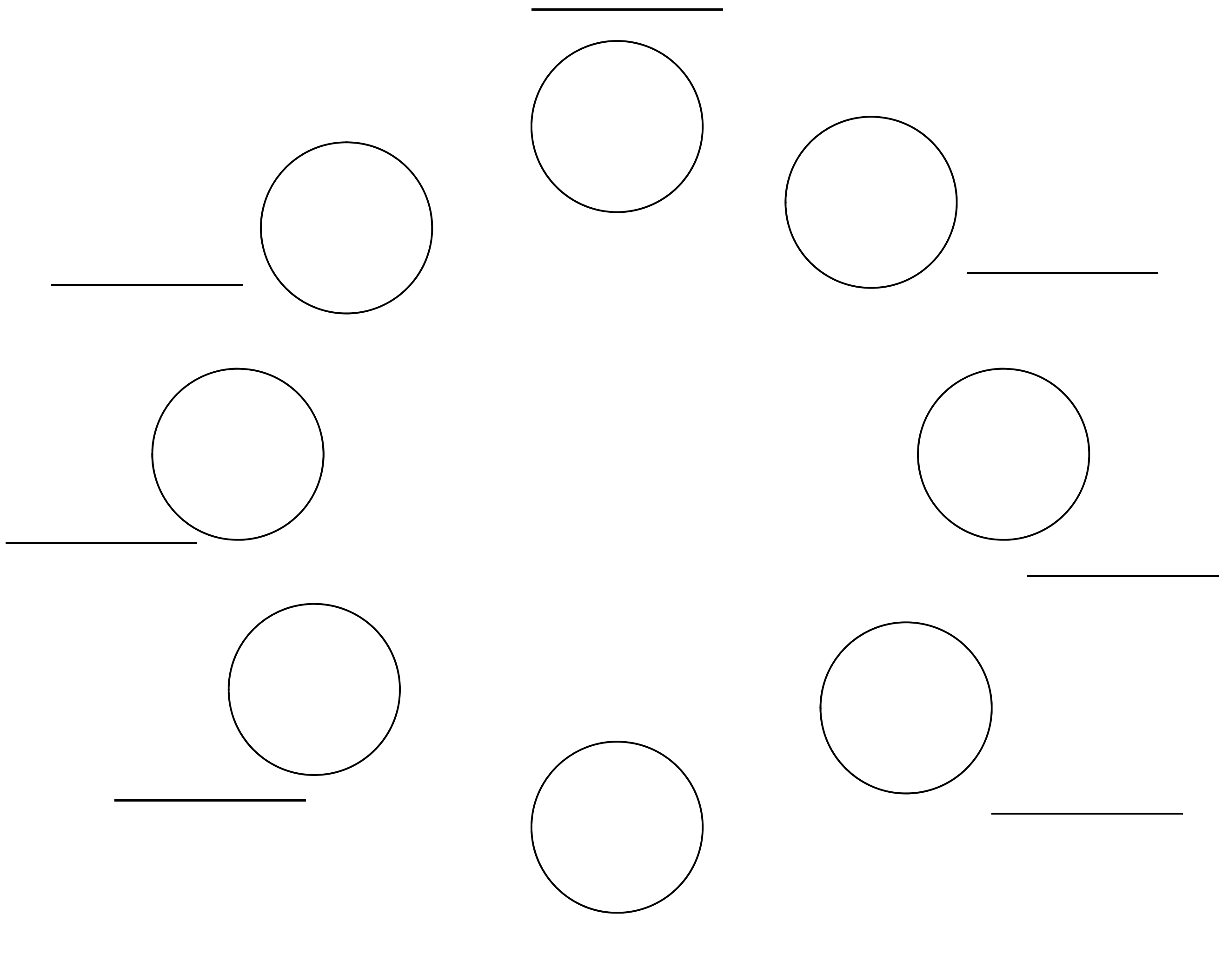
- Ball
- Flashlight

Experiment

1. This lab works best if your room is very *dark*. Button down those shades and make it as dark as you can.
2. Assign one person to be the Sun and hand them the flashlight. Stay standing up about four feet away from the group. The Sun doesn't move at all for this activity.
3. Assign one person to be the Moon and hand them the ball. Stay standing up, as you'll be circling the Earth.
4. The rest of the people are the Earth, and they stand or sit right the middle (so they don't get a flashlight in their eyes as the Moon orbits).
5. Start with a new Moon. Shine the flashlight above the heads of the Earth. Move the Moon (ball) into position so that the ball blocks all the light from the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be none). Which phase of the Moon is this?

6. Now the Moon moves around to the opposite side of the Earth so that the Earth kids can see the entire half of the ball lit up by the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be half the ball). Which phase of the Moon is this?
7. Now find the positions for first quarter. Where does the Moon need to stand so that the Earth kids can see the first quarter Moon?
8. Continue around in a complete circle and fill out the diagram. Color in the circles to indicate the dark half of the Moon. For example, the new Moon should be completely darkened.

Lunar Phases Data Observations



1. Now it's time to investigate why Venus and Mercury have phases. Put the Sun in the center and assign a student to be Venus. Venus gets the ball.
2. Venus should be walking slowly around the Sun. The Sun is going to have to rotate to always face Venus, since the Sun normally gives off light in every direction.
3. The Earth kids need to move further out from the Sun than Venus, so they will be watching Venus orbit the Sun from a distance of a couple of feet.
4. Earth kids: What do you notice about how the Sun lights up Venus from your point of view? Is there a time when you get to see Venus completely illuminated, and other times when it's completely dark?

5. Draw a diagram of what's going on, labeling Venus's full phase, new phase, half phases, crescent, and gibbous phases. Label the Sun, Earth, and all eight phases of Venus like we did on the board for the Earth at the beginning of this lesson:

Reading

The Sun illuminates half of the Moon all the time. Imagine shining a flashlight on a beach ball. The half that faces the light is lit up. There's no light on the far side, right? So for the Moon, *which* half is lit up depends on the rotation of the Moon. And which part of the illuminated side we can see depends on where we are when looking at the Moon. Sound complicated? This lab will straighten everything out so it makes sense.

One question you might have is: *Why don't we have eclipses every month when there's a new Moon?* The next lesson is all about eclipses, but remember that the Moon's orbit around the Earth is not in the same plane as the Earth's orbit around the Sun (called the ecliptic). It's actually off by about 5^o. In fact, only twice per month does the Moon pass through the ecliptic.

The lunar cycle is approximately 28 days. To be exact, it takes on average 29.53 days (29 days, 12 hours, 44 minutes) between two full moons. The average calendar month is 1/12 of a year, which is 30.44 days. Since the Moon's phases repeat every 29.53 days, they don't quite match up. That's why on Moon phase calendars, you'll see a skipped day to account for the mismatch.

A second full Moon in the same month is called a *blue Moon*. It's also a *blue Moon* if it's the third full Moon out of four in a three-month season, which happens once every two or three years.

The Moon isn't the only object that has phases. Mercury and Venus undergo phases because they are closer to the Sun than the Earth. If we lived on Mars, then the Earth would also have phases.

Questions to Answer

1. Does the Sun always light up half the Moon?
2. How many phases does the Moon have?
3. What is it called when the Moon appears to grow?
4. What is it called when you see more light than dark on the Moon?
5. How long does it take for a complete lunar cycle?

Lesson #5: Eclipses and Transits

Overview: It just so happens that the Sun's diameter is about 400 times larger than the Moon, but the Moon is 400 times closer than the Sun. This makes the Sun and Moon appear to be about the same size in the sky as viewed from Earth. This is also why the eclipse thing is such a big deal for our planet. You're about to make your own eclipses as you learn about *syzygy*.

What to Learn: A total eclipse happens about once every year when the Moon blocks the Sun's light. Lunar eclipses occur when the Sun, Moon, and Earth are lined up in a straight line with the Earth in the middle. Lunar eclipses last hours, whereas solar eclipses last only minutes.

Materials

- 2 index cards
- Flashlight or sunlight
- Tack or needle
- Black paper
- Scissors

Experiment

1. Trace the circle of your flashlight on the black paper and cut out the circle with paper. This is your Moon. If you are using the Sun instead, cut out a circle about the size of your fist.
2. Make a tiny hole in one of the index cards by pushing a tack through the middle of the card.
3. Hold the punched index card a couple inches above the plain one and shine your light through the hole so that a small disk appears on the lower card. Move the cards closer together or further apart until it comes into focus. The disk of light is the Sun.
4. Ask your lab partner to slowly move the black paper disk in front of your light as you watch what happens to the Sun on the bottom index card.
5. Continue moving the black paper until you can see the Sun again.
6. Where does your circle need to be in order to create an annular eclipse? A partial eclipse?
7. How would you simulate Mercury transiting the Sun? What would you use?
8. Fill out the table.

Eclipses and Transits Data Table

For the second column, describe where your object was compared to the flashlight/Sun, and how large it was.
For the third column, draw the change you saw in the Sun.

Type of Eclipse	Where was the Moon located?	What did it look like?
Total		
Partial		
Annular		
Transit		

Reading

An eclipse is when one object completely blocks another. If you're big on vocabulary words, then let the students know that eclipses are one type of *syzygy* (a straight line of three objects in a gravitational system, like the Earth, Moon, and Sun).

A lunar eclipse is when the Moon moves into the Earth's shadow, making the Moon appear copper-red.

A solar eclipse is when the Moon's shadow crawls over the Earth, blocking out the Sun partially or completely. There are three kinds of solar eclipses. A total eclipse blocks the entire Sun, whereas in a partial eclipse the Moon appears to block part, but not all of the Sun's disk. An annular eclipse is when the Moon is too far from Earth to completely cover the Sun, so there's a bright ring around the Moon when it moves in front of the Sun.

It just so happens that the Sun's diameter is about 400 times larger than the Moon, but the Moon is 400 times closer than the Sun. This makes the Sun and Moon appear to be about the same size in the sky as viewed from Earth. This is also why the eclipse thing is such a big deal for our planet.

Transits are where the disk of a planet (like Venus) passes like a small shadow across the Sun. Io transits the surface of Jupiter. In rare cases, one planet will transit another. These are rare because all three objects must align in a straight line.

Astronomers use this method to detect large planets around distant bright stars. If a large planet passes in front of its star, the star will appear to dim slightly.

Note: A transit is not an occultation, which completely hides the smaller object behind a larger one.

Questions to Answer

1. What other planets can have eclipses?
2. Which planets transit the Sun?
3. How is a solar eclipse different from a lunar eclipse?
4. What phase can a lunar eclipse occur?
5. Can a solar eclipse occur at night?

Lesson #6: Rusty Balloon

Overview: Mars is coated with iron oxide, which not only covers the surface but is also present in the rocks made by the Martian volcanoes.

