NEWTON'S APPLE®
Multimedia

Phases of the Moon

Sun

Teacher's Guide

NEWTON'S APPLE. Multimedia

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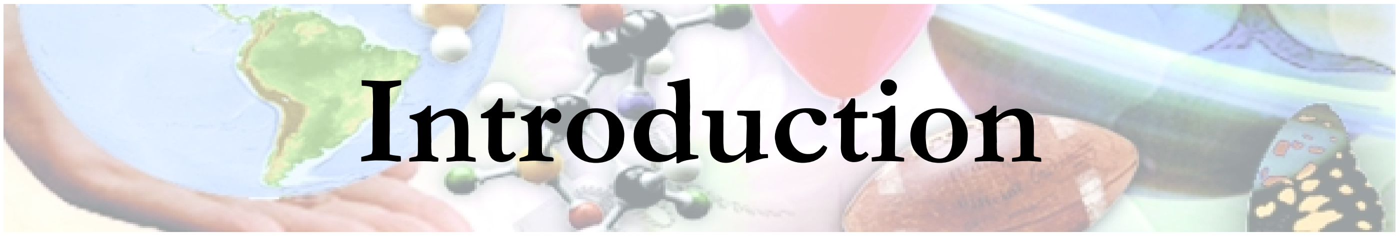


Introduction

Welcome to the *Newton's Apple Multimedia Collection*™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. Each module of the *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two *Newton's Apple* ® segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessment, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat ® file containing the teacher's manual along with student reproducibles
- UGather ® and UPresent ® software that allows you and your students to create multimedia presentations
- QuickTime ® 3.0, QuickTime ® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons, activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

WE SUPPORT THE NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Newton's Apple's goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.

Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

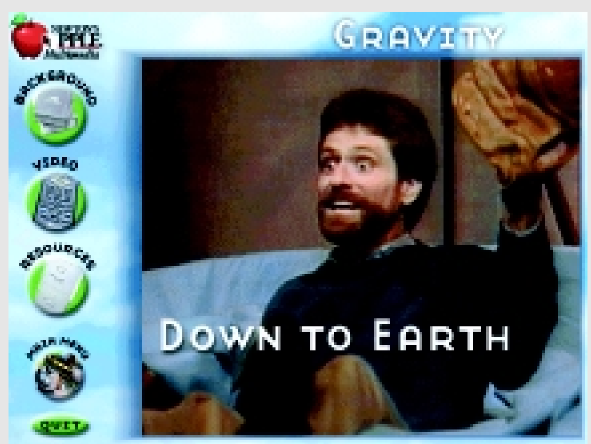
GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

Using the CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.

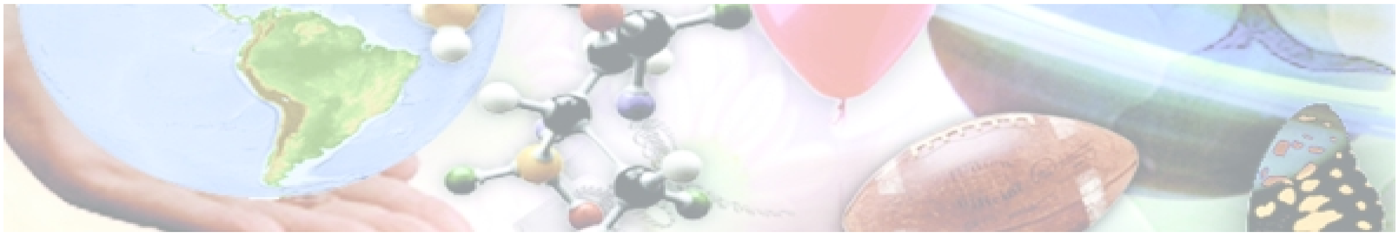
Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose the information you want to display.



Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.



Playing the Video

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.

Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff has designed a product that is flexible, so that you can use it in many different ways. All of the video clips used in the program are available for you to use outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You may use these clips for classroom use only. They may not be repackaged and sold in any form.

You will also find a folder for UGather™ and UPresent™. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.

Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

Integrating Multimedia

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can also choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.

Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.

Our Own Star

How far away are we from the Sun? Why is it so hot? What are sunspots and what do we know about them? How do scientists study the Sun? How can they know what stars are made of?

Themes and Concepts

- models and scale
- solar system
- energy
- astronomy

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of transfer of energy.
Content Standard D: Students should develop an understanding of Earth in the solar system.

Activities

1. *How Far Is Far?—Approx. 10 min. prep; 60 min. class time*

How far are the planets from the Sun? Students use a roll of adding machine tape to construct a scale model of the solar system. Based on the speed of light and their model, they discover how long it would take for a ray of light from the Sun to reach Earth and beyond.

2. *Beginning to See the Light—Approx. 20 min. prep; 45 min. class time*

How do scientists know what stars are made of? Students observe different light sources with a diffraction grating to determine how each type of light produces a different spectrum. Based on this phenomenon, they discover how scientists can determine the composition of distant stars by looking at the light they produce.

3. *Seeing Spots Before Your Eyes—Approx. 10 min. prep; 55 min. class time*

Can scientists predict how many sunspots will appear in a year? Students graph the annual sunspot data for the 20th century. Based on their graph, they first see if any pattern develops, then use the graph to predict when the next sunspot maximums and minimums will occur.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with a searchable database of science activities on many different subjects.)

Solar Information and Photos — High Altitude Observatory of the National Center for Atmospheric Research
http://www.hao.ucar.edu/public/education/slides/slides.html
(One of the most complete sources of solar information on the web.)

The Virtual Sun - Astronomical Institute of Amsterdam
http://spaceart.com/solar/eng/sun.htm
(Take a tour through the Sun containing diagrams, movies, and photos.)

Sun — University of Michigan
http://windows.engin.umich.edu/cyi-bin/tour.cgi/level.button.map
(Contains images, games, facts, and myths on the interior, surface, and atmosphere of the Sun.)

Yohkoh Public Outreach Project — Montana State University Solar Physics Group
http://solar.physics.montana.edu/YPOP
(Take a tour, see the latest images, and make your own movies of the Sun.)

The Virtual Sun
http://www.astro.uva.nl/~michielb/od95/
(A virtual tour of the Sun from a university in the Netherlands.)

Sun

Internet Search Words
Sun
solar physics/photography
astronomy
stars
solar system

Books
Dunlop, Storm and Kippenhahn, Rudolf. *Discovering the Secrets of the Sun*. New York, NY: John Wiley & Sons, 1994.

Hendrickson, Nancy L. and Peter O. Taylor. *Beginner's Guide to the Sun.* Waukesha, WI: Kalmbach Publishing Company, 1996.

Phillips, Kenneth J.H. *Guide to the Sun.* New York, NY: Cambridge University Press, 1995.

Taylor, Peter O. *Observing the Sun.* New York, NY: Cambridge University Press, 1992.

Taylor, Roger J. *The Sun as a Star*. New York, NY: Cambridge University Press, 1997.

Community Resources
Local planetarium
Local university astronomy department

Background

Although the Sun seems incredibly powerful to us on Earth, to astronomers the Sun is just an average-sized, middle-aged star, one of more than a hundred billion stars in our Milky Way Galaxy. While the Sun is merely average on a cosmic scale, from our perspective it is perfect, providing exactly the right amount of light and heat to allow life to flourish on Earth.

Average-sized or not, a few statistics illustrate the Sun's gargantuan proportions: It is 1,391,785 kilometers (865,000 miles) in diameter, or 109 times Earth's diameter. More than 1.3 million Earths could fit inside of the Sun! It is 332,946 times more massive than the Earth. In fact, the Sun accounts for 99.8 percent of all of the mass in the solar system — far more than all of the planets, moons and asteroids put together.

From Earth, the Sun looks no larger than the Moon. That's because the Sun is so far away — about 150 million kilometers (93 million miles) or about eight light-minutes from Earth. The next closest star, Proxima Centauri, is 4.2 light-years, or 40 trillion kilometers (24.8 trillion miles), away.

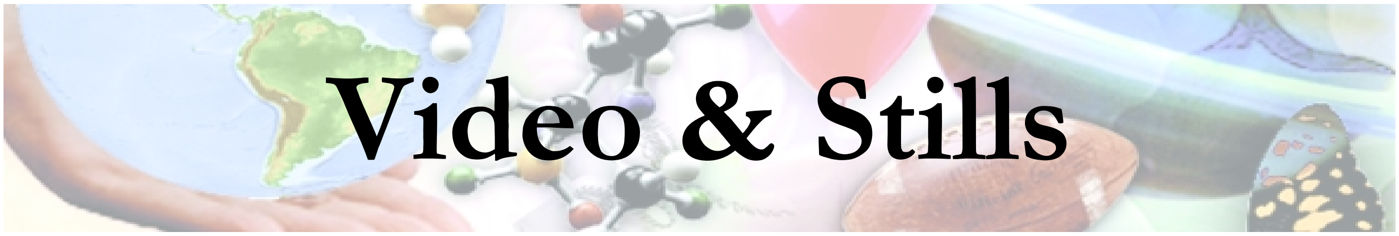
The Sun is a giant ball of gas made of about 75 percent hydrogen, 24 percent helium, and 1 percent other elements such as nitrogen and oxygen. Because the Sun is so massive, the pressure at its core is enormous. This extreme pressure actually squeezes hydrogen atoms together, causing them to fuse and turn into helium atoms. The Sun's energy comes from a tiny excess of matter that results from this reaction.