What to Learn: Today you get to perform a chemistry experiment that investigates the different kinds of rust and shows that given the right conditions, anything containing iron will eventually break down and corrode. When iron rusts, it's actually going through a chemical reaction: *Steel (iron) + Water (oxygen) + Air (oxygen) = Rust*

Materials

- Four empty water bottles
- Four balloons
- Water
- Steel wool
- Vinegar
- Water
- Salt

Experiment

1. This lab is best done over two consecutive days. Plan to set up the experiment on the first day, and finish up with the observations on the next.
2. Line up four empty bottles on the table.
3. Label your bottles so you know which is which: *Water, Water + Salt, Vinegar, Vinegar + Salt*
4. Fill two bottles with water.
5. Fill two with vinegar.
6. Add a tablespoon of salt to one of the water bottles.
7. Add one tablespoon of salt to one of the vinegar bottles.
8. Stuff a piece of steel wool into each bottle so it comes in contact with the liquid.
9. Stretch a balloon across the mouth of each bottle.
10. Let your experiment sit (overnight is best, but you can shorten this a bit if you're in a hurry).
11. The trick to getting this one to work is in what you expect to happen. The balloon should get shoved inside the bottle (not expand and inflate!). Check back over the course of a few hours to a few days to watch your progress.
12. Fill in the data table.

Rusty Balloon Data Table

What's in the Bottle?	What happened? *Describe what happened to the wool, bottle, and balloon.*

Reading

Rust is a common name for iron oxide. When metals rust, scientists say that they oxidize, or corrode. Iron reacts with oxygen when water is present. The water can be liquid or the humidity in the air. Other types of rust happen when oxygen is not around, like the combination of iron and chloride. When rebar is used in underwater concrete pillars, the chloride from the salt in the ocean combines with the iron in the rebar and makes a green rust.

Mars has a solid core that is mostly iron and sulfur, and a soft pastel-like mantle of silicates (there are no tectonic plates). The crust has basalt and iron oxide. The iron is in the rocks and volcanoes of Mars, and Mars appears to be covered in rust.

When iron rusts, it's actually going through a chemical reaction:
Steel (iron) + Water (oxygen) + Air (oxygen) = Rust

There are many different kinds of rust. Stainless steel has a protective coating called chromium (III) oxide so it doesn't rust easily.

Aluminum, on the other hand, takes a long time to corrode because it's already corroded — that is, as soon as aluminum is exposed to oxygen, it immediately forms a coating of aluminum oxide, which protects the remaining aluminum from further corrosion.

An easy way to remove rust from steel surfaces is to rub the steel with aluminum foil dipped in water. The aluminum transfers oxygen atoms from the iron to the aluminum, forming aluminum oxide, which is a metal polishing compound. And since the foil is softer than steel, it won't scratch.

Questions to Answer

1. Why did one balloon get larger than the rest?
2. Which had the highest pressure difference? Why?

Lesson #7: Meteorites

Overview: A meteoroid is a small rock that zooms around outer space. When the meteoroid zips into the Earth's atmosphere, it's now called a meteor or "shooting star." If the rock doesn't vaporize en route, it's called a meteorite as soon as it whacks into the ground. The word meteor comes from the Greek word for "high in the air."

What to Learn: Meteorites are black, heavy (almost twice the normal rock density), and magnetic. However, there is an Earth-made rock that is also black, heavy, and magnetic (magnetite) that is not a meteorite. To tell the difference, scratch a line from both rocks onto an unglazed tile. Magnetite will leave a mark whereas the real meteorite will not.

Materials

- White paper
- Strong magnet
- Unglazed porcelain tile
- Handheld magnifying glass (optional)

Experiment

1. Imagine you are going on a rock hunt. You are to find which rocks are meteorites and which are Earth rocks. If you don't have access to rock samples, just watch the experiment video of the different rock samples. If you'd like to make your own sample collection, here are some ideas:
    a. 8-10 different rocks, including pumice (from a volcano), lodestone (a naturally magnetized piece of magnetite, and often mistaken for meteorites), a fossil, tektite (dry fused glass), pyrite (also known as *fool's gold*), marble (calcite or dolomite), and a couple of different kinds of real meteorites (iron meteorite, stony meteorite, etc.) Also add to your bag an unglazed tile and a magnet.
2. As you watch the experiment video, record your observations on your data sheet.
    a. Since nearly all meteorites have lots of iron, they are usually attracted to a magnet. However, lodestone is an Earth rock that also has a lot of iron. Iron is heavy, and meteorites contain a lot of iron. When looking through the possibilities, remove any lightweight rocks, as they are not usually meteorites.
    b. Meteorites are small. Most never get big enough or hot enough for metal to sink into the core, so the majority are mixed with rock and dust (stony meteorites). The few that do get big and form metal cores are called iron meteorites.
    c. Most meteorites come from the Asteroid Belt. Some meteorites get a dark crust. While others look like splashed metal. They are all dark, at least on the outside. Remove any light-colored rocks.
    d. Rocks that have holes vaporize or explode when they go through the atmosphere, they don't burn up. Only strong space rocks without holes make it to the ground. Remove any porous rocks.
    e. The ones you have left are either meteorites or lodestone. To tell the difference, scratch a line from both rocks onto an unglazed tile. Magnetite (lodestone) will leave a mark whereas the real meteorite will not.

<u>Finding Meteorites</u>

3. Place a sheet of white paper outside on the ground. Do this in the morning when you first start up class.
4. After a few hours (like just before lunchtime), your paper starts to show signs of "dust."

5. Carefully place a magnet underneath the paper, and see if any of the particles move as you wiggle the magnet. If so, you've got yourself a few bits of space dust.
6. Use a magnifying lens to look at your space meteorites up close.

Meteorites Data Table

Rock Sample #	Color?	Heavy or Light?	Large or Small?	Porous or Dense?	Magnetic?	Marks on Tile?

Reading

94% of all meteorites that fall to the Earth are stony meteorites. Stony meteorites will have metal grains mixed with the stone that are clearly visible when you look at a slice.

Iron meteorites make up only 5% of the meteorites that hit the Earth. However, since they are stronger, most of them survive the trip through the atmosphere and are easier to find since they are more resistant to weathering. More than half the meteorites we find are iron meteorites. They are the one of the densest materials on Earth. They stick strongly to magnets and are twice as heavy as most Earth rocks. The Hoba meteorite in Namibia weighs 50 tons.

Since nearly all meteorites have lots of iron, they are usually attracted to a magnet. However, lodestone is an Earth rock that also has a lot of iron. Iron is heavy, and meteorites contain a lot of iron. When looking through the possibilities, remove any lightweight rocks, as they are not usually meteorites.

Meteorites are small. Most never get big enough or hot enough for metal to sink into the core, so the majority are mixed with rock and dust (stony meteorites). The few that do get big and form metal cores are called iron meteorites.

Most meteorites come from the Asteroid Belt. Some meteorites get a dark crust, while others look like splashed metal. They are all dark, at least on the outside.

Rocks that have holes vaporize or explode when they go through the atmosphere, they don't burn up. Only strong space rocks without holes make it to the ground.

Every year, the Earth passes through the debris left behind by comets. Comets are dirty snowballs that leave a trail of particles as they orbit the Sun. When the Earth passes through one of these trails, the tiny particles enter the Earth's atmosphere and burn up, leaving spectacular meteor showers for us to watch on a regular basis. The best meteor showers occur when the moon is new and the sky is very dark.

Meteorites are black, heavy (almost twice the normal rock density), and magnetic. However, there is an Earth-made rock that is also black, heavy, and magnetic (magnetite) that is not a meteorite. To tell the difference, scratch a line from both rocks onto an unglazed tile (or the bottom of a coffee mug or the underside of the toilet tank). Magnetite will leave a mark, whereas the real meteorite will not.

If you find a meteorite, head to your nearest geology department at a local university or college and let them know what you've found. In the USA, if you find a meteorite, you get to keep it … but you might want to let the experts in the geology department have a thin slice of it to see what they can figure out about your particular specimen.

Annual Meteor Showers

Jan 3-4	Quadrantids	Oct 21-22	Orionids
Apr 21-22	April Lyrids	Nov 3-13	Taurids
May 4-5	Eta Aquarids	Nov 16-17	Leonids
Jul 28-29	Delta Aquarids	Dec 13-14	Geminids
Aug 12-13	Perseids	Dec 21-22	Ursids

Questions to Answer

1. Are meteors members of the solar system?
2. How big are meteors?
3. Why do we have meteor showers at predictable times of the year?

Lesson #8: Neptune's Furnace

Overview: We're going to do a chemistry experiment to simulate the heat generated by the internal core of Neptune by using a substance used for melting snow mixed with baking soda.

What to Learn: Calcium chloride splits into calcium ions and chloride ions when it is mixed with water, and energy is released in the form of heat. The energy released comes from the bond energy of the calcium chloride atoms, and is actually electromagnetic energy. When the calcium ions and chloride ions are floating around in the warm solution, they are free to interact with the rest of the ingredients added, like the sodium bicarbonate, to form carbon dioxide gas and sodium chloride (table salt).

Materials

- Calcium chloride
- Sodium bicarbonate (baking soda)
- Phenol red or red food dye
- Resealable plastic baggie
- Gallon milk jug container
- Straight pin
- Warm water
- Cold water

Experiment

1. Cut the top off the milk jug just above the handle so you can easily put your experiment in the jug.
2. Fill your milk jug with cold water most of the way. Leave enough room for you to add the bag without overflowing the water, and make sure you put in very <u>cold</u> water. Set this aside.
3. Add an inch of <u>warm</u> water to the plastic bag.
4. Add a couple of drops of red dye to the bag.
5. If you are using a hot pack, open the hot pack (use scissors) carefully. You don't want to puncture the water pouch inside. Throw the water pouch away and pour the rest of the contents into a container (this is calcium chloride). You want a couple of tablespoons of calcium chloride in the plastic baggie.
6. Seal the bag closed and roll the pellets between your fingers.
7. Use a straight pin and make six holes near the top of the bag, away from the water.
8. Open the bag and add a couple of tablespoons of sodium bicarbonate (baking soda). Quickly zip up your bag!
9. Make sure the bag is sealed *before* inserting it into your cold water jug. Watch carefully for several minutes and record your observations with the next step.
10. Draw your experiment during step 9. Label all parts of what's going on with your experiment:

Reading

We're simulating the heat generation on Neptune using a chemistry experiment with a hot pack.

Most instant hot packs available in drugstores work on this same principle we're about to investigate. When the hot pack is needed, the bag is squeezed to cause the water and salt to mix. Depending on the salt used in the pack, energy is either absorbed (cold pack) or given off (hot pack). Ammonium nitrate is the most commonly used salt in cold packs. And calcium chloride is the most commonly used salt in hot packs.