When four hydrogen atoms fuse to form a helium atom, about 0.7 percent of the hydrogen isn't needed by the helium atom. This unused part is converted into energy. Using Albert Einstein's formula on the conversion of mass into energy, $E=mc^2$, scientists realized that the tiny amount of excess hydrogen in each fusion reaction is converted into an awesome amount of energy. This process is called "hydrogen burning" even though what is actually occurring is not burning, but thermonuclear fusion — the same energy source that powers a hydrogen bomb.

Thermonuclear fusion occurs in the Sun's core, which is believed to be about the size of Jupiter. Core temperatures are believed to reach an astounding 15 million degrees Celsius (27 million degrees Fahrenheit). Because the Sun is so huge, it takes millions of years for the energy created in the core to travel up to the surface through the different layers, or zones, inside the Sun.

The Sun will eventually convert all of its hydrogen into helium and slowly expand until it engulfs Earth. Then its surface will drift into space and a small, glowing ember called a "white dwarf" will be all that remains.

But don't worry, the Sun is only middle-aged, so we still have another 5 billion years to find another solar system to call home!



Video & Stills

Video Segments

Introduction

00:00 to 00:45—Sun Me Chomet basks in the Sun's warmth and comes up with some questions for you to discuss. (45 sec.)

Video Clip 1

00:53 to 02:42—David Heil goes out of his way to discover how far away Earth is from the Sun.

Video Clip 2

03:24 to 05:03—David Heil and Derrick Pitts visit Lord Calvin's laboratory for some explosive conversation about hydrogen and the Sun.

Video Clip 3

05:13 to 06:01—David Heil and Derrick Pitts compare the Sun's energy to a nuclear explosion.

Video Clip 4

06:26 to 07:41—Field reporter Peggy Knapp goes inside the world's largest solar telescope at the National Solar Observatory in Arizona.

Additional Resources

Button A

Slide Show: Photos of the sun spots taken at different wavelengths.

Button B

Slide Show: Photo of the sun viewed at the wavelength of helium and an illustrated cross section.

Button C

Slide Show: A comparison of the size of the Earth to other planets and the sun.

Button D

Image: Illustration displaying the various rotational velocities withing the sun.

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it

1. The Sun is the closest star to Earth. This allows scientists to more easily study the Sun's behavior and composition. By studying the Sun, scientists can learn about the composition of other stars and theorize how the universe began. Studying how the Sun produces energy may provide clues to new ways of producing energy on Earth.
2. Lord Calvin applied physics concepts to study how the Sun burns.
3. The Sun's core is under extremely high pressure. This extreme pressure actually squeezes hydrogen atoms together, causing them to fuse and turn into helium atoms. This fusion reaction produces tremendous amounts of energy from very small amounts of matter.
4. Life on Earth as we know it could not exist without the Sun. The Sun's energy, in the form of heat and light, are needed for most of Earth's plant and animal life to exist.
5. Light from stars and planets can be distorted or blocked as it passes through the atmosphere. By locating observatories on high mountains where the air is thinner, scientists minimize the effects of the Earth's atmosphere.

What would you say?

6. d   7. b   8. d   9. c   10. c

What do you know about the Sun?

Write the answers to these questions in your journal or on a separate piece of paper.

Think about it

1. Why would scientists want to study the Sun?
2. What contribution did Lord Calvin make to the study of the Sun?
3. What causes the Sun's core to be so hot?
4. Without the Sun, would life as we know it be possible on Earth? Why or why not?
5. Why are observatories like the Kitt Peak National Solar Observatory located on mountaintops?

What would you say?

6. How far is the Sun from Earth?
   a. 93,000 miles
   b. 93,000,000 kilometers
   c. 39,000,000 miles
   d. 93,000,000 miles
7. Which gas makes up 75% of the Sun?
   a. oxygen
   b. hydrogen
   c. nitrogen
   d. helium
8. Which of the following is true about sunspots?
   a. They are the hottest areas of the Sun.
   b. They are very rare.
   c. They cover most of the Sun's surface.
   d. They are cooler than the surface of the Sun around them.
9. The Sun—
   a. is made up of molten rock, like the lava in a volcano.
   b. has an atmosphere that is very similar to Earth's atmosphere.
   c. is a medium-sized star.
   d. is one of the largest and hottest stars in our galaxy.
10. The Sun's diameter is approximately ________ times larger than Earth's diameter.
    a. 2
    b. 5,000
    c. 100
    d. 10

Activity 1

How Far Is Far?

How big is the Sun? How does its size compare with other objects in our solar system? How far away from the Sun is Earth? How big is Earth compared to the Sun? How long does it take light from the Sun to reach Earth?

Getting Ready

Overview

Students use a roll of adding machine tape to construct a scale model of the solar system. Based on the speed of light and their model, they discover how long it would take for a ray of light from the Sun to reach Earth and the other planets.

Objectives

After completing this activity, students will be able to—

- convert distances from one scale to another
- create an accurate scale map from a data table
- describe the relative distance between the Sun, Earth and other planets
- predict the travel time of light from the Sun to each of the planets in the solar system

Time Needed:

Preparation: Approximately 10 minutes
Classroom: Approximately 60 minutes

Materials

For the teacher:

- globe
- U.S. or world map with a printed scale

For each team of students:

- roll of adding machine tape 40 meters long
- meter stick with mm markings
- pencil
- calculator

Important Terms

light year — The distance a beam of light travels in one year. Light travels at a speed of 300,000 km/sec. A light year is 9.5 trillion km.

scale — A ratio that relates an actual distance to a distance on a map.

Sun

Here's How

Video Clip 1

00:53 to 02:42—David Heil goes out of his way to discover how far away Earth is from the Sun. (1 min. 49 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [00:00 to 00:45]. Find out what students already know about the Sun. As a class, discuss the questions posed by Sun Me Chomet.
- String may be substituted for the adding machine tape. Students can mark the string with colored markers to indicate planetary locations.
- When calculating the initial scale, it's better to have a measurement value that is a round number. If you use the exact distance to Pluto (5.9 billion km) and divide it by 40 meters (or whatever length of tape is being used), you have a scale that is 1 cm = 1,475,000 km. A better approach might be to use a maximum distance of 6 billion km. In this way, the scale works out to 1 cm = 1.5 million km. This not only makes the measurement more manageable, but it also gives the students a little extra room at the end of the tape in case they make a mistake.
- Shorter lengths of tape result in the inner planets being very close together.
- If students have access to a computer, they could set up their data tables using a spreadsheet program.
- Before the students start plotting the planets, suggest to them to also calculate the distance from each planet to the next one farther out. In this way, when they actually plot their data, they don't have to go back to the Sun each time to measure. They can simply continue from one planet to the next.
- When students are plotting, have them work on a desktop and work in a "conveyor belt" fashion with one team member unrolling the tape, a second re-rolling the tape on the back end, and the third actually measuring. In this way, they won't be in each other's way. (And you won't have several hundred feet of tape piled up on the floor!)
- If time allows, you may wish to view the entire *Newton's Apple* segment on the Sun after completing this activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the teacher demo and the student experiments.
- Make a copy of Activity Sheet 1 for each student.
- Review the Background information on page 8.

Engage (Approx. 15 min.)

Begin class by holding up a globe. Ask students how big the Sun would be if Earth were the size of the globe. Write the student responses on the board. Play Video Clip 1 [00:53 to 02:42] and pause after Derrick says that the Sun is 864,000 miles in diameter. How does this compare to Earth? (Earth is 13,000 km or about 8,000 miles in diameter.) Resume the video and pause again after Derrick asks how big Earth would be if the Sun were 7 1/2 feet across. What do the students think? Resume the video to show the answer.

Pause one more time when Derrick asks David how far he would have to go with the model Earth to be the correct scale distance from the Sun. Ask the students to make their predictions and then resume playing the video to the end of the clip. After viewing the clip, have students rethink the comparative size of the Sun to the globe.

Most students have a hard time conceptualizing how large a billion is. Draw a line on the board that's about 3 to 4 feet long. Label one end "0" and the other end "1,000,000,000." Tell students that this is a number line from zero to 1 billion. Ask two or three volunteers to mark the location of 1 million on the number line. Accept all answers. (The actual position of 1,000,000 on the number line is only 1/1000 of the way along the line from zero.) Discuss how this demonstration might have changed students' concept of the size of 1 billion. Ask where 1 billion would be located if the line went from zero to 1 trillion. (One billion would be 1/1000 of the way along the line from zero.)

Explain to the students that we use scale models to represent things that are too big or too far to see completely. Ask students for examples of scale models. Accept all answers. A map is one example of a scale model. Show students a map of either the U.S. or the world. Ask a student volunteer to come forward and explain to the class how he or she would figure out how far it is from New York City to Los Angeles. (Using the scale, the student would measure the distance between the two cities with a ruler, then multiply by the scale to get the actual distance.)

Hold up a roll of adding machine tape. Ask students if they can think of a way that they can make a scale model of the solar system using the tape. What information would they have to know? (The length of the tape and the distance to the planets.)

Activity 1

Explore (Approx. 45 min.)

Have students work in small groups. Explain that they are going to create their own scale models of the solar system using the adding machine tape.

Creating the Scale

Have students begin by calculating what the scale for their map should be. Explain that students need to calculate a scale that would allow all nine planets to be plotted on the map. Have students figure out how to calculate the scale. (When calculating the ratio of kilometers to centimeters, students should take the longest distance to be plotted on the map in kilometers—the distance to Pluto—and divide it by the total length of the tape in centimeters. The result will give them a ratio or scale that can then be used on the other eight planets.)

Once the ratio is calculated, students should fill out the data table on Activity Sheet 1 that shows the scale distance to each planet.

Plotting the Planets

After students have completed the data chart, they can plot the actual position to each planet on the tape. Start at one end of the tape and mark it SUN. From this point, use the meter stick to measure the distance to Mercury. Repeat the procedure until all nine planets have been plotted. Once all the groups have completed their plots, have the class take their maps out to the school yard or a long hallway and unroll them side by side to see how they compare with each other. Discuss any differences and why they might have occurred.

Evaluate

1. How would you go about constructing an accurate scale model of the Solar System that would actually fit along one wall of your classroom? (You would have to measure the wall and calculate a new scale based on its length.)

2. If the speed of light is approximately 300,000 km/second, how long will a beam of light take to reach Earth from the Sun? How about from the Sun to Pluto? (Earth: 150,000,000/300,000 = 500 seconds or 8.3 minutes; Pluto: 5,900,000,000/300,000 = 19,667 seconds or about 5.5 hours!)

3. All of the distances you used in this activity were average distances. Since planets orbit the Sun in elliptical orbits, how might you revise your plots to show the true distances to the planets? (You would have to plot the maximum and minimum distance from the Sun to each planet. If you did, you would find that Pluto and Neptune actually cross at two points in their orbits.)

Try This

Try making another scale model of the solar system, only this time, instead of plotting distances, try plotting the diameters of the planets relative to the Sun. It's best to start with the Sun first and work your way down. Think of different spheres, such as beach balls, baseballs, marbles, etc., to represent the various planet sizes.

In the activity, you plotted a scale map to the planets, but distances between stars is much greater. Using the same scale that you did for the planet plot, calculate how far you would have to place the next closest star to the Sun. The star is Proxima Centauri and it's 4.22 light years away. First you have to find out how many kilometers are in a light year. (If you don't want to look it up, do the math. Simply multiply 300,000 by 60 seconds by 60 minutes by 24 hours by 365.25 days and you have it!)

There is a direct relationship between the amount of time it takes for a planet to orbit the Sun and its distance from the Sun. Look up the orbital period for each planet and create a "timeline" similar to your distance map.

HOW FAR IS FAR?

Activity Sheet 1

WHAT YOU'RE GOING TO DO

You're going to create a scale model of our solar system.

NAME ______________________________ **CLASSPERIOD** __________

HOW TO DO IT

Work with your group. Begin by selecting a scale for your map. Remember, all nine planets have to fit on the map, so your scale has to be small enough to make sure that you can plot the distance to the furthest planet. Your teacher will tell you how long the adding machine tape is.

Record your scale here:__________ cm on tape = ________ km in space

Using the data chart below, calculate the scale distance to each planet:

Planet	Distance From Sun (km)	Scale Distance (cm)
Mercury	58,000,000	
Venus	110,000,000	
Earth	150,000,000	
Mars	230,000,000	
Jupiter	780,000,000	
Saturn	1,400,000,000	
Uranus	2,900,000,000	
Neptune	4,500,000,000	
Pluto	5,900,000,000	

Using your data from the completed table, plot each planet on the tape in its proper scale location from the Sun. Label one end of the tape SUN and use a meter stick to measure and plot the location of each planet.

WHAT DID YOU FIND OUT?

Based on your plots of the planets, can you explain why they are often grouped as "Inner" and "Outer" planets?

When you compare your plots to those of the other members of your class, were all the planets in the same positions? How would you explain any difference in results?

Over the years, many astronomers have tried to figure out if there is a "natural pattern" that would explain the spacing of the planets. Study your plots. What pattern can you see?

Activity 2

Beginning To See the Light

What is the Sun made of? How can scientists on Earth determine the composition of the Sun and other stars without leaving the planet? How can light be used to tell the composition of matter? What is a spectrum and what does it tell you?

Getting Ready

Overview

Students observe different light sources with a diffraction grating to determine how each type of light produces a different spectrum. Based on this concept, they discover how scientists can determine the composition of distant stars by looking at the light they produce.

Objectives

After completing this activity, students will be able to—

- explain how scientists use spectral information to determine the composition of stars
- demonstrate how different sources of light produce different spectra
- identify the source of a light by matching its spectrum

Time Needed

Preparation: Approximately 20 minutes
Classroom: Approximately 45 minutes

Materials

For the teacher:

- candle or Bunsen burner
- sodium chloride crystals (salt)
- lithium chloride crystals (or Cream of Tartar)
- desk lamp with a standard incandescent bulb
- very dark room
- overhead projector
- set of 2 different spectrum tubes with power supply or a red incandescent floodlight bulb and a green incandescent floodlight bulb

For each team of students:

- diffraction grating
- set of colored pencils (red, orange, yellow, green, blue, violet)

Important Terms

hydrogen — The lightest and most abundant chemical element.

prism — A device that separates a beam of light into its component colors.

spectrum — A band of colored light produced when a light beam is passed through a prism or diffraction grating.

Sun

Here's How

Video Clip 2

03:24 to 05:03—David Heil and Derrick Pitts visit Lord Calvin's laboratory for some explosive conversation about hydrogen and the Sun. (1 min. 39 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [00:00 to 00:45]. Find out what students already know about the Sun. As a class, discuss the questions posed by Sun Me Chomet.
- Remind students that they should never look directly at the Sun. It can cause eye damage and blindness.
- Two sources for inexpensive diffraction gratings are Project Star (800) 537-8703 or Steve Jacobs (520) 621-2944.
- Although this activity works with colored spotlights, the spectrum tubes produce excellent results and are worth the expense.
- When doing this activity, the room must be as dark as possible. Any extraneous light sources will produce "mixed spectra" which will make it very hard to complete the activity. Remind the students to move carefully in the darkened room to avoid injury.
- You may have to turn the room lights on and off at regular intervals so that the students will have enough light to draw the different spectra on the activity sheet.
- As an alternative to having the overhead transparency, you may want to make several color copies of the mystery spectrum for the students to use.
- If time allows, you may wish to view the entire *Newton's Apple* segment on the Sun after completing this activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the teacher demo and the student experiments.
- Draw a color spectrum produced by one of the light sources you will use onto a overhead transparency. This will be the "mystery spectrum" that the students must identify.
- Make a copy of Activity Sheet 2 for each student.
- Review the Background information on page 8.

Engage (Approx. 15 min.)

Light a candle or Bunsen burner in the front of the room and make the room as dark as possible. Have the students observe as you sprinkle some table salt in the flame. What color was the flame? (yellow) Now sprinkle some Lithium Chloride crystals on the flame. (If you don't have LiCl use Cream of Tartar.) What color was the flame this time? (red)

Play Video Clip 2 [03:24 to 05:03]. Ask students if they've ever watched a fireworks display. Based on what they just saw in the video, where do fireworks get the different colors from? (Different chemicals are placed in the shells to produce different colors.) That's what they saw when you sprinkled the chemicals on the flame.

Explain that each element produces its own unique spectrum when burned. Astronomers use a device called a spectroscope to analyze the light from a star to determine what elements are present. Give each student a diffraction grating and have them observe the flame test again so they can see the spectra. After they finish, explain that they are going to observe and record the spectrum produced by several different light sources. Tell them that they are going to use their data to identify a "mystery spectrum."

Activity 2

Explore (Approx. 30 min.)

Have students work with a partner. Explain that they are going to observe several different light sources and draw the spectra they produce on the activity sheet.

Set the light source up near the front of the room. Make the room as dark as possible and turn on the desk lamp with the regular incandescent bulb. Have them color the spectrum on the activity sheet under the heading "Incandescent Light Bulb." Repeat the same procedure using either the gas spectrum tubes or colored floodlights. Have students record either the name of the element or the color of the floodlight next to the spectrum they draw.

After students have plotted the spectra for each of the light sources, turn on the overhead projector and have them copy the "mystery spectrum." Based on the spectra they observed, have them determine which of the original three light sources produced the "mystery spectrum."

Evaluate

1. Sunlight is a very bright source of light and producing a clear spectrum of it is easy. How would astronomers determine the composition of a distant star whose light is very dim? (They would need to take the spectrum through a powerful telescope.)

2. Why is it important to make sure that there are no other light sources on when you are trying to produce the spectrum from a single source? (Outside light sources can interfere with and contaminate the spectrum produced by the target source.)

3. The element Helium was first found on the Sun before it was found on Earth. Based on this activity, how do you think scientists knew that they were dealing with a new element on the Sun? (When they looked at the spectrum, they found that it didn't match anything that they had identified to date on Earth.)

Try This

Conduct your own "light scavenger hunt." Use a diffraction grating in the evening and look at as many different light sources as possible including street lights, bridge lights, the full moon, neon lights, etc. Compare the different spectra produced by the lights. Take notes and report your observations to the class.

Astronomers have determined that the universe is expanding because most of the spectra from distant stars and galaxies have been "red-shifted." Research the red-shift and find out how far away the most distant objects in the universe are and how this all relates to the Big Bang theory. Report your findings to the class.