Calcium chloride splits into calcium ions and chloride ions when it is mixed with water, and energy is released in the form of heat. This is the same heat energy you will feel when holding the baggie and rubbing the pellets.

Dissolving calcium chloride is highly exothermic, meaning that it gives off a lot of heat when mixed with water (the water can reach up to 140^{o}F, so watch your hands!). The energy released comes from the bond energy of the calcium chloride atoms, and is actually electromagnetic energy.

When the calcium ions and chloride ions are floating around in the warm solution, they are free to interact with the rest of the ingredients added, like the sodium bicarbonate, to form carbon dioxide gas and sodium chloride (table salt). You can tell there's carbon dioxide gas inside when the bag puffs up.

As the gas in the bag increases, it puffs out and increases the pressure. This stretches the bag and some of the gas is released out the holes in the top of the bag, bubbling up to the surface of the milk jug. After a while, the warm water will also rise out of the holes due to the temperature difference between the bag and jug and you'll see red drift up to the top surface of the milk jug. The heat generated by Neptune is deep in the core, and it bubbles up and radiates out to space, just like the warm bag bubbling its contents to the cold water jug. The entire planet is a whirling, swirling, fast-moving ball of gas and ice that move because of temperature and pressure differences.

Neptune is one of the ice giants of our solar system, and the furthest planet from the sun. Because it's a gas giant, you couldn't land your spaceship on the surface because it doesn't have one. You'd continuously fall until the pressure crushed your ship. And then when you got down far enough, you'd be roasted, because Neptune radiates 2.6 times more energy than it gets from the Sun. That's impressive, especially since it's so far from the Sun (30.1 AU, or more than 30 times the Earth-Sun distance). The average daily wind speed on Neptune is 1,200 mph. That's four times *faster* than the biggest hurricanes on Earth!

Neptune has more mass than Uranus even though it's smaller than Uranus. The rings around the planet weren't confirmed until a space probe passed it and sent us back pictures of the blue planet. It's hard for backyard astronomers to find this planet, since it's not a naked-eye object. You need a complicated-looking set of star charts or a GPS tracking system coupled with astronomical data to point your scope in the right direction. Even then, all you see is a white-blue looking star.

Although it's a gas giant, it's classified as an ice giant, since there are large amounts of methane and ammonia ices in the upper atmosphere, giving the planet its blue color. The largest of 13 moons is Triton (not to be confused with Saturn's massive moon, *Titan*), which orbits Neptune in the opposite direction from the planet's rotation and also up at an incline from the planet's equator.

Questions to Answer

1. What happens when the chemicals come in contact with each other?
2. What did you notice when you sealed the bag closed and rolled the pellets between your fingers?
3. What happened when the solution was placed in the cold water jug?
4. What does this experiment have to do with Neptune? Why did we use the baking soda at all?

Lesson #9: Binary Planetary Systems

Overview: A binary system exists when objects approach each other in size (and gravitational fields), the common point they rotate around (called the center of mass) lies outside both objects and they orbit around each other. Astronomers have found binary planets, binary stars, and even binary black holes. Students will know that the path of a planet around an object is due to the gravitational attraction between the object and the planet.

What to Learn: The path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet. This is true for the path of the Moon around the Earth, and Titan around Saturn, and the rest of the planets that have an orbiting moon.

Materials

- Soup cans or plastic containers with holes punched (like plastic yogurt containers, butter tubs, etc.)
- String
- Water
- Sand
- Rocks
- Pebbles
- Baking soda
- Vinegar

Experiment

1. Thread one end of the string through one of the holes and tie a strong knot. Really strong.
2. Tie the other end through the other hole and tie off.
3. Go outside.
4. Fill your can partway with water.
5. Move away from everyone before you start to swing your container in a gentle circle. As you spin faster and faster, notice where the water is inside the container.
6. Now empty out the water and replace it with rocks. Spin again and fill out the data table.
7. To make carbon dioxide gas, you'll need to work with another lab team. Cover the bottom of your container with baking soda. Add enough vinegar so that the bubbles reach the top without overflowing. Wait patiently for the bubbles to subside. You now have a container filled with carbon dioxide gas (and a little sodium acetate, the leftovers from the reaction). Carefully pour the carbon dioxide into the empty container from the other lab team. They can spin again and record their results. When they are done, borrow their container and give them yours so they can fill it for you.

Binary Planetary Systems Data Table

When filling out the third column, notice how hard or easy it was to spin the container, what it felt like, which way it faced, etc. Record everything you can about each one.

Item in the Can	State of Matter *(solid, liquid, or gas?)*	What did you notice?
Water		
Rocks		
Sand		
Air		
Pebbles		
Carbon Dioxide Gas		

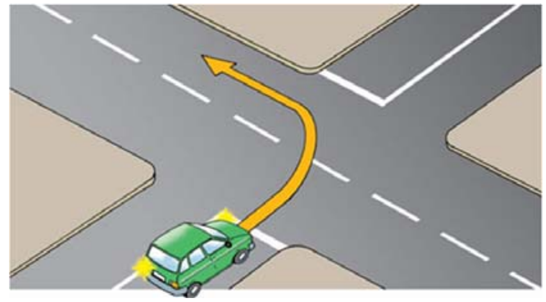
Reading

The path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet. This is true for the path of the Moon around the Earth, and Titan around Saturn, and the rest of the planets that have an orbiting moon.

Charon and Pluto orbit around each other due to their gravitational attraction to each other. However, Charon is *not* the moon of Pluto, as originally thought. Pluto and Charon actually orbit around each other. Pluto and Charon also are tidally locked, just like the Earth-Moon system, meaning that one side of Pluto is always faces the same side of Charon.

Imagine you have a bucket half full of water. Can you tilt a bucket completely sideways without spilling a drop? Sure thing! You can swing it by the handle, and even though it's upside down at one point, the water stays put. What's keeping the water inside the bucket?

Before we answer this, imagine you are a passenger in a car, and the driver is late for an appointment. They take a turn a little too fast, and you forgot to fasten your seat belt. The car makes a sharp left turn. Which way would you move in the car if they took this turn too fast? Exactly – you'd go sliding to the right. So, who pushed you?



No one! Your body wanted to continue in a straight line, but the car is turning, so the right side car door keeps pushing you to turn you in a curve – into the left turn. The car door keeps moving in your way, turning you into a circle. The car door pushing on you is called centripetal force. Centripetal means "center-seeking**.**" It's the force that points toward the center of the circle you're moving on. When you swing the bucket around your head, the bottom of the bucket is making the water turn in a circle and not fly away. Your arm is pulling on the handle of the bucket, keeping it turning in a circle and not letting it fly away. That's centripetal force.

Think of it this way: If I throw a ball in outer space, does it go in a straight line or does it wiggle all over the place? Straight line, right? Centripetal force is the force needed to keep an object following a curved path.

Remember how objects will travel in a straight line unless they bump into something or have another force acting on them, such as gravity, drag force, and so forth? Well, to keep the bucket of water swinging in a curved arc, the centripetal force can be felt in the tension experienced by the handle (or your arm, in our case). Swinging an object around on a string will cause the rope to undergo tension (centripetal force), and if your rope isn't strong enough, it will snap and break, sending the mass flying off in a tangent (straight) line until gravity and drag force pull the object to a stop. This force is proportional to the square of the speed - the faster you swing the object, the higher the force.

Questions to Answer

1. How is spinning the container like Pluto and Charon?
2. What would happen if we cut the string while you are spinning? Which way would the container go?
3. What happens if we triple the size of your container and what's inside of it?

Lesson #10: Build Your Own Solar System

Overview: What would happen if our solar system had three suns? Or the Earth had two moons? You can find out all these and more with this lesson on orbital mechanics. Instead of waiting until you hit college, we thought we'd throw some university-level physics at you … without the hard math.

What to Learn Key concepts about gravity:

a. Gravity is a force that attracts things to one another.
b. All bodies (objects) have a gravitational field.
c. The larger a body is, the greater the strength of the gravitational field.
d. Bodies must be very, very large before they exert any noticeable gravitational field.
e. Gravity accelerates all things equally. Which means all things speed up the same amount as they fall.
f. Gravity does not care what size things are or whether things are moving. All things are accelerated toward the Earth at the same rate of speed.
g. Gravity does pull on things differently. Gravity is pulling greater on objects that weigh more.
h. Weight is a measure of how much gravity is pulling on an object.
i. Mass is a measure of how much matter (how many atoms) make up an object.

Materials

- Access to a computer with Internet
- Ruler

Experiment

<u>About the Concept of Gravity</u>

1. Even though we deal with gravity on a constant basis, there are several misconceptions about it. Let's get to an experiment right away and I'll show you what I mean.
2. When you drop a golf ball and a ping pong ball from the same height, what happens?
3. What you should see is that both objects hit the ground at the same time! Gravity accelerates both items equally and they hit the ground at the same time. Any two objects will do this, a brick and a Buick, a flower and a fish, a kumquat and a cow!
4. But what if you drop a feather and a ball at the same time? There is one thing that will change the results and that is *air resistance*. The bigger, lighter and fluffier something is, the more air resistance can affect it and so it will fall more slowly. Air resistance is a type of friction which we will be talking about later. In fact, if you removed air resistance, a feather and a flounder would hit the ground at the same time!!!
5. Where can you remove air resistance? The Moon!!! One of the Apollo missions actually did this (well, they didn't use a flounder, they used a hammer). An astronaut dropped a feather and a hammer at the same time and indeed, both fell at the same rate of speed and hit the surface of the moon at the same time.
6. Which will hit the ground first, if dropped from the same height, a bowling ball or a tennis ball? Most people will say the bowling ball. In fact, if you asked yourself that question 5 minutes ago, would you have gotten it right? It's conventional wisdom to think that the heavier object falls faster.
7. Unfortunately, conventional wisdom isn't always right. Gravity accelerates all things equally. In other words, gravity makes all things speed up or slow down at the same rate.

8. This is a great example of why the scientific method (more on this later) is such a cool thing. Many, many years ago, there was a man of great knowledge and wisdom named Aristotle. Whatever he said, most people believed to be true. The trouble was, he didn't test everything that he said. One of his statements was that objects with greater weight fall faster than objects with less weight. Everyone believed that this was true. Hundreds of years later, Galileo came along and said "Ya know ... that doesn't seem to work that way. I'm going to test it" The story goes that Galileo grabbed a melon and an orange and went to the top of the Leaning Tower of Pisa. He said, "Look out below!" and dropped them! By doing that, he showed that objects fall at the same rate of speed no matter what their size. It is true that it was Galileo who "proved" that gravity accelerates all things equally no matter what their weight, but there is no real evidence that he actually used the Leaning Tower of Pisa to do it.
9. Key concepts about Gravity:
    a. Gravity is a force that attracts things to one another.
    b. All bodies (objects) have a gravitational field.
    c. The larger a body is, the greater the strength of the gravitational field.
    d. Bodies must be very, very large before they exert any noticeable gravitational field.
    e. Gravity accelerates all things equally. Which means all things speed up the same amount as they fall.
    f. Gravity does not care what size things are or whether things are moving. All things are accelerated toward the Earth at the same rate of speed.
    g. Gravity does pull on things differently. Gravity is pulling greater on objects that weigh more.
    h. Weight is a measure of how much gravity is pulling on an object.
    i. Mass is a measure of how much matter (how many atoms) make up an object.