See how many ways that you can make a spectrum. With a bright flashlight and a dark room, try using prisms, lenses, mirrors and the back of compact discs. Do all the spectra produced look the same? Are they all being produced the same way? Check it out and report back to your class.

NEWTON'S APPLE Multimedia

BEGINNING TO SEE THE LIGHT

Activity Sheet 2

NAME ____ CLASS PERIOD __________

WHAT YOU'RE GOING TO DO

Using a diffraction grating, you are going to observe and record the spectra produced by three different light sources. Then, you will try to identify a "mystery spectrum" by comparing it to one of the sources you already know.

HOW TO DO IT

Work with a partner. Begin by looking at the different lights with the diffraction grating. Use the colored pencils to draw the spectrum that you see. Label the light source used for each spectrum.

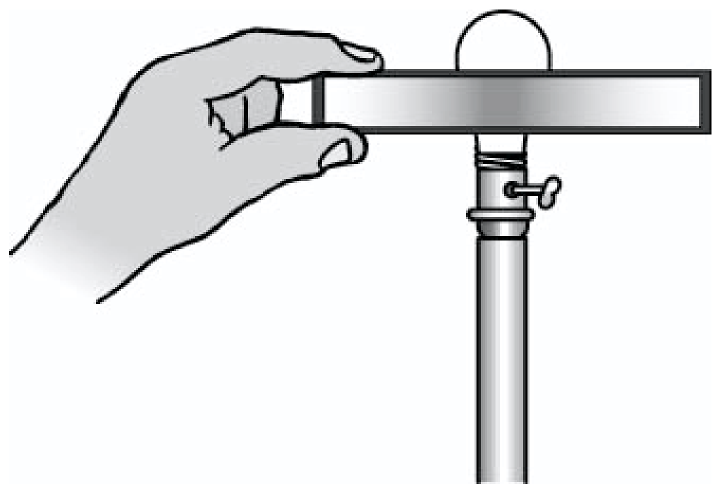
RECORDING YOUR DATA

Use the space below to draw the spectrum you observed from each light source. Record any other observations you may have in your science journal.

Spectrum # 1
Type of light: _____________________

Spectrum # 2
Type of light: _____________________

Spectrum # 3
Type of light: _____________________



WHAT DID YOU FIND OUT?

Which of the original three light sources produced the "Mystery Spectrum"? How can you tell?

Would this activity work in a brightly lit room? Why or why not?

How did your results compare to those of your classmates? What sources of errors do you think might have altered the results of your experiment?

Activity 3

Seeing Spots Before Your Eyes

How does the Sun stay so hot? How can you safely observe the surface of the Sun? How does the surface of the Sun change? What's a sunspot and what causes it? What are solar flares and what effect do they have on Earth?

Getting Ready

Overview

Students graph the annual sunspot data for the 20th century. Based on their graph, they first see if any pattern develops, then use the graph to predict when the next sunspot maximum and minimums will occur.

Objectives

After completing this activity, students will be able to—

- graph data and infer patterns from the graph
- demonstrate that sunspot activity follows a regular cycle
- use a graph to predict future events

Time Needed

Preparation: Approximately 10 minutes
Classroom: Approximately 55 minutes

Materials

For each team of students:

- graph paper
- pencil and eraser
- ruler or straight edge

Important Terms

combustion reaction — A chemical reaction that involves burning with oxygen.

fusion — A nuclear reaction that involves combining two or more atoms into another atom.

nuclear reaction — A reaction that takes place in the nucleus of an atom. The two most common reactions are fusion and fission.

solar flare — A large burst of energy off the surface of the Sun.

sunspot — A cool dark area viewed on the Sun's surface.

NEWTON'S APPLE Multimedia

Sun

Video Clip 3

05:13 to 06:01—David Heil and Derrick Pitts compare the Sun's energy to a nuclear explosion. (48 sec.)

Video Clip 4

06:26 to 07:41—Field reporter Peggy Knapp goes inside the world's largest solar telescope at the National Solar Observatory in Arizona. (1 min. 15 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [00:00 to 00:45]. Find out what students already know about the Sun. As a class, discuss the questions posed by Sun Me.
- Remind students that it's best to do their initial graph in pencil so that if they make mistakes, they can erase them.
- Students should use line graphs. These not only plot faster, but they give a clearer view of the trends. Remind students to leave sufficient space along the edges of the graph to put in a legend along each axis. Usually a three- or four-box margin is sufficient.
- Before the students start plotting the sunspots, make sure that they can plot the maximum number of sunspots and fit it on their graph paper. Students may have to tape several sheets of graph paper together to show their data.
- Sunspots follow 11-year cycles. Students should discover this in their data. They can use the 11-year cycle to predict future sunspot activity or to estimate the number of sunspots in any given year.
- Graphing the data may take some students more time than others. You may wish to assign plotting the data as homework.
- There are many excellent graphing software programs available, including the graphing capabilities of most spreadsheets. If one is available, students may wish to plot their data using a computer.
- If time allows, you may wish to view the entire *Newton's Apple* segment on the Sun after completing the activity.

Here's How

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the teacher demo and the student experiments.
- Make a copy of Activity Sheet 3 for each student.
- Review the Background information on page 8.

Engage (Approx. 10 min.)

Ask students what they know about nuclear reactions. Accept all answers. Play Video Clip 3 [05:13 to 06:01] and pause right after Derrick says that the Sun is using a nuclear reaction to produce energy. Ask students what else beside bombs uses nuclear reactions? (nuclear power plants)

Explain that power plants use *fission* reactions, which involve splitting atoms apart. In the Sun, the reaction is a *fusion* reaction, which involves joining atoms together. Explain that to date, the only fusion reactions we have been able to create on Earth are in hydrogen bombs, but scientist are still working on fusion as an energy source for the future. Resume the video and play to the end of the clip.

Ask students why you might need a special observatory to look at the Sun. (Because the Sun is so bright that it would blind you in seconds if you were to look at it directly.) Explain that they are going to get a close up look at the Sun's surface via the solar telescope on Kitt Peak.

Play Video Clip 4 [06:26 to 07:41] in its entirety. Explain to the students that the first person to take a close-up look at the Sun was Galileo. Using his simple telescope, he pointed it straight at the Sun and saw that the surface was not a smooth round ball, but actually quite active. Galileo observed dark patches on the solar surface that today we call sunspots. You can find several images of sunspots at Resource Button D on the CD-ROM.

Over the years, scientists learned not to look at the Sun directly. They also have kept track of sunspot activity. They found that the number of sunspots varies from year to year. Explain to the class that their mission is to see if they can find a pattern hidden in the data!

Activity 3

Explore (Approx. 45 min.)

Have students work with a partner. Explain that they are going to graph sunspot data for 1900 through 1998, and then interpret the graph to try to make some sense out of the way that the Sun behaves.

Have the students begin by scanning the sunspot data to see what the maximum number of sunspots in any one year was. Using this figure, they can set up an appropriate scale for the sunspot axis so that all the data will plot on a single sheet of graph paper. Once they have selected a scale, they should set up their graph with a proper legend along each axis.

After students have completed setting up their graph, they can begin plotting the data. After they have completed the graph, the students should examine the plot to see if they can recognize any pattern in the data. Based on the pattern, they should answer the questions on the activity sheet.

Evaluate

1. Scientists often use graphs to "sort out" complicated tables of data. What is the advantage of using a graph rather than just a list of numbers? (A graph lets you see a quick picture of what's happening. It also allows you to identify general trends in the data.)

2. Based on this activity, why would it be impossible to tell exactly how many sunspots would happen in any particular year in the future? (The sunspot cycle seen on this graph is just a general trend showing approximate peaks and valleys. Within each cycle there is still too much variation to predict an exact number.)

3. High incidences of sunspot activity have been related to certain atmospheric disturbances here on Earth. How might a graph like this be used by scientists who are looking to launch sensitive communications satellites into our upper atmosphere? (By knowing in advance what year sunspot peaks will happen, they can avoid launching until a period of minimum activity and minimize the risk to the spacecraft.)

Try This

Scientists have known about sunspots since Galileo's time, but they are still trying to find out exactly what causes them. Conduct a research project on your own to find out the latest information on sunspots. Use the Internet as a research tool. Report your findings to the class.

You should never look at the Sun directly, even with a pair of sunglasses. In order to view what's happening on our nearest star, you can build a pinhole viewer. Take an index card and punch a small hole in the center of it with a pin. Turn your back to the Sun and hold the card up in front of you, so the Sun shines right through the hole. Hold a second blank white index card about 12-18 inches behind the pinhole so that it acts like a projection screen. Presto, you've got a pinhole viewer that will allow you to look indirectly at the Sun. By adjusting the distance between the two cards, you can make the image of the sun bigger and smaller. If you're lucky, you might even catch some sunspots in action!

Like the Earth, our Sun is made of layers. The major difference is that most of these layers are hot gas rather than rock. Research the composition of the Sun and build a model showing its structure. Label the different parts with their relative temperatures. You'll be surprised how hot the Sun really is! Share the information with the class.

NEWTON'S APPLE Multimedia

SEEING SPOTS

Activity Sheet 3

NAME ____ CLASSPERIOD ____________

WHAT YOU'RE GOING TO DO

You're going to graph the sunspot activity for the 20th century and see if you can find any patterns in the data.

HOW TO DO IT

Look at the data table below. Observe the maximum and minimum number of sunspots that occurred during the period between 1900 and 1998. Take your piece of graph paper and hold it so that the long side is across the bottom. This axis will be for the years. Count the number of boxes along the shorter edge making sure you leave at least three boxes along the bottom to record the years. Calculate a scale that would allow you to plot the maximum number of sunspots for any given year along the side axis.

Record your scale here:
Each box equals _____ sunspots.

Plotting the data

Using the data chart below, graph the number of sunspots that happened each year starting at 1900 and ending in 1998.

Annual Sunspots

Year	Number	Year	Number	Year	Number	Year	Number
1900	9	1925	44	1950	84	1975	16
1901	3	1926	64	1951	69	1976	13
1902	5	1927	69	1952	32	1977	28
1903	24	1928	78	1953	14	1978	93
1904	42	1929	65	1954	4	1979	155
1905	64	1930	36	1955	38	1980	155
1906	54	1931	21	1956	142	1981	141
1907	62	1932	11	1957	190	1982	116
1908	48	1933	6	1958	185	1983	67
1909	44	1934	9	1959	159	1984	46
1910	19	1935	36	1960	112	1985	18
1911	6	1936	80	1961	54	1986	13
1912	4	1937	114	1962	38	1987	29
1913	1	1938	110	1963	28	1988	100
1914	10	1939	89	1964	10	1989	158
1915	47	1940	68	1965	15	1990	143
1916	57	1941	48	1966	47	1991	146
1917	104	1942	31	1967	94	1992	94
1918	81	1943	16	1968	106	1993	55
1919	64	1944	10	1969	106	1994	30
1920	38	1945	33	1970	105	1995	18
1921	26	1946	93	1971	67	1996	9
1922	14	1947	152	1972	69	1997	22
1923	6	1948	136	1973	38	1998	64
1924	17	1949	135	1974	35		

WHAT DID YOU FIND OUT?

Based on your graph of the annual sunspot occurrence, can you identify any cycle or pattern?

Based on your graph, in what years do you think the next sunspot maximum and minimum will occur?

From the graph, what would be a "ballpark estimate" of the number of sunspots for the year 1890?

Made in the Shade

Does the Moon change shape? Why do we always see the same side of the Moon? Does the Moon spin on its axis? What's the relationship among the Moon, Earth, and the Sun?

Themes and Concepts

- systems
- models and scales
- solar system

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard D: Students should develop an understanding of Earth in the solar system.

Activities

1. *I See the Light!—Approx. 10 min. prep; 85 min. class time (over two days)*

How do the Earth and Moon revolve around the Sun? Students model the Sun-Earth-Moon system, demonstrating how light from the Sun reflects off the Moon and shines on Earth.

2. *Do You See What I See?—Approx. 10 min. prep; 40 min. class time*

How does the Moon move in relationship to Earth? Students model the Sun-Earth-Moon system, demonstrating how the positions of the three bodies determine what phase of the Moon is seen from Earth.

3. *The Shadow of Your Planet—Approx. 10 min. prep; 40 min. class time*

Does the Moon ever pass through Earth's shadow? Students explore lunar eclipses. They model the Sun-Earth-Moon system to discover the tilt of the Moon's orbit around Earth

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with a searchable database of science activities on many different subjects.)

Phases of the Moon — University of Missouri, Coumbia
http://riker.ps.missouri.edu/RICKSPAGE/MoonPhases.html
(Great animation clearing showing why there are phases in the Moon.)

The Moon — Arizona University
http://seds.lpl.arizona.edu/nineplanets/nineplanets/luna.html
(This site has information about the Moon and its phases.)

Lunar Phases Web Tools — Calvin College
http://www.calvin.edu/~lmolnar/Moon/index.html
(Fun diagrams and animations displaying the phase of the Moon according to daily, weekly, and monthly movement.)

Internet Search Words

phases of the moon
lunar cycles
moon
astronomy

Phases of the Moon

Books and Articles

Azimov, Isaac. *Why does the Moon Change Shape?.* Milwaukee, WI: Gareth Stevens Publishing, 1991.

Palmquist, Bruce. "Moon Rise, Moon Set," *The Science Teacher*, Oct 1997, p 62. (A stand-up activity to learn about the phases of the Moon.)

Sachs, Maryam. *The Moon*. New York, NY: Abbeville Press, 1998.

Szpir, Michael. "Lunar Phases and Climatic Puzzles," *American Scientist*, Mar-Apr 1996, p 119.

Tesar, Jenny E. *The Moon*. Des Plaines, IL: Heinemann Interactive, 1998.

Community Resources

Local planetarium

Local college or university astronomy departments

Amateur astronomy clubs

Background

What object looks biggest in the night sky? It's the Moon, of course. It's about a quarter the size of Earth and relatively close to us, about 238,900 miles away. But it doesn't always look the same, and sometimes you can't see it at all. It depends on the *phase* of the Moon, where it is in its orbit around Earth.

The Moon's phases fascinated ancient astronomers, including Greek astronomer Parmenides (512-400 B.C.), who determined that the Moon reflects light from the Sun. By watching the changes in the lunar phases, other ancient astronomers concluded that the Moon must be orbiting Earth.

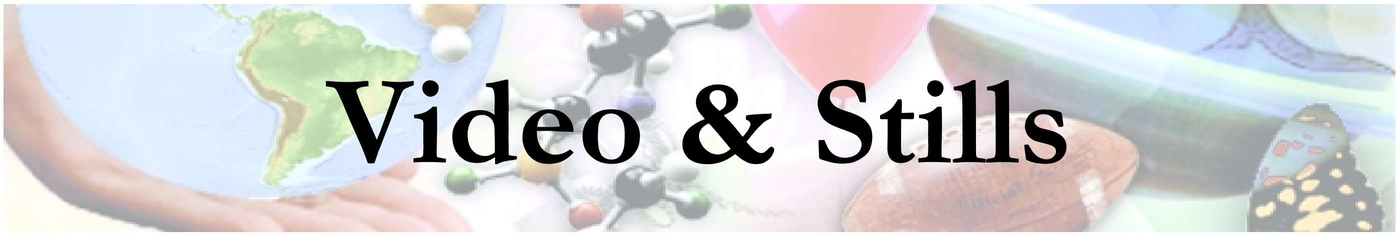
Like every celestial body that orbits the Sun, the Moon is always half in sunlight and half in darkness. But its position relative to Earth changes constantly, as the Moon goes around Earth. As a result, a viewer on Earth sometimes sees the entire illuminated half of the Moon, sometimes only a portion of it, and sometimes only the side of the Moon that's in shadow. There are four main phases, each with a different view of light and shadow—new Moon, first quarter, full Moon, and last quarter. The new Moon occurs when the Moon's dark half faces Earth. At this point, the Moon is between the Sun and Earth. Imagine holding a tennis ball out toward a light bulb. All of the light would fall on the far side of the ball, leaving the side facing you dark.

The next phase, the first quarter, occurs when the Moon has moved 90 degrees around its orbit moving away from the Sun in relation to Earth. The Moon is still half bright and half dark, as always, but from Earth we see half of the illuminated hemisphere (the right) and half of the dark hemisphere (the left).

When the Moon moves to the opposite side of Earth from the Sun, its face is fully lit by sunlight and we see the full Moon. It takes about two weeks to move from a new Moon to a full Moon. If Earth is in an exact line between the Sun and the Moon, you might see Earth cast its shadow across the Moon in a lunar eclipse. But lunar eclipses are relatively rare because the Moon's orbit usually takes it a little above or below Earth in relation to the Sun.

After becoming full, our view of the Moon begins its two-week fade into darkness as more of its lit side moves away from Earth. As the Moon wanes through the last quarter Moon, we see less and less of its illuminated hemisphere. Finally, when it returns to its position between Earth and the Sun, the Moon goes dark and becomes "new" again. Then the cycle begins anew.

Even if all this makes your head spin, it's clear that our nearest neighbor in space is worth watching. Just be careful not to become too moonstruck!



Video & Stills

Video Segments

Introduction

00:03 to 00:31 Dave Huddleston observes the ever-changing shape of the Moon and poses some questions for discussion. (28 sec.)

Video Clip 1

00:37 to 2:20—David Heil and Derrick Pitts study a miniature model of the Earth-Moon-Sun system. (1 min. 43 sec.)

Video Clip 2

07:09 to 07:52—Derrick Pitts shows David Heil how the Moon keeps its "best face" forward. (43 sec.)

Video Clip 3

02:31 to 04:33—David Heil is "sitting on top of the world" to observe the Moon move through its waxing phases. (2 min. 2 sec.)

Video Clip 4

04:34 to 06:51—David Heil and Derrick Pitts use a giant model to demonstrate how the Moon moves through its waning phases. (2 min. 17 sec.)

Additional Resources

Button A

Slide Show: Photos of the Moon with major landforms labeled.

Button B

Animation: 360° animation of the Moon.

Button C

Animation: The Moon as it moves through its phases.

Button D

Chart: Comparisons between Earth and the Moon.