<u>About the Computer Simulation</u>

1. To get you experienced with the force of gravity without getting lost in the math, there's an excellent computer program that allows you to see how multi-object systems interact. Most textbooks are limited to the interaction between a very large object, like the Earth, and much smaller objects that are very close to it, like the Moon. This seriously cuts out most of the interesting solar systems that are out there in the real universe.
2. The University of Colorado at Boulder designed a great system to do the hard math for you. Don't be fooled by the simplistic appearance – the physics behind the simulation are rock-solid … meaning that the results you get are exactly what scientists would predict to happen.
3. Go to the My Solar System simulation on the PhET website and carefully follow the instructions for each activity. Answer the questions and record your results before going on to the next activity. Visit: *http://phet.colorado.edu/sims/my-solar-system/my-solar-system.swf*
4. Once the program opens, hit start. You'll see the purple Earth orbit around the yellow Sun. Do you notice how the Earth also causes the Sun to follow a tiny orbit? That's because the Earth pulls on the Sun just as the Sun pulls on the Earth.
5. Press stop. Notice the "V?" That stands for direction and speed, as in 55 mph north. It gives how fast you are going as well as the direction you're going. Or in this case, the planet. Notice near the bottom that you can change the mass of the object. Increase the mass so that it's larger than the Sun. Press start.
6. Reset, and change the purple object (Earth) to be the size of the Moon (make it 1). Did you notice a change in the orbit path?
7. Change the purple mass back to 10, and increase the speed to a larger number. What happened?
8. The Earth is at a very special mass and speed, isn't it?
9. Reset and make your speed 200. Did it stay in orbit?

10. Add a third and fourth object by pulling down the menu on the upper right. Select "Sun, planet, and moon" and hit "Start."
11. What happens if you uncheck "show trace?" (You'll only see the objects themselves orbiting, not the path they take.)
12. What happens if you uncheck "system centered?" (The system will eventually wander off the screen as the entire system has acceleration.)
13. Play with the program for a bit, changing the location distance the objects are apart, the speed and direction they initially start out at, and their masses.

    b. What does the yellow object represent?_______________________________________

    c. What is the mass of the yellow object? _______________________________________
    (Note: No units are given, so no units are necessary.)

    d. What does the purple object represent? _______________________________________

    e. What is the mass of the purple object? _______________________________________

    f. What does the red arrow represent? _______________________________________

14. Complete the data table. Notice at the end that you will predict the necessary mass, velocity, and distance from the sun of a planet in order for this planet to make a circular orbit around a sun.

Reading

In 1666, Isaac Newton did his early work on his Three Laws of Motion. To this day, those laws still hold true. There has been some allowances for really big things (like the cosmos) and for really small things (like the atom). Other than that, Newton's Laws are pretty much dead on.

Newton's Laws are all scientists and engineers used to get the first man to the moon. They are an amazingly powerful and wonderful area of physics. I like them because evidence of them is everywhere. If something moves or can be moved, it follows Newton's Laws. You can't sit in a car, walk down the road, drink a glass of milk, or kick a ball without using Newton's Laws. I also like them because they are relatively easy to understand and yet open up worlds of answers and questions. They are truly a foundation for understanding the world around you.

Whenever I teach a class about gravity, I'll drop something (usually something large). After the heads whip around, I ask the hard question: *"Why did it fall?"* You already know the answer – **gravity**.

But *why?* Why does gravity pull things down, not up? And when did people first start noticing that we stick to the surface of the planet and not float up into the sky?

No one can tell you *why* gravity is … that's just the way the universe is wired. Gravitation is a natural thing that happens when you have mass. Galileo was actually one of the first people to do science experiments on gravity.

Build Your Own Solar System Data Table 1

Use the original preset for all values for a sun and planet,
except change the mass of body 2 (purple object) as shown below:

Mass of Body 2	Diameter of Orbit *(measure with ruler)*
1000	
100	
10	
1	
0.1	
0.01	
0.001	
0.0001	

Questions to Answer: *(Note that the exercise questions are below each data table)*

1. What effect does changing the mass of orbiting planet have on the diameter of the orbit?

Build Your Own Solar System Data Table 2

Use the original preset for all values for a sun and planet,
except change the mass of body 2 (purple object) and velocity as shown below:

Mass of Body 2	Velocity of Body 2	Describe what happened…?
0.1	y velocity = 130	
0.1	y velocity = 140	
0.1	y velocity = 150	
0.1	y velocity = 600	
0.1	y velocity = 80	
0.1	y velocity = 40	
0.1	y velocity = 20	
0.1	y velocity = 0	

2. What effect does changing the speed have on a planet's orbit?

Build Your Own Solar System Data Table 3

Use the original preset for all values for a sun and planet,
except change the mass of body 2 to 50 and the x-distance of body 2 as shown below:

x distance for Body 2	**Diameter of Orbit** *(measure with ruler)*
30	
60	
90	
120	
150	
180	
210	
240	

3. What happens to the planet's orbit when you increase the initial distance between the planet and the sun?

Build Your Own Solar System Data Table 4

Use the original preset for a binary star and planet. Change only the masses and record your observations below.

Mass of Body 1	Mass of Body 2	Mass of Body 3	Is the orbit stable?

4. Find the mass values needed for a stable orbit. Circle the values on the table that make a stable orbit.

Build Your Own Solar System Data Table 5

Use the original preset for ellipses. Change only the masses and record your observations below.

Mass of Body 1	Mass of Body 2	Mass of Body 3	Mass of Body 4	What happened?
250	10	1	0.1	

5. Why don't a feather and a brick hit the ground at the same time?

Lesson #11: Watch Your Weight

Overview: If you could stand on the Sun without being roasted, how much would you weigh? The gravitational pull is different for different objects. Let's find out which celestial object you'd crack the pavement on, and which your lightweight toes would have to be careful about jumping on in case you leapt off the planet.

What to Learn: Weight is nothing more than a measure of how much gravity is pulling on you. Mass is a measure of how much stuff you're made out of. Weight can change depending on the gravitational field you are standing in. Mass can only change if you lose an arm.

Materials

- Scale to weigh yourself
- Calculator
- Pencil

Experiment

1. We need to talk about the difference between weight and mass. In everyday language, weight and mass are used interchangeably, but scientists know better.
2. Mass is how much stuff something is made out of. If you're holding a bowling ball, you'll notice that it's hard to get started, and once it gets moving, it needs another push to get it to stop. If you leave the bowling ball on the floor, it stays put. Once you push it, it wants to stay moving. This "sluggishness" is called inertia. Mass is how much inertia an object has.
3. Every object with mass also has a gravitational field, and is attracted to everything else that has mass. The amount of gravity something has depends on how far apart the objects are. When you step on a bathroom scale, you are reading your weight, or how much attraction is between you and the Earth.
4. If you stepped on a scale in a spaceship that is parked from any planets, moons, black holes, or other objects, it would read zero. But is your mass zero? No way. You're still made of the same stuff you were on Earth, so your mass is the same. But you'd have no weight.
5. What is your weight on Earth? Let's find out now.
6. Step on the scale and read the number. Write it down.
7. Now, what is your weight on the Moon? The correction factor is 0.17. So multiply your weight by 0.17 to find what the scale would read on the Moon.
8. For example, if I weigh 100 pounds on Earth, then I'd weight only 17 pounds on the Moon. If the scale reads 10 kg on Earth, then it would read 1.7 kg on the Moon.
   Complete the data table..

Watch Your Weight Data Table

Weight on Planet/Object = Weight on Earth x Gravity Correction

Planet/Object	Weight on Earth	Gravity Correction	Weight on Planet/Object
The Sun		28	
Mercury		0.38	
Venus		0.91	
Earth		1	
Moon		0.17	
Mars		0.38	
Jupiter		2.14	
Saturn		0.91	
Uranus		0.86	
Neptune		1.1	
Pluto		0.08	
Outer Space		0	
Betelgeuse		14,000	
White Dwarf		1,300,000	
Neutron Star (Pulsar)		140,000,000,000	
Black Hole		∞	

Reading

Weight is nothing more than a measure of how much gravity is pulling on you. This is why you can be "weightless" in space. You are still made of stuff, but there's no gravity to pull on you so you have no weight. The larger a body is, the more gravitational pull (or in other words the larger a gravitational field) it will have.

The Moon has a fairly small gravitational field (if you weighed 100 pounds on Earth, you'd only be 17 pounds on the Moon).The Earth's field is fairly large and the Sun has a HUGE gravitational field (if you weighed 100 pounds on Earth, you'd weigh 2,500 pounds on the Sun!).

As a matter of fact, the dog and I both have gravitational fields! Since we are both bodies of mass, we have a gravitational field which will pull things toward us. All bodies have a gravitational field. However, my mass is so small that the gravitational field I have is miniscule. Something has to be very massive before it has a gravitational field that noticeably attracts another body.

So what's the measurement for how much stuff you're made of? Mass. Mass is basically a weightless measure of how much matter makes you ***you***. A hamster is made of a fairly small amount of stuff, so she has a small mass. I am made of more stuff, so my mass is greater than the hamster's. Your house is made of even more stuff, so its mass is greater still. So, here's a question. If you are "weightless" in space, do you still have mass? Yes, the amount of stuff you're made of is the same on Earth as it is in your spaceship. Mass does not change, but since weight is a measure for how much gravity is pulling on you, weight will change.

Did you notice that I put weightless in quotation marks? Wonder why?

Weightlessness is a myth! Believe it or not, one is never weightless. A person can be pretty close to weightless in very deep space, but the astronauts in a spaceship actually do have a bit of weight.

Think about it for a second. If a spaceship is orbiting the Earth, what is it doing? It's constantly falling! If it wasn't moving forward at tens of thousands of miles an hour it would hit the Earth. It's moving fast enough to fall around the curvature of the Earth as it falls but, indeed, it's falling as the Earth's gravity is pulling it to us.

Otherwise the ship would float out to space. So what is the astronaut doing? She's falling, too! The astronaut and the spaceship are both falling to the Earth at the same rate of speed and so the astronaut feels weightless in space. If you were in an elevator and the cable snapped, you and the elevator would fall to the Earth at the same rate of speed. You'd feel weightless! (Don't try this at home!)