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the video segment and the background on the Unit Theme section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it

1. The Moon spins on its axis very slowly. A lunar day is approximately 29 days. The Moon makes one orbit around Earth every 29 days. Because the time to orbit Earth and the time to rotate one lunar day are the same, the same face of the Moon is directed toward Earth all the time.
2. The right half of the portion of the Moon that is visible from Earth. However half of the entire Moon is illuminated by the Sun.
3. Earth partially protects the Moon from meteors and comets that come from Earth's direction. Small meteors are caught in Earth's gravitational field and burn up in the atmosphere. The far side of the Moon is relatively unprotected and more vulnerable to being struck by debris from outer space.
4. [ART: Moon orbit path]
5. The time of day that the Moon is in the sky varies. It is most clearly visible at night when sunlight isn't illuminating Earth's atmosphere, but the Moon can still be seen during daylight hours when the sky is clear. The waxing Moon is visible in the afternoon and the waning Moon is visible in the morning.

What would you say?

6. b 7. c 8. d 9. c 10. a

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Unit Assessment

What do you know about Phases of the Moon?

Write the answers to these questions in your journal or on a separate piece of paper.

Think about it

1. If the Moon rotates on its axis like Earth, why is it that we always see the same side (face) of the Moon?

2. As you look at the Moon, which portion of the Moon is lit during a First Quarter Moon?

3. Photographs taken by astronauts of the far side of the Moon show that there are many more craters than on the side facing Earth. Why might that be?

4. The Moon is orbiting Earth while Earth is orbiting the Sun. If you could go far into outer space and look down on Earth and the Moon, what would the motion of the Moon look like as it moves around the Sun? Draw an illustration of what the path would look like.

5. How can the Moon be visible during the day?

What would you say?

6. What is the length of a lunar day?
   a. 24 hours
   b. 29 days
   c. 1 week
   d. 6 months

7. When you see a full moon, what is the relationship of Earth, the Moon, and the Sun?
   a. The Sun is between Earth and the Moon.
   b. The Moon is between Earth and the Sun.
   c. Earth is between the Sun and the Moon.
   d. The Moon is closer to the Sun than Earth.

8. Moonlight is _______
   a. generated by the Moon in a similar way that the Sun generates sunlight.
   b. entirely light reflected from Earth's surface.
   c. dimmer later at night.
   d. reflected sunlight.

9. Lunar eclipses occur when Earth's shadow darkens the moon. This type of eclipse______
   a. happens twice a month.
   b. happens once a month.
   c. happens rarely.
   d. happens the night after a solar eclipse.

10. Which is the correct order of the phases of the Moon.
    a. new Moon, first quarter Moon, full Moon, last quarter Moon, new Moon
    b. full Moon, first quarter moon, new Moon, last quarter Moon, full Moon
    c. full Moon, first quarter Moon, second quarter Moon, third quarter moon, new Moon
    d. none of the above

Activity 1

I See the Light!

What makes objects shine in the sky? Why do some shine during the day? Why do we only see some at night? Where does their light come from?

Getting Ready

Overview
Students model the Sun-Earth-Moon system, demonstrating how light from the Sun reflects off the Moon and shines on Earth.

Objectives
After completing this activity, students will be able to—
- explain the source of moonlight
- demonstrate how light from the Moon reaches a viewer on Earth

Time Needed
Preparation: Approximately 10 minutes
Classroom: Approximately 55 minutes on day 1 and 30 minutes on day 2

Materials
- fairly powerful flashlight
- 30- to 50-cm square of shiny white poster board

Important Terms

reflection — The light bouncing off an object or surface.

Phases of the Moon

Here's How

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 1 for each student.
- Review the Background information on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [00:03 to 00:31]. Find out what students already know about the Moon's phases. As a class, discuss the questions posed by Dave Huddleston.

- For the parts of the demonstration where the classroom lights are off, make sure that the room is as dark or dim as possible, closing blinds and window shades.

- Involve as many students as possible in the Engage demonstration. Perhaps have several different groups work through the demo, so that all students have an opportunity to be observers. During the demonstration remind the students who are observing to continue to record their observations. Encourage them to draw diagrams as well.

- The posterboard may be cut into a circle to better represent the Moon. However, the purpose of the lesson is to focus on the light path.

- Because they can't see the Sun at night, many students have a misconception that moonlight is light reflected from Earth. This activity should help to dispel the misconception.

- If it is appropriate, view the entire *Newton's Apple* video segment on the Phases of the Moon after completing this activity.

Engage (Approx. 15 minutes)

Ask students to describe the Sun. What sorts of energy does the Sun produce? (heat, light, other forms of electromagnetic energy) Ask students to describe the Moon. What sort of energy does the Moon produce? (nothing that we can detect without sensing instruments of some sort) Where does moonlight come from? (It is sunlight reflected off the Moon.) Darken the classroom and ask students for their observations. Do the walls give off any light? (no) Shine a flashlight at the walls. Ask students for their observations. They can now see the detail of the walls, but the light is still not produced by the wall.

Turn the room lights back on. Ask students for their observations. Lead them to understand that what they see on the walls is really reflected light from the lightbulbs in the room. Ask students how can we see sunlight reflected from the Moon at night when the Sun is nowhere to be seen. Accept all answers.

Involve students in a demonstration of the relationship of the Sun, Moon, and Earth. Instruct students to take notes on their observations and to draw diagrams to represent the relationships among the three heavenly bodies. Have one student sit in a chair or on a stool that pivots. Have another student spin the chair slowly in a counter-clockwise direction. Explain that the seated student represents Earth spinning on its axis.

Have another student hold a flashlight, representing the Sun. The flashlight should be directed at the student in the chair. As the student spins, his or her face goes from daytime to nighttime. Dim the room and allow students to observe day and night on the "Earth's" face.

Turn on the lights and introduce the Moon. The student representing the Moon should hold a circle of white cardboard above his or her head. The "Moon" should stand opposite the Sun with the Earth between them. Ask the student playing the Earth to describe what he or she observes while turning on the axis. (Student should observe that during the day he or she sees the Sun and during the night they see the Moon.) Darken the classroom again. The flashlight should be directed so that its light strikes both the Earth and Moon. Have the student representing the Earth stop spinning and face the Moon. Tell "Earth" to look directly at the Moon, then ask if that student can see the Sun. (no) Is there light reflected from the Moon? (yes) Is the reflected light coming from the Earth? (no, it's coming from the Sun)

Activity 1

Explore (Approx. 40 min. one day and 30 min. the next)

Separate the class into four groups. Tell them that their objective is to figure out a way to explain how the Moon reflects sunlight so it can be seen on Earth. Tell students that the real challenge is that their explanation should be directed to students in the 3rd or 4th grade.

Each group will make a short presentation to the class that explains this phenomenon. The presentation should include a diagram of the relationship of the Sun, Earth, and Moon. It should also have a drawing of what an observer on Earth would see based on the diagram.

After students have made their presentations, discuss any differences in the way they explained the phenomenon, why differences may have happened, and any inaccuracies that might have been presented.

Evaluate

1. Describe the path the flashlight beam took in order to reach Earth in the demonstration. (It traveled to the white poster board, then reflected off it and traveled to the student in the chair.)

2. When you look at the Moon in the night sky, what is the source of the moonlight? Where is that source? (The Sun. It's on the other side of Earth.)

3. Describe the process your group went through to create the presentation. How did you decide what to show on the diagram? (Answers will vary. Students should provide logical explanations.)

Try This

When the Moon is full, it rises at sunset and sets at sunrise. But there are several days each month when the Moon rises around noon. On those days, the Moon is often visible in the daytime sky along with the Sun. Repeat the demonstration that your teacher did, only this time find a way that the light from the flashlight and the light reflecting off the white poster board can both be seen by the observer representing Earth.

There is one day each month when the Moon rises when the Sun does and sets when the Sun does. On this day, the Moon is between Earth and the Sun. Model this situation using the flashlight (the Sun), the white poster board (the Moon), and the observer in the chair (Earth). At times like this, the entire Moon is very dimly visible to people on Earth. What do you think might be illuminating it?

NEWTON'S APPLE Multimedia

I SEE THE LIGHT!

Activity Sheet 1

NAME____________________ CLASS PERIOD__________

What you're going to do

You're going to do a presentation on how Earth and the Moon move around the Sun.

How to do it

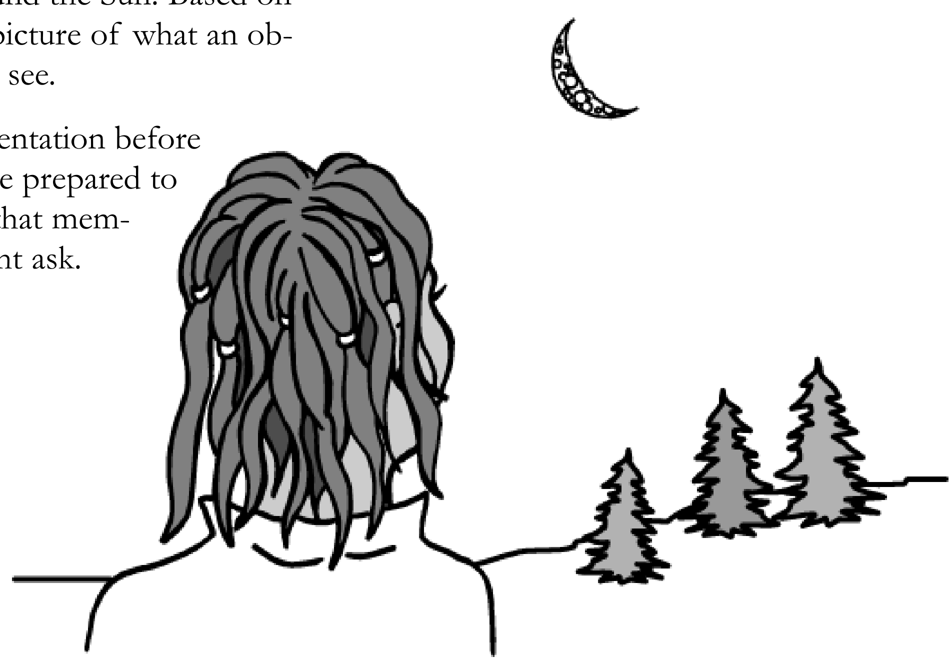
1. Work with your group. Compare your observations of the demonstration that your teacher conducted on the relationship of the Sun, Earth, and Moon. Discuss ways that you could explain this relationship so that third- or fourth-grade students would understand it.