Either now, or at some point in the future you may ask yourself this question, "How can gravity pull harder (put more force on some things, like bowling balls) and yet accelerate all things equally?" When we get into Newton's laws in a few lessons, you'll realize that doesn't make any sense at all. More force equals more acceleration is basically Newton's Second Law.

Well, I don't want to take too much time here since this is a little deeper then we need to go but I do feel some explanation is in order to avoid future confusion. The explanation for this is inertia. When we get to Newton's First Law we will discuss inertia. Inertia is basically how much force is needed to get something to move or stop moving.

Now, let's get back to gravity and acceleration. Let's take a look at a bowling ball and a golf ball. Gravity puts more force on the bowling ball than on the golf ball. So the bowling ball should accelerate faster since there's more force on it. However, the bowling ball is heavier so it is harder to get it moving. Conversely, the golf ball has less force pulling on it but it's easier to get moving. Do you see it? The force and inertia thing equal out so that all things accelerate due to gravity at the same rate of speed!

Gravity had to be one of the first scientific discoveries. Whoever the first guy was to drop a rock on his foot, probably realized that things fall down! However, even though we have known about gravity for many years, it still remains one of the most elusive mysteries of science. At this point, nobody knows what makes things move toward a body of mass.

Why did the rock drop toward the Earth and on that guy's foot? We still don't know. We know that it does, but we don't know what causes a gravitational attraction between objects. Gravity is also a very weak force. Compared to magnetic forces and electrostatic forces, the gravitational force is extremely weak. How come? No one knows. A large amount of amazing brain power is being used to discover these mysteries of gravity. Maybe it will be you who figures this out!

Questions to Answer

1. Of the following objects, which ones are attracted to one another by gravity?
   a) Apple and Banana b) Beagle and Chihuahua c) Earth and You d) All of the above
2. True or False: Gravity accelerates all things differently
3. True or False: Gravity pulls on all things differently
4. If I drop a golf ball and a golf cart at the same time from the same height, which hits the ground first?
5. There is a monkey hanging on the branch of a tree. A wildlife biologist wants to shoot a tranquilizer dart at the monkey to mark and study him. The biologist very carefully aims directly at the shoulder of the monkey and fires. However, the gun makes a loud enough noise that the monkey gets scared, lets go of the branch and falls directly downward. Does the dart hit where the biologist was aiming, or does it go higher or lower than he aimed? (This, by the way, is an old thought problem.)

Lesson #12: Sundial

Overview: Using the position of the Sun, you can tell what time it us by making one of these sundials. The Sun will cast a shadow onto a surface marked with the hours, and the time-telling *gnomon* edge will align with the proper time.

What to Learn: In general, sundials are susceptible to different kinds of errors. If the sundial isn't pointed north, it's not going to work. If the sundial's gnomon isn't perpendicular, it's going to give errors when you read the time. Latitude and longitude corrections may also need to be made. Some designs need to be aligned with the latitude at which they reside (in effect, they need to be tipped toward the Sun at an angle). To correct for longitude, simply shift the sundial to read exactly noon when indicated on your clock. This is especially important for sundials that lie between longitudinal standardized time zones. If daylight savings time is in effect, then the sundial timeline must be shifted to accommodate for this. Most shifts are one hour.

Materials

<u>Simple Sundial</u>

- Index card
- Scissors
- Tape

<u>Intermediate Sundial</u>

- 2 yardsticks or metersticks
- Protractor
- Chalk
- Clock

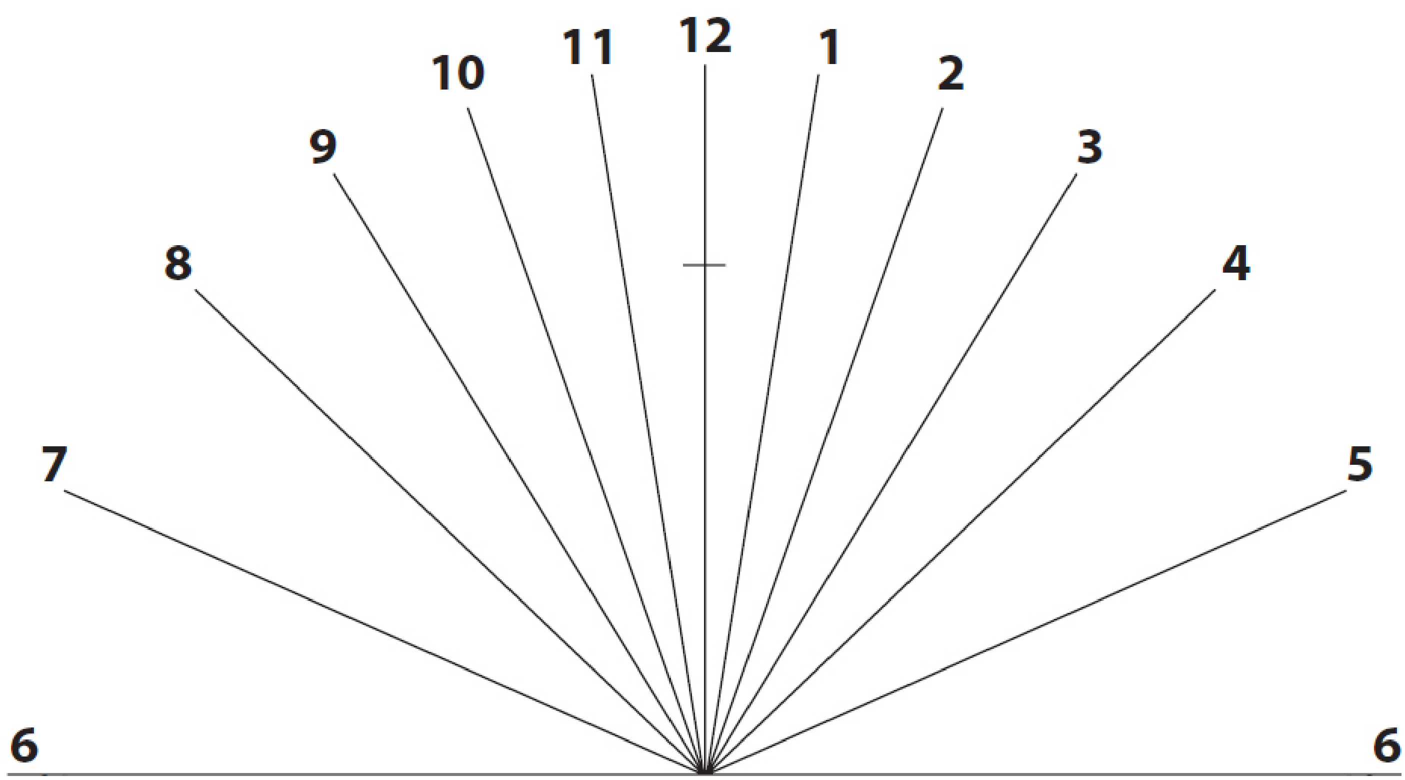
<u>Advanced Sundial</u>

- Old CD (this can also be the transparent CD at the top of DVD/CD spindles)
- Empty CD case
- Skewer
- Sticky tape
- Cardboard or small piece of clay
- Protractor
- Scissors
- Tape
- Hot glue

Simple Sundial

1. This sundial takes only a couple of minutes to make, and reads easily for beginner students.
2. Cut out the template below.
3. Cut your index card into two triangles by cutting from one corner to the opposite diagonal corner. Stack the two triangles and tape together. This is called your *gnomon*.
4. Tape the triangle to your 12-hour line, putting tape on both sides of the gnomon as you stick it to the paper.
5. Put the sundial in a sunny place where it won't be disturbed (like inside of a sunny window or on a table outdoors).
6. Point the sundial so that the gnomon is pointing north. This is most easily done if you orient your sundial at exactly noon in your location. Line up the sundial with the Sun so that the shadow the gnomon makes lines up exactly with the 12.
7. Tape the sundial down so it won't move or get blown away.
8. The gnomon must be exactly perpendicular to the hour markers. Use a ruler or a book edge to help you line this up.

Simple Sundial Template



Questions to Answer

1. What kinds of corrections need to be made for your sundial?
2. When wouldn't your sundial work?
3. How can you improve your sundial to be more accurate?

Intermediate Sundial

1. Find a sunny spot that has concrete and grassy area right next to each other. You're going to poke the yardstick into the grass and draw on the concrete with chalk, so be sure that the concrete goes in an approximately east-west direction.
2. First thing in the morning, stick one of the yardsticks into the dirt, right at the edge of the concrete.
3. At the top of the hour (like at 8 a.m. or 9 a.m.), go out to your yardstick to mark a position.
4. Lay the second yardstick down along the shadow that the upright yardstick makes on the ground. Use chalk to draw the shadow, and use the yardstick to make your line straight.
5. Label this line with the hour.
6. Set your timer and run back out at the top of the next hour.
7. Repeat steps 3-6 until you finish marking your sundial.
8. When you've completed your sundial, fill out the table.

Intermediate Data Table

Don't forget to label your units for columns 2 and 3!

Exact Time of Day	Shadow Length	Angle that the Sun Moved from Last Hour

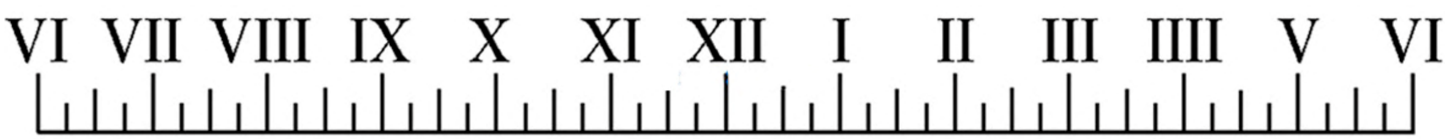
Questions to Answer

1. What kinds of corrections need to be made for your sundial?
2. When wouldn't your sundial work?
3. How can you improve your sundial to be more accurate?

Advanced Sundial

This sundial will work for all longitudes, but has a limited range of latitudes. If you live in the far north or far south, you'll need to get creative about how to mount the CD so that the gnomon is pointed at the correct angle. For example, at the equator, the CD will lie flat (which is easy!), but near the north and south poles, the CD will be upside down.