2. Create a diagram that shows how Earth and the Moon revolve around the Sun. Based on your diagram, draw a picture of what an observer on Earth would see.

3. Practice your presentation before giving it to the class. Be prepared to answer any questions that members of your class might ask.

Recording your data

In your science journal, draw a diagram showing the relationship among Earth, the Sun, and the Moon that you observed during the demonstration. Draw arrows representing the path light takes as it reaches the observer on Earth's night side. Then make a sketch of what a person on Earth would observe.



What did you find out?

Compare your presentation with the presentations of other groups. Discuss any differences that may have occurred. What might account for these differences?

Based on the presentations, come up with a clear and simple explanation of the way the Earth and Moon move around the Sun. Write that explanation in your science journal.

Do You See What I See?

How does the Moon move in relationship to Earth? How does Earth move in relationship to the Sun? How does the Moon move in relationship to the Sun? What causes the phases of the Moon?

Getting Ready

Overview
Students model the Sun-Earth-Moon system, demonstrating how the positions of the three bodies determine what phase of the Moon is seen from Earth.

Objectives
After completing this activity, students will be able to—
- describe how the Sun illuminates the Moon
- demonstrate the formation of the various phases of the Moon

Time Needed
Preparation: Approximately 10 minutes.
Classroom: Approximately 40 minutes.

Materials
For each group of students:
- light source
- ball at least 6 inches in diameter

Important Terms

revolve — To move in a path around another object; the earth revolves, or orbits, around the sun.

rotate — To spin around an axis like a top or a wheel.

Phases of the Moon

Here's How

Video Clip 1
00:37 to 2:20—David Heil and Derrick Pitts study a miniature model of the Earth-Moon-Sun system. (1 min. 43 sec.)

Video Clip 2
07:09 to 07:52—Derrick Pitts shows David Heil how the Moon keeps its "best face" forward. (43 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 2 for each student.
- Review the Background information on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [00:03 to 00:31]. Find out what students already know about the Moon's phases. As a class, discuss the questions posed by Dave Huddleston.
- This activity will be easier for the students if the classroom is fairly dim. You may want to turn off the lights.
- Each group needs a bright light source, but several groups can share one light source.
- The student with the ball must hold it high enough so that it is not in his or her shadow and so that light from the light source reaches it. The observer should also avoid blocking any light from the light source.
- A Stryofoam ball can be used for this activity. The student holding the ball can put it on a stick or a pencil.
- It may be helpful to suspend the ball from a string, rather than having it held by a student.
- If it is appropriate, view the entire *Newton's Apple* video segment on the Phases of the Moon after completing the activity.

Engage (Approx. 10 min.)

Ask students to describe how Earth moves in relation to the Sun. (The Earth has two movements that occur at the same time. Earth spins on its axis, which causes day and night. At the same time, the Earth revolves around the Sun in an orbit; a full orbit takes one year.) Then ask them to describe how the Moon moves in relation to Earth. (It orbits around Earth; one orbit is approximately four weeks long. The Moon spins on its axis much more slowly than the Earth One "day" on the Moon lasts about four weeks. That's why the same face of the Moon's surface is always facing Earth.) Show students Video Clip 1 [00:37 to 2:20] and then Video Clip 2 [07:09 to 07:52].

Ask students to describe the phases of the Moon. (new Moon, first quarter, full Moon, last quarter, etc.) Challenge students to explain what causes the change in the phases of the Moon. Is Earth's shadow moving across the surface of the Moon? (No, except during lunar eclipses, which are rare.) Is a larger or smaller portion of the Moon's surface illuminated each night? (Half of the Moon's total surface is illuminated each night. From our vantage point on Earth, it looks like larger and smaller portions are illuminated.)

Have students work in small groups. In each group, one student represents an observer on Earth. This student sits in a chair near a light source—either the classroom windows or a bare 100-watt bulb. Another student holds the ball, which represents the Moon. This student "orbits" in a circle around the student in the chair, being sure to pass between the chair and the light source.

Activity 2

Explore (Approx. 30 min.)

Groups should begin by modeling the full Moon. The student in the chair should be directly between the light source and "the Moon." A student recorder draws the pattern of light on the ball visible to the student in the chair. A second observer is free to observe the ball from any angle or position. The student recorder notes how much of the ball's surface is illuminated based on the findings of the second observer.

Students need to determine which direction the "Moon" moves around the chair. (counter clock-wise) Next, the student with the ball moves one quarter of the way around the chair, and the recording procedure is repeated. The student with the ball then moves another quarter of the way around the chair—to a position between the chair and the light source—and the recording procedure is repeated. Finally, the student with the ball moves another quarter of the way around the chair, and the procedure is repeated again.

As a group, the students should prepare a diagram or series of diagrams based on their observations. The diagram should show the relative positions of the Sun, Earth, and Moon for each of the four phases.

Each group should compare their observations and diagrams with other groups and discuss any differences.

Evaluate

1. How much of the Moon's (ball's) total surface was illuminated in each trial? (one half)

2. How much of the illuminated portion was visible to the student in the chair? (It varied from the full amount down to one half and then none and back up to one half again.)

3. What causes the phases of the Moon? (As the Moon revolves around Earth, larger and smaller sections of the illuminated portion of the Moon's surface are visible to us on Earth.)

Try This

Imagine a lunar observation satellite positioned above the Moon in such a way that a line drawn from the satellite to the Moon is always at right angles to a line drawn from the Moon to Earth. Determine what phase of the Moon is visible from the satellite when each of the four main phases (full Moon, last quarter, new Moon, first quarter) are visible from Earth. You may do this using the setup from the activity, or by drawing diagrams.

The Moon rotates once each time it orbits around Earth. This means that the same side of the Moon is always facing toward Earth. Is the same side of the Moon always facing toward the Sun? Does a given place on the surface of the Moon experience night and day? And if so, how long is a lunar day? You may find the answers to these questions using the setup from the activity, or by drawing diagrams.

NEWTON'S APPLE Multimedia

DO YOU SEE WHAT I SEE?

Activity Sheet 2

NAME ______________________________ **CLASS PERIOD** __________

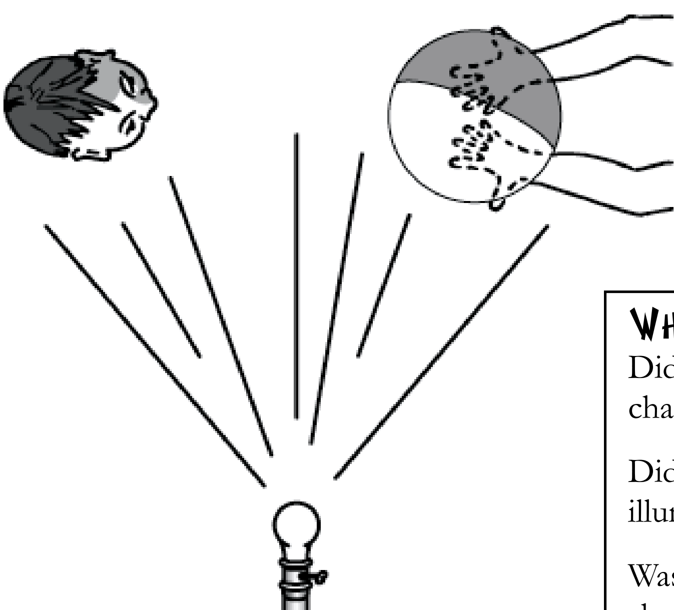
WHAT YOU'RE GOING TO DO

You're going to investigate the phases of the Moon.

HOW TO DO IT

1. Work with your group. One group member, representing an observer on Earth, should sit on a chair or stool near a light source—the "Sun." Another group member can hold a ball—the "Moon." A third group member will move around, observing things from "outer space."

2. Begin with the observer on Earth directly between the Sun and the Moon. The observer on Earth should note the pattern of light and darkness on the ball. The observer in outer space, who is free to move around, should note how much of the Moon's total surface is illuminated.



3. Discuss which direction the Moon should move in order for the observer on Earth to see a first quarter moon. You may want to discuss this with your teacher or the whole class.

4. Repeat the procedure three more times. The student with the Moon should move one quarter of the way around the chair each time.

RECORDING YOUR DATA

In your science journal, create a data table like the one shown here to record your observations. The second column of the table should be fairly wide, as it will contain sketches of the ball.

For each of the four positions of the ball, record this information:

Pattern of Light/Darkness
Amount of Ball's Surface Illuminated
Position #
Visible from Chair
Surface That's Lit

WHAT DID YOU FIND OUT?

Did the visible pattern of light and darkness on the ball change? If so, how?