1. Cut out the timeline.
2. Put a line of double-sided sticky tape along the back of the timeline. Extend the tape about ¼" (on the bottom edge) so it's hanging off the paper a little.
3. Flip the timeline over and roll the CD along this bottom edge, sticking the timeline to the edge of the CD. The timeline should be facing inward toward the center of the CD, perpendicular to the CD surface.
4. Now it's time to plug up the center hole. You can cut out circles from a CD and attach with tape, or use a small piece of clay.
5. Push the skewer through the exact middle of the CD.
6. Open up the CD case.
7. Position the noon marker at the bottom and stick it using a piece of double-sided sticky tape or hot glue.
8. The other side of the CD is glued to the CD case at the same angle as your latitude. For example, if I live at 43° north, I would use my protractor on the ground along the base of the CD case and lift the CD until the gnomon reads at 43°. Put a dab of hot glue to attach the CD to the lid of the case.
9. Go outside and point the gnomon north (you may want to use a compass for this if it's not noon.)
10. The dial will have a shadow that falls on the timeline. You can read the time right off the timeline.
11. *For advanced students:* Timeline correction: Do you remember how the Sun was fast or slow in the Stargazer's Wall Chart from the lesson entitled: *What's in the Sky*? That wavy line is called the Equation of Time, and you'll need it to correct your sundial if you want to be completely accurate. This is a great demonstration for a Science Fair project, especially when you add a model of the Sun and Earth to help you explain what's going on.



Questions to Answer

1. What kinds of corrections need to be made for your sundial?
2. When wouldn't your sundial work?
3. How can you improve your sundial to be more accurate?

Reading

Sundials have been used for centuries to keep track of the Sun. There are different types of sundials. Some use a line of light to indicate what time it is, while others use a shadow.

Here are a few different models that, although they look a lot different from each other, actually all work to give the same results! Your sundial will work all days of the year when the Sun is out.

You'll notice that north is the direction that your shadow's length is the shortest. However, if you don't know where east and west are, all you can do is know where north is. The equinox is a special time of year because the Sun rises in the exact east and sets in the exact west, making these two points exactly perpendicular with the north for your location (which they usually aren't). At sunset, you can view your shadow (quickly before it disappears) and draw it with chalk on the ground, making a line that runs east-west. 90^{o} counterclockwise from the line is north.

In general, sundials are susceptible to different kinds of errors. If the sundial isn't pointed north, it's not going to work. If the sundial's gnomon isn't perpendicular, it's going to give errors when you read the time. Latitude and longitude corrections may also need to be made. Some designs need to be aligned with the latitude they reside at (in effect, they need to be tipped toward the Sun at an angle). To correct for longitude, simply shift the sundial to read exactly noon when indicated on your clock. This is especially important for sundials that lie between longitudinal standardized time zones. The Equation of Time from the advanced lesson entitled: *What's in the Sky?* can be used to correct for the Sun running slow or fast. Remember, this effect is due to both the Earth's orbit not being a perfect circle and the fact that the tilt axis is not perpendicular to the orbit path. If daylight savings time is in effect, then the sundial timeline must be shifted to accommodate for this. Most shifts are one hour.

Lesson #13: Diffraction

Overview: When light passes through diffraction gratings, it splits (diffracts) the light into several beams traveling in different directions. If you've ever seen the "iridescence" of a soap bubble, an insect shell, or on a pearl, you've seen nature's diffraction gratings.

What to Learn: Ever play with a prism? When sunlight strikes the prism, it gets split into a rainbow of colors. Prisms un-mix the light into its different wavelengths (which you see as different colors). Diffraction gratings are tiny prisms stacked together. The direction in which the beam gets split and diffracted depends on the spacing of the diffraction grating and also the wavelength of the incoming light.

Materials

- Feather
- CD or DVD
- Diffraction grating

Experiment

1. Take a feather and put it over an eye.
2. Stare at a light source through the feather, like an incandescent light.
3. You should see two or three lights and a rainbow X.
4. Aim the CD so the light hits the CD and makes rainbows.
5. Look at the light source through the diffraction grating.
6. Draw what you see for all three. Were they the same?
7. Find another light source and repeat the experiment, recording your observations as you go.
8. Complete the table as you view the different light sources through your diffraction gratings.

Diffraction Data Table

Light Source	Diffractive Object *(Feather, CD, or Grating?)*	Draw What You See:

Reading

Ever play with a prism? When sunlight strikes the prism, it gets split into a rainbow of colors. Prisms un-mix the light into its different wavelengths (which you see as different colors). Diffraction gratings are tiny prisms stacked together. The direction in which the beam gets split and diffracted depends on the spacing of the diffraction grating and also the wavelength of the incoming light. The feather works because there are tiny "hairs" on the feather that are acting like tiny prisms.

Diffraction gratings were first discovered by James Gregory, right around the time Newton performed his famous prism experiments with bird feathers. The first diffraction gratings took a long time to construct, as they were individual hairs strung between screws.

Questions to Answer

1. Which light source gave the most interesting results?
2. What happens when you aim a laser beam through the diffraction grating?
3. How is a CD different and the same as a diffraction grating?
4. Why does the feather work?

Lesson #14: Infrared Vision

Overview: Infrared light is in the part of the electromagnetic spectrum that isn't usually visible to human eyes, but using this nifty trick, you will easily be able to see the IR signal from your TV remote, remote-controller for an RC car, and more!

What to Learn: When you press the button on your remote control to your TV, you're using infrared light (IR) to control your TV. Infrared light is invisible to our eyes. However, snakes can detect IR and see the redder hues that we can't. Every warm body gives off light in the IR, so snakes use this to find mice in the cool night.

Materials :

You will need these items:

- Remote control for TV or stereo
- Camera (video or still camera)

This is just a suggested list of objects. Feel free to find your own!

- Metal frying pan or cookie sheet
- Plastic sheet
- Plastic baggie
- Trash bag (white or black, or both)
- Wooden cutting board

Experiment

1. Grab a remote control and verify that it is indeed working. Turn the device on and off using the remote.
2. Grab a sheet of plastic, like a cutting board, and place it between your remote and the device. Does it turn on when you aim the beam at it? Does the plastic block the beam?
3. Open up a trash bag and place one side of the bag between your remote and the device. Did that block the beam, or did the remote turn on the device?
4. What else can you try? How about a clear bag?
5. A clear bag filled with water?
6. A sheet of paper?
7. What about a metal pan? Find something that's not coated with Teflon. Does infrared go through metal?
8. What if you point it at a white wall behind you, pretending the white wall is a mirror and aiming it so it will reflect it back to the device?
9. Complete the data table.
10. Now let's make the invisible infrared light *visible*. Take your camera (either still or video camera will work) and turn it on. Put it on a mode where you can see through the view screen. Aim the camera right at the emitter for the remote (usually near the top) and press a button. Point the remote right at the camera and watch through the camera. Our eyes normally can't see the infrared light, but the camera can!
11. The camera can also see the otherwise dark end of the remote! Does your camera have a special night vision mode, where it's especially sensitive to infrared light? If so, try it!

Infrared Data Table

Item/Object Tested	Guess FIRST! *Will the Infrared Light Pass Through?*	What Happened? *(Did it pass through or not?)*

Reading

Different detectors are sensitive to different colors. Your eyeballs are sensitive to specific colors in the 400-700 nm (nanometer) range, which is how long one wavelength is. A nanometer is extremely tiny!

The frequency of red light is around 430 trillion Hz (Hertz, which is one wave cycle per second). If you were to count the number of waves passing a certain point in one second, you'd count 430 trillion waves. If you counted 750 trillion waves, the light would be violet. Different colors have different frequencies.

Light energy (also called *electromagnetic radiation)* with the lowest amounts of energy and longest wavelengths (1mm to 1km) are **radio waves**. These are emitted by radio galaxies like quasars, supernova leftovers, and the radio tower at the top of the hill. Radio waves from space with a wavelength greater than 100 meters are reflected back into space by our atmosphere. Radio waves are detected in space by the COBE satellite, the VLA in New Mexico, and the Arecibo Observatory in South America.

The next step down in wave size is **microwaves,** which have more energy than radio waves but are a shorter wavelength. These are the ones inside your microwave that excite the water molecules inside your food so that your food heats up.

Infrared (IR) has slightly more energy and an even smaller wavelength (700 nanometers, or nm to 1mm), and you can feel this light as warmth on your skin when you step into the Sun. There's a lot of infrared radiation in space around the star-forming clouds and objects with a temperature above 1000^{o}C. SOFIA and the Infrared Observatory both detect infrared from various stars in space.

Visible light or optical light waves are the visible rainbow you can see with your eyes after a rainy day. These wavelengths have more energy and shorter wavelengths (300 to 700 nm) than infrared. The Hubble Space Telescope and Earth-bound optical telescopes look at stars, galaxies, and planets.

Ultraviolet (UV) light has more energy and shorter wavelengths (10nm to 390nm) than visible light, and you'll find hot stars emit largely in this region of the spectrum. The ozone layer protects us from most of the UV, but not all. That's why you get a sunburn if you don't wear sunblock, and why colors fade in sunlight. SkyLab, Astrotelescope and SOHO all search for UV. SOHO looks directly at the Sun's corona to get amazing images in UV.

X-rays have even more energy and short wavelengths (0.01nm to 10 nm) than UV light, and you'll find these are emitted by active black holes, supernova remnants, and very hot stars (we're talking 1 million to 100 million ^{o}C). Fortunately for us, these are quickly absorbed in the upper atmosphere and most never make it to the surface of Earth. X-rays generated on earth are emitted by electrons outside the nucleus of an atom. ROSAT looked at cluster galaxies to detect X-ray sources.

Deadly **gamma rays** have the most amount of energy and the shortest frequency (less than 0.01 nm), and you'll find these in areas of superflares from pulsars, supernovas, and radioactive atoms. Gamma rays are like X-rays, in that they both can go through thick materials, and would rather go through your detector than into it to be detected. Gamma rays on Earth are generated inside the nucleus of an atom. The Compton Observatory looked at quasars to detect gamma rays.

Questions to Answer

1. Look over your data table. What *kinds* of objects (plastic, metal, natural, etc.) allow infrared light to pass through them?

2. Why does the camera work in making the infrared light visible?

Lesson #15: UV Light

Overview: Stars, including our Sun, produce all kinds of wavelengths of light, including UV (ultra-violet). That's the wavelength that gives you sunburns. We're going to find out the best way to protect you from the harmful rays.

What to Learn: The UV beads we're going to use in our experiment are made from a chemical that reacts with light. It takes the UV light from the Sun and then re-emits it in a different wavelength that's visible to us.

Materials

- 5 UV beads (these change colors when exposed to the Sun)
- Tape (double-sided is easier)
- Sun block
- Sunglasses
- Sunny day
- Water
- Piece of fabric
- Clear plastic bag

Experiment

1. Place a piece of tape on the data table, and stick your beads to the tape, one in each box.
2. Walk outside with your data table and record your observations.

UV Light Data Table 1

Bead	**Color Inside**	**Color When in Sunlight**	**How Long Did It Take to Return to Indoor Color?** *(measure in seconds)*
1			
2			
3			
4			
5			

3. Walk back indoors and cover the beads, blocking out all light. Peek at them every minute or two to find out when they've returned to their unexposed color.

4. Now prepare your second round of testing by doing the following *before* exposing the beads to the Sun:
    a. Place a bead inside a baggie.
    b. Place a second bead inside a baggie filled with water.
    c. Smear a clean baggie with sun block and place a third bead inside.
    d. Place a pair of sunglasses over a fourth bead.
    e. Place a fifth bead under a piece of fabric.
5. Walk your 5 beads outside and record your observations in the data table.

UV Light Data Table 2

Bead	Color Inside	Color When in Sunlight
1: Baggie		
2: Baggie + Water		
3: Sun block		
4: Sunglasses		
5: Fabric		

6. Bring your beads back inside and return them to their unexposed color.
7. Prepare your third round of testing by exposing your beads to some of the following:
    f. A fluorescent lamp
    g. An incandescent lamp
    h. Flashlight
    i. Glow stick
    j. Computer screen
    k. Reflected sunlight using a mirror
    l. Candle flame (please be careful with this!)
    m. Any other light source you have access to
8. Record your observations in the data table.

UV Light Data Table 3

Light Source	Color Inside	Color When Exposed	How Long Did It Take to Change Color when Exposed?

Reading

UV-sensitive materials have a pigment inside that changes color when exposed to UV light from either the Sun or lights that emit in the 350nm – 300nm wavelength. (UVA is high-energy: 400-320nm, and UVB is low energy: 320-280nm). If you have fluorescent black lights, use them. (Do regular incandescent bulbs work? If not, you know they emit light outside the range of the beads!)

Stars, including our Sun, produce all kinds of wavelengths of light, even UV. The UV beads we're going to use in our experiment are made from a chemical that reacts with light. It takes the UV light from the Sun and then re-emits it in a different wavelength that's visible to us. When a particle of UV light smacks into an atom, it collides with an electron and makes the electron jump to a higher, more energetic state that is a bit further from the center of the atom than it's comfortable being. That's how energy gets absorbed by an atom. The amount of energy an electron has determines how far from the atom it has to be. The electron prefers being in its lower state, so it relaxes and jumps back down, transferring a blip of energy away as it does. This blip of energy is the light we see emitted from the UV beads. This process continues as long as we see a color coming from the UV beads.

When light hits the pigment molecule, it absorbs the energy and actually expands asymmetrically (one end of the molecule expands more than the other). Different expansion amounts will give you a different color. Although it's a bit more complicated than that, you now have the basic idea. Your beads will change colors thousands of times before they wear out, so enjoy these super-inexpensive UV detectors.

A note about sun block: You can test different SPF levels of sun block, but here's the main idea behind the ratings: the number for SPF is the number of minutes it takes to get the same Sun exposure than if you weren't wearing any for one minute. For example, SPF 30 will give you the same Sun exposure after 30 minutes that you would normally get if you weren't wearing any after just one minute.

Questions to Answer

1. What kinds of light sources didn't work with the UV beads?
2. Did your sun block really block out the UV rays?
3. Which was the best protection against UV rays?

Lesson #16: Star Wobble

Overview: How do astronomers find planets around distant stars? If you look at a star through binoculars or a telescope, you'll quickly notice how bright the star is, and how difficult it is to see anything other than the star, especially a small planet that doesn't generate any light of its own! Astronomers look for a shift, or wobble, of the star as it gets gravitationally "yanked" around by the orbiting planets. By measuring this wobble, astronomers can estimate the size and distance of larger orbiting objects.

What to Learn: Doppler spectroscopy is one way astronomers find planets around distant stars. If you recall the lesson where we created our own solar system in a computer simulation, you remember how the star could be influenced by a smaller planet enough to have a tiny orbit of its own. This tiny orbit is what astronomers are trying to detect with this method.

Materials

- Several bouncy balls of different sizes and weights, soft enough to stab with a toothpick
- Toothpicks

Experiment

1. Does your ball have a number written on it? If so, that's the weight, and you can skip measuring the weight with a scale.
2. If not, weigh each one and make a note in the data table.
3. Take the heaviest ball and spin it on the table. Can you get it to spin in place? That's like a Sun without any planets around it.
4. Insert a toothpick into the ball. Now insert the end of the toothpick into the smallest weight ball. Now spin the original ball. What happened?
5. Complete the data table.

Star Wobble Data Table

Weight of Ball #1	Weight of Ball #2	How Much Did it Wobble? *(Use a scale of 1 to 5, with 5 being the most wobble)*

Reading

Nearly half of the extrasolar (outside our solar system) planets discovered were found by using this method of detection. It's very hard to detect planets from Earth because planets are so dim, and the light they do emit tends to be infrared radiation. Our Sun outshines all the planets in our solar system by one billion times.

This method uses the idea that an orbiting planet exerts a gravitational force on the Sun that yanks the Sun around in a tiny orbit. When this is viewed from a distance, the star appears to wobble. Not only that, this small orbit also affects the color of the light we receive from the star. This method requires that scientists make very precise measurements of its position in the sky.

Questions to Answer

1. For homework tonight, find out how many extrasolar planets scientists have detected so far.
2. Also for homework, find out the names (they will probably be a string of numbers and letters together) of the 3 most recent extrasolar planet discoveries.

Lesson #17: Space Telescopes

Overview: NASA's Great Observatories consist of four space telescopes, each designed to look at the universe in one small part of the electromagnetic spectrum: infrared, visible, X-ray, and gamma rays. Each telescope is a satellite that orbits the Earth in a very specific way.

What to Learn: There's a common misconception about gravity and space, in that most folks believe satellites don't move in orbit. The truth is, satellites must maintain a very specific velocity in order to maintain their stable orbits.

Materials

- Five different sizes of small balls: marbles, ping-pong, rubber bouncy, etc.
- Tape
- Sheet of paper

Experiment

1. Curl your paper into a cone shape so one end is wider than the other. It should look like an ice cream cone.
2. Tape the cone into place using your tape. You might need a couple of pieces.
3. Hold the cone with the small end down.
4. Your job is to place your marble on the inside edge of the cone near the top and rotate the cone so that the marble stays near the top edge without falling down inside or flying out of the top.
5. Place your small satellites in order from lightest to heaviest. Enter them in this order in the data table. Record how fast you had to circle the cone to keep the satellite in orbit in the observations column. Did you have to move the satellite slower, faster, or something in between?

Space Telescopes Data Table

Item/Object	Observations

Reading

Many people think that satellites don't move in orbit. Nothing could be further from the truth! If you drop a ball on Earth, it falls 16 feet the first second you release it. If you throw the ball horizontally, it will also fall 16 feet in the first second, even though it is moving horizontally… it moves both away from you and down to the ground.

Now consider another object, like a bullet shot horizontally. It travels a lot faster than you can throw – about 2,000 feet each second. But it will still fall 16 feet during that first second. Gravity pulls on all objects (like the ball and the bullet) the same way, no matter how fast they go.

What if you shoot the bullet faster and faster? Gravity will still pull it down 16 feet during the first second. Remember that the surface of the Earth is round. Can you imagine how fast we'd need to shoot the bullet so that when the bullet falls 16 feet in one second, the Earth curves away from the bullet at the same rate of 16 feet each second?

Answer – that bullet needs to travel nearly *5 miles per second*. This is how satellites stay in orbit – going just fast enough to keep from falling inward and not too fast that they fly out of orbit. Satellites need to constantly course-correct to keep on track.

If we launch a rocket straight into the sky to be in orbit around the Earth, unless we give that rocket a horizontal velocity as well, it's going to crash right back to Earth. Everything that orbits the Earth has a specific speed at which it travels in order to maintain its stable orbit.

The Hubble Space Telescope was launched by the space shuttle in 1990, and is the best-known observatory. Hubble orbits 380 miles above the surface of the Earth and has sent thousands of photos to scientists on Earth to study. Hubble operates in the visible part of the spectrum.

The Compton Observatory was the second to be launched in 1991, and holds the record for heaviest astrophysical payload ever (17 tons). Compton collected information in the gamma ray part of the spectrum, which meant it looked at some of the most violent parts of the universe to record its data. It was safely de-orbited in 2000.

The Chandra Observatory was launched in 1999, and currently studies X-rays from black holes, quasars, dark matter, supernovas, and high-temperature gases. Chandra holds the record for the best mirrors: They are the most accurately shaped, precisely aligned, smoothest mirrors ever created. Chandra's alignment is so precise that you can use it to read a newspaper from a half mile away.

The Spitzer Space Telescope was the fourth to be launched into the program in 2003. Spitzer specializes in thermal infrared light, most of which is blocked by the Earth's atmosphere and never makes it to the surface of the Earth. So this scope is seeing things we've never been able to before. Since viewing in the infrared means that you can see through dust and gas particles, Spitzer is able to show us things that would normally be hidden to us if we were to view them optically. Spitzer looks for cooler space objects (thermally speaking) such as small stars, extrasolar planets, and giant molecular clouds.

Questions to Answer

1. What happens when your marble satellite moves too slowly?
2. What happens when the marble satellite orbits too fast?
3. What effect does changing the marble mass have on your satellite speed?
4. How is this model like the real thing?

Astronomy 2 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 for your turn to show your teacher 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 astronomy from the perspective of the Sun or a light particle itself. You'll read this aloud to your class.
    b. Make a poster that teaches a main concept of either the Sun, a moon, a planet, or a particular spacecraft. When you're finished, you'll use it to teach to a class o younger students and demonstrate the principles that you've learned.
    c. Write and perform a poem or song about the Sun, a moon, a planet, or a particular spacecraft. This will be performed to your class.

Astronomy 2 Quiz

Student Quiz Sheet

Name____

1. Name two ways you can find a black hole.

2. What is a galaxy?

3. How many phases does the Moon have and what are they?

4. Which planets do not have a magnetic field?

5. Can you see the Moon during the daytime?

6. How many AUs is the Earth from the Sun?

7. What is the Sun made out of, and how much of each?

8. Can we see all light? If not, which kind can we see with our eyes?

9. How hot is the Sun?

10. How does the Sun make energy?

11. Which are light sources (LS) and which are seen by reflected light (RL)?

a. Stars __ ______________________________

b. The Moon ________________________________

c. Venus________________________________

d. Pluto__ ______________________________

e. Comets________________________________

f. Asteroids__ ______________________________

g. The Sun ________________________________

Astronomy 2 Lab Practical

Teacher's Answer Key

This is your chance to show how much you have picked up on important key concepts, and if there are any holes. You also will be working on a homework assignment as you do this test individually with a teacher.

Materials

- Lamp
- Two balls of different sizes (like a tennis ball and a ping pong ball)
- Sheets of paper
- Pencil

Lab Practical:

- Show how the Moon's appearance changes during the four-week lunar cycle.

- On a sheet of paper, draw the solar system. Include the Sun, eight planets, and the Asteroid Belt. Approximate the scale of the planets and distances between them.