Did the amount of the ball's total surface that was illuminated change? If so, how?

Was there anything in your model to represent Earth's shadow? How is Earth's shadow involved in the phases of the Moon?

What additional questions did this activity make you think of about the Moon? What experiment could you set up that might help you answer the question?

Activity 3

The Shadow of Your Planet

How does the Moon move in relationship to Earth? What's a lunar eclipse? Does the Moon ever pass between Earth and the Sun? Does the Moon ever pass through Earth's shadow?

Getting Ready

Overview

Students explore lunar eclipses. They model the Sun-Earth-Moon system to discover the tilt of the Moon's orbit around Earth.

Objectives

After completing this activity, students will be able to—

- draw a diagram of the path the Moon takes in its orbit around Earth
- demonstrate the cause of lunar eclipses

Time Needed

Preparation: Approximately 10 minutes
Classroom: Approximately 40 minutes

Materials

For each group of students:

- light source
- 1-inch foam ball
- 6-inch foam ball
- 2 thumbtacks
- thread
- scissors
- 2-inch ball
- hula hoop

Important Terms

eclipse — An occurrence where the shadow from one object in space is cast on another object in space.

lunar eclipse — An occurrence where the Moon passes through Earth's shadow. During a lunar eclipse, Earth is directly between the Sun and the Moon.

Phases of the Moon

Video Clip 3
02:31 to 04:33—David Heil is "sitting on top of the world" to observe the Moon move through its waxing phases. (2 min. 2 sec.)

Video Clip 4
04:34 to 06:51—David Heil and Derrick Pitts use a large model to demonstrate how the Moon moves through its waning phases. (2 min. 17 sec.)

Guide on the Side

- This activity will be easier for the students if the classroom is fairly dim. You may want to turn off the overhead lights. Each group needs a bright light source, but several groups can share one light source.
- The foam balls are hung from threads in order to prevent shadows from students' hands and arms from interfering with the observations.
- When the activities are completed, you may wish to describe the Moon's actual orbit to the students. It is a tilted orbit that itself moves in a circle around Earth. You can demonstrate this by suspending a 2-inch ball (representing Earth) from the ceiling and shining a bright light on it. A hoop will approximate the path of the Moon's orbit. Anywhere the ball's shadow falls on the hoop represents a place in the orbit where the Moon will be eclipsed by Earth. Tilt the hoop so that the point directly behind the ball is high enough to be out of its shadow. The low point of the hoop should be an equal distance below the ball. Now, without changing the angle of your wrist, walk around the ball. As you walk, the high point of the hoop will move from behind the ball to in front of it and back behind it again. More importantly, the middle part of the hoop will move into and out of the ball's shadow. This demonstrates how the Moon's orbit moves. At times the entire hoop is lit and no eclipses are possible. At other times, part of the hoop is in the shadow of the ball. If the Moon happens to be in that part of its orbit at that time, a lunar eclipse will occur.

Here's How

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 3 for each student.
- Review the Background information on page 24.

Engage (Approx. 20 min.)

Ask students to describe how the Moon moves in relation to Earth. (It revolves around Earth.) What causes the phases of the Moon? (As the Moon revolves around Earth, larger and smaller sections of the illuminated portion of the Moon's surface are visible to us on Earth.)

Ask students to describe the relative positions of the Sun, Earth, and the Moon during a new Moon. Show students Video Clip 3 [02:31 to 04:33]. Ask students to describe the relative positions of the three bodies when the Moon is in the first quarter phase. (The Sun, Moon, and Earth form a triangle. Looking down from above, the three bodies would make a right triangle with the angle Sun, Earth, Moon being 90°.) Ask students to describe the relative positions of the three bodies when the Moon is full. (Looking down from above, the Earth, Moon, and Sun would be in a straight line with Earth in the middle.) Show students Video Clip 4 [04:34 to 06:51]. Ask students to describe the relative positions of the three bodies when the Moon is in new moon phase. (Looking down from above, they would form a straight line with the Moon in the middle.)

Ask students to describe a lunar eclipse. (Earth passes between the Moon and the Sun, casting its shadow on the Moon and blocking the sunlight from reaching the Moon.) Tell students that, from the Moon, Earth appears to be much larger in the sky than the Sun is. During a lunar eclipse, Earth can completely block out the Sun. Yet during the full Moon, Earth is between the Moon and the Sun. How can the Sun's light reach the Moon? Accept all answers.

In this activity students use a hula hoop to model the Moon's orbit. Remind students that the actual distance to the Moon is much greater than is indicated in this activity.

Activity 3

Explore (Approx. 20 min.)

Have students work in small groups. Tell them they are going to explore the Moon's orbit.

Members of each group should prepare their materials by sticking a thumbtack into each foam ball, then tying a length of thread around each thumbtack. Threads should be trimmed to about a half-meter in length.

Part One

In each group, one student holds the large ball, which represents Earth, near the light source. Another student holds the small ball, which represents the Moon. Using the hula hoop as the path of the Moon's orbit, students try to find possible orbits for the Moon around Earth, in which the large ball does not block the light falling on the smaller ball. They should find several possibilities. Students record their findings. (Students should discover that the Moon would orbit slightly above or below Earth in order for it not to fall into Earth's shadow.)

Part Two

Using the same setup, student groups try to find possible orbits for the small ball around the large ball that allow for lunar eclipses—that is, orbits in which the large ball blocks the light falling on the small ball. They should find several possibilities. Students record their findings. (Students should discover that the Moon's orbit is tilted at an angle that crosses above and below Earth.)

Evaluate

1. What orbits allowed light to shine on the small ball at all times? (Possibilities include: an orbit around and above the large ball, an orbit around and below the large ball, a tilted orbit in which the small ball is either above or below the large ball when it is behind it.)

2. What orbits allowed the large ball to eclipse the small ball? (any orbit in which the small ball passed through the shadow of the large ball)

3. Could you find an orbit that allowed light to fall on the small ball most of the time, but occasionally allowed the large ball to eclipse the small ball? (A tilted orbit in which the high points of the orbit gradually moves around the small ball.)

Try This

What's the difference between a lunar eclipse and a solar eclipse? Research this question on the Internet or at the library. Report your findings to the class.

From the surface of the Moon, Earth appears to be four times larger in the sky than the Sun does. That is, Earth's apparent diameter is four times larger than the Sun's apparent diameter. Draw a series of sketches illustrating what a lunar eclipse would look like to an observer on the surface of the Moon.

In this activity the Moon's orbit was represented by a hula hoop. The Moon is much farther from Earth than your model may suggest. If the Moon's orbit were the size of the hula hoop, what size would Earth be? Make some calculations and find an object that would accurately model the size of the Earth.

THE SHADOW OF YOUR PLANET

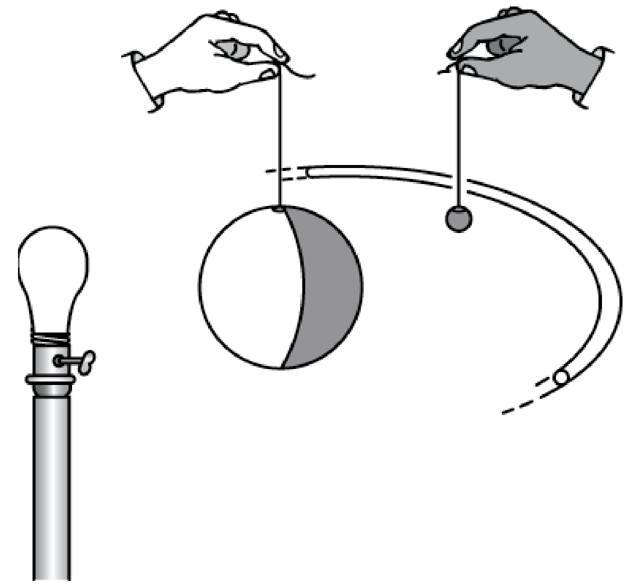
NAME____________________________________ **CLASS PERIOD** ______________

WHAT YOU'RE GOING TO DO

You're going to investigate the orbit of the Moon.

HOW TO DO IT

Work with your group. Start by preparing the foam balls. Stick a thumbtack into each one. Tie a length of thread to each thumbtack. Trim the threads to one-half meter in length.



Part One

One group member should hold the large ball near the light source. Another group member moves the small ball in an orbit around the large ball. Find an orbit in which the large ball never blocks the light from shining on the small ball. How many can you find? Use the hoop as the orbit path for the Moon.

Part Two

Repeat the procedure. This time, find an orbit that allows for lunar eclipses—the large ball blocking all the light from shining on the small ball. How many can you find? Use the hoop as the orbit path for the Moon.

RECORDING YOUR DATA

In your science journal, sketch a diagram showing each of the orbits you find that meet the given requirements.

WHAT DID YOU FIND OUT?

What orbits did you find that did not allow the large ball to eclipse the small ball?

What orbits did you find that did allow the large ball to eclipse the small ball?

Did you find any orbits that allowed the large ball to eclipse the small one occasionally, but not on every orbit? If so, what were they?

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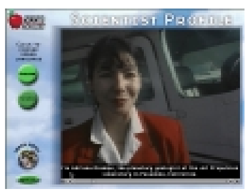



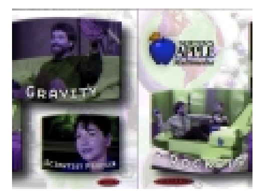

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