Answers to Exercises and Activities

Lesson #1: Stars, Planets, and Black Holes

1. Is Mercury the hottest planet? Why or why not? (No, Venus is because it's got a thick atmosphere that keeps the heat trapped inside.)
2. What is solar wind? What protects planets from it? (Mars, Earth and Venus are bathed in a flow of plasma that comes from the sun, called solar wind. The Earth has a magnetic field which acts like an invisible coat to protect the earth because it deflects the solar wind away from us, but Venus and Mars don't have this protection so they get blasted with this solar wind. Solar wind isn't really wind (there's no air in space, so it can't be like the normal kind of wind), but it's a steam of highly charged particles coming from the Sun.)
3. Can asteroids have moons? (Yes! Ida is an asteroid detected in 1884, and in 1993 the Galileo spacecraft discovered its moon Dactyl.)
4. Why is Io different colors? (From volcanic activity.)
5. Can moons have atmospheres? Do all planets have atmospheres? (Moons like Titan have atmospheres. Not all planets have atmospheres, because of a planet's low gravity; the atmosphere can get blown away by strong solar winds. Mercury and Mars have very thin atmospheres.)
6. How many objects in the Pluto system? (Four: Pluto, Charon, Hydra, and Nix.)
7. Name two ways you can detect black holes. (Look for X-ray emissions, look for light bending around the black hole, or look for a star wobbling or orbiting something that isn't there.)
8. If a star collapses when it runs out of fuel, then why do supernovas explode? (When the core of a star collapses, it smacks together so HARD that it rebounds – it bounces back. When it rebounds and bounces back out, it collides with the rest of the gas that is still falling inward (remember the foil in the balloon experiment?) When the rebounding core hits the in-falling gas, the core blasts everything out into space … and this makes a giant explosion.)
9. Name two scientists who contributed to the work on black holes. (Stephen Hawking, Karl Schwarzschild, Robert Oppenheimer, Roger Penrose, Albert Einstein, John Mitchell …)
10. What is a galaxy, and how is it different from a quasar? (A galaxy is a system, of millions or billions of stars, together with gas and dust that is held together by gravity. We think quasars are the brilliant cores of a galaxy, which is powered by a black hole.)

Lesson #2: Solar System Scale Model

1. What do you notice about the position of the rocky terrestrial planets? (They are all bunched up together close to the Sun.)

2. Are the ice giants further apart from each other than the gas giants are? (Neptune-Uranus is 9.8 AU and Saturn-Jupiter is 5 AU when they are on the same side of the Sun.)

3. Mariner 10 took 147 days to reach Mercury from Earth. How long do you think it would take to get to Neptune? (Approximately 12-22 years, depending on the flight path and the speed chosen.)

4. If the Earth is 93 million miles (150 million km) from the Sun, and Ceres is 413 million miles (665 million km) from the Sun, where would you place it in your scale model? (Ceres is 4.4 AU or 3 meters or 9.91 feet away. If your

students haven't covered this yet, it's okay to eyeball the distance and approximate Ceres to be about four times the distance from the Sun that the Earth is.)

Lesson #3: Atmospheres

1. Which atmosphere reached the highest temperature? (Refer to data table, but you should find the waxed paper heated up the most. If the baggie jar did, then you packed it too tightly in the jar.)

2. Each of the jars received the same amount of energy from the Sun. Why is this not quite like the real solar system? (Each planet is a different distance from the Sun, and receives less energy the further out it's located. This experiment works because it's over a short period of time, and we're figuring out which conditions trap heat the best.)

Lesson #4: Lunar Phases

1. Does the Sun always light up half the Moon? (Yes. We don't always get to see it, which is because the Moon has phases.)

2. How many phases does the Moon have? (Eight)

3. What is it called when the Moon appears to grow? (Waxing)

4. What is it called when you see more light than dark on the Moon? (Gibbous)

5. How long does it take for a complete lunar cycle? (About 29 ½ days)

Lesson #5: Eclipses and Transits

1. What other planets can have eclipses? (Mercury and Venus don't have moons, and the moons of Mars are too small. Jupiter, Saturn, Uranus and Neptune can have eclipses as their moons are large enough and the Sun appears smaller. Pluto and Charon are in a weird orbit so that only one side of either one will ever experience eclipses, and even when they do, it's every 120 years or so.)

2. Which planets transit the Sun? (Venus and Mercury)

3. How is a solar eclipse different from a lunar eclipse? (A lunar eclipse is when the Earth comes between the Sun and Moon. A solar eclipse is when the Moon comes between the Earth and Sun.)

4. What phase can a lunar eclipse occur? (Only on a night of a full moon.)

5. Can a solar eclipse occur at night? (No, because the Sun isn't visible at night.)

Lesson #6: Rusty Balloon

1. Why did one balloon get larger than the rest? (The balloon will show you how much gas is generated – the larger the balloon, the more gas was produced. The rust (iron oxide) is the name of the reaction taking place between the steel wool and the liquids.)

2. Which had the highest pressure difference? Why? (Check results from data table. In the video, the bottle with just water not only sucked in the balloon, it also sucked in the sides of the water bottle itself, showing you that it used the oxygen in the air to generate the rust. You'll see this more dramatically when you add salt to the water before adding the steel wool.)

Lesson #7: Meteorites

1. Are meteors members of the solar system? (Yes – they are the smallest members.)

2. How big are meteors? (They range from pebble size to smaller than a grain of sand, usually weighing less than 2 grams.)

3. Why do we have meteor showers at predictable times of the year? (Every year, the Earth passes through the debris left behind by comets. The particles enter our atmosphere and burn up. The ones that make it to the ground are meteorites.)

Lesson #8: Neptune's Furnace

1. What happens when the chemicals come in contact with each other? (When the calcium ions and chloride ions interact with the sodium bicarbonate, they form carbon dioxide gas and sodium chloride (table salt).)

2. What did you notice when you sealed the bag closed and rolled the pellets between your fingers? (Dissolving calcium chloride is highly exothermic, meaning that it gives off a lot of heat when mixed with water.)

3. What happened when the solution was placed in the cold water jug? (This removes energy from the reactions and causes the table salt to precipitate out more quickly.)

4. What does this experiment have to do with Neptune? Why did we use the baking soda at all? (As the gas in the bag increases, it puffs out and increases the pressure. This stretches the bag and some of the gas is released out the holes in the top of the bag, bubbling up to the surface of the milk jug. After awhile, the warm water will also rise out of the holes due to the temperature difference between the bag and jug and, you'll see red drift up to the top surface of the milk jug. The heat generated by Neptune is deep in the core, and it bubbles up and radiates out to space, just like the warm bag bubbling its contents to the cold water jug. The entire planet is a whirling, swirling, fast-moving ball of gas and ice that move because of temperature and pressure differences.)

Lesson #9: Binary Planetary Systems

1. How is spinning the container like Pluto and Charon? (You are always facing the same side of the container, just like Pluto and Charon are always facing the same sides of each other.)

2. What would happen if we cut the string while you are spinning? Which way would the container go? (In a straight line tangent to the curve at the moment we cut the string.)

3. What happens if we triple the size of your container and what's inside of it? (It takes more energy to swing a larger load around. For one object to orbit another, they must have strong gravitational attraction to move that much mass around.)

Lesson #10: Build Your Own Solar System

1. What effect does changing the mass of an orbiting planet have on the diameter of the orbit?

2. What effect does changing the speed have on a planet's orbit?

3. What happens to the planet's orbit when you increase the initial distance between the planet and the Sun?

4. Find the mass values needed for a stable orbit. Circle the values on the table that make a stable orbit.

5. Why don't a feather and a brick hit the ground at the same time? (They do… if you're on the moon! On Earth, the friction between the air and the feather causes the feather to slow down and the brick to win the race.)

Lesson #11: Watch Your Weight

1. Of the following objects, which ones are attracted to one another by gravity?

a) Apple and Banana b) Beagle and Chihuahua c) Earth and You d) All of the above

2. True or False: Gravity accelerates all things differently

3. True or False: Gravity pulls on all things differently

4. If I drop a golf ball and a golf cart at the same time from the same height, which hits the ground first? (They both hit the ground at the same time.)

5. There is a monkey hanging on the branch of a tree. A wildlife biologist wants to shoot a tranquilizer dart at the monkey to mark and study him. The biologist very carefully aims directly at the shoulder of the monkey and fires. However, the gun makes a loud enough noise that the monkey gets scared, lets go of the branch and falls directly downward. Does the dart hit where the biologist was aiming or does it go higher or lower than he aimed? (The monkey and the dart fall downward at the same rate of speed. So the dart would hit exactly where the biologist aimed! In fact, if the monkey didn't let go, the dart would have hit lower than the biologist aimed.)

Lesson #13: Diffraction

1. Which light source gave the most interesting results? (This varies with data.)
2. What happens when you aim a laser beam through the diffraction grating? (It splits into three beams of light, as shown in the second video.)
3. How is a CD different and the same as a diffraction grating? (A CD has a spiral of finely-spaced data tracks while the diffraction grating has a series of parallel lines. The CD splits the light the same way as the diffraction grating. The CD splits the beam into more than three beams.)
4. Why does the feather work? (There are tiny "hairs" on the feather that are acting like tiny prisms.)

Lesson #14: Infrared Vision

1. What kinds of objects allow infrared light to pass through them? (Check data.)

2. Why does the camera work in making the infrared light visible? (The camera is a viewer that lets us see this special frequency of light. Light is technically what we call *electromagnetic radiation.* Radio waves, infrared, microwaves, X-rays, and gamma rays are all *electromagnetic radiation*. If you could see the radio waves, then you could see radio towers as they transmit. They would appear to light up. If you could see all forms of light, then not only could you see the radio towers, but also your cell phone, the doctor's X-ray cameras, and your car radio would all be lit up as they operated. It's all made out of the same stuff, just not all of it is visible to our eyes.)

Lesson #15: UV Light

1. What kinds of light sources didn't work with the UV beads? (Check data.)

2. Did your Sun block really block out the UV rays? (Check data.)

3. Which was the best protection against UV rays? (Check data.)

Lesson #16: Star Wobble

1. For homework tonight, find out how many extrasolar planets scientists have detected so far.

2. Also for homework, find out the names (they will probably be a string of numbers and letters together) of the 3 most recent extrasolar planet discoveries.

Lesson #17: Space Telescopes

1. What happens when your marble satellite moves too slowly? (It crashes back to Earth.)

2. What happens when the marble satellite orbits too fast? (The satellite leaves orbit.)

3. What effect does changing the marble mass have on your satellite speed? (The heavier the marble, the faster you have to make it move in order to keep its orbit stable.)

4. How is this model like the real thing? (Your marble is your satellite and the top of the cone is the orbit it makes around the Earth.)

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 are 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, right behind the 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. Eclipses 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, c. 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 stars that are pulled and held together by gravity.

Globular clusters are massive groups of stars held together by gravity, usually 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.

Magnetoshpere. 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 a 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 a 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